ENDOGENOUS AIR VERSUS ATMOSPHERIC AIR IN MIDDLE EAR VENTILATION. ARISTOTLE VERSUS JOSEPH GUICHARD DUVERNEY

MARIAN RĂDULESCU[1]

[1] *"Prof. Dr. Dorin Hociotă" Institute of Phonoaudiology and ORL Functional Surgery Bucureşti*

Keywords: *Middle Ear, Eustachian Tube, Air, Respiratory Gases, Thermodynamic System*

Abstract: *The purpose of this paper is to draw attention to the collective illusion otologists live first and then all who accept without reservation that the origin of the so-called ‹‹middle ear air›› is from the ambient air and arrives here simply through the Eustachian tube (ET). The instrument used to achieve this goal is to analyze the concept of air and the analysis of experimental measurements published in the literature. The last shows that ‹‹air in the middle ear›› is not at all similar to, in regard to its composition, atmospheric air, as it was expected to be, according to the current acceptance about the ET function. Instead, the composition of air middle ear is identical to that of mixed venous blood respiratory gases. Therefore, the latter are at the origin of gas in the Middle Ear (ME). In the final analysis, the middle ear gas mixture comes from the internal environment of the body. More precisely, they come from physically dissolved gases in total body water. This endogenous origin was intuited brilliantly and surprisingly by Aristotle of Stagira when he supposed the existence of endogenous air – aerus innatus – which exists per se (by itself) in the ear, isolated from exterior air and from external ear. Eustachian tube is just a valve through which gas masses pass in both directions with the aim of quickly equalising the pressure on both sides of the tympanic membrane. This valve enters in action only when the above mentioned pressures vary in the opposite directions with a speed which overcomes the processes speed which are the real base of ME ventilation.*

Cuvinte cheie: *ureche medie, Trompa lui Eustachio, aer, gaze respiratorii, sistem termodinamic*

Rezumat: *Scopul lucrării este să atragă atenţia asupra iluziei colective pe care o trăiesc otologii în primul rând şi apoi toţi cei care admit fără rezerve că aşa-zisul ‹‹aer›› din urechea medie provine din aerul ambiental şi ajunge aici, pur şi simplu pe calea Trompei lui Eustachio. Mijlocul folosit pentru atingerea scopului este analiza noţiunii de aer şi analiza măsurătorilor experimentale publicate în literatură. Aceasta din urmă arată că ‹‹aerul›› din urechea medie nu seamănă deloc, în ceea ce priveşte compoziţia sa, cu aerul atmosferic, aşa cum ar fi de aşteptat conform accepţiunii actuale asupra funcţiei Trompei lui Eustachio. În schimb, compoziţia ‹‹aerului›› din urechea medie este identică cu aceea a gazelor respiratorii din sângele venos amestecat. Prin urmare, ultimele sunt la originea gazelor din urechea medie. În ultimă analiză, amestecul de gaze din urechea medie provine din mediul intern al organismului. Mai precis, ele provin din gazele dizolvate fizic în apa totală a organismului. Această origine endogenă a fost intuită în mod genial şi surprinzător de Aristotel Stagiritul, atunci când a presupus existenţa aerului endogen – aerus innatus – care există per se în ureche, izolat de aerul exterior şi de urechea externă. Trompa lui Eustachio este o doar o supapă prin care pot trece în ambele sensuri mase de gaz cu scopul de egalizare rapidă a presiunilor de pe cele două feţe ale membranei timpanului. Această supapă intră în funcţiune numai atunci când presiunile amintite variază în sens contrar, cu o viteză care o depăşeşte cu mult pe aceea a proceselor care stau la baza ventilaţiei reale a urechii medii.*

INTRODUCTION

At first glance, the subject can be considered as physicists do when they are presented with a new work about perpetuum mobile, an unconventional physiology worth very little of our scientific interest or an outright bizarre time-consuming and nothing more.

Its importance is felt today in full in the most real way as possible, just by the negative consequences of ignoring the subject, consequences which are encountered, not in books pages but in the real world of the disease and of patients in deafness and the world of deaf people and deafness. This world could have been avoided if they acted reasonably and appropriate by those appointed to do so.

Physiology of the middle ear, commonly accepted today that the undeniable presence of ‹‹air›› in her bony cavities and exactly how get the ‹‹air›› here is an illusion that has lived many generations of otologists and continues to live today.

It is an illusion about which warned over a century and a half from now (1855–1856) Claude Bernard (1813–1878), the father of experimental physiology and founder of experimental medicine, in his lecture entitled Sur le rôle de l'anatomie dans la découverte des fonctions, something we have exhibited extensively in another paper.(1,2)

[1]Corresponding author: Marian Rădulescu, Str. Mihail Cioranu, Nr. 21, Sector 5, Bucureşti, România, E-mail: focaargintie@yahoo.com, Tel: +40788 414497

Article received on 16.02.2013 and accepted for publication on 12.06.2013
ACTA MEDICA TRANSILVANICA December 2013;2(4):303-307

Aristotle of Stagira (384–322 BC) intuited absolutely in an incredible way the presence of air inside the ear, air insulated from outdoor environment, present there by divine will – aerus implantus or aerus innatus – and only based on that genial suspicion produced a brilliant hypothesis about how humans hear. This hypothesis has dominated over two millennia ear physiology.

Is to understand how physicians of the eighteenth century were quick to replace at any price this hypothesis: The Renaissance had passed, also Newtonian Era, was the Era of Enlightenment and The Scientific Revolution, The Divine Will could not be mentioned in scientific paper.

That may explain why the discovery in 1761 of liquid known today as perilymph by Domenico Felice Antonio Cotugno (1736–1822) – De aquaeductibus auris humani internae anatomica dissertatio. Ex typ Naples, Simoniana, 1761 – student of Giovanni Battista Morgagni (1682–1771), is considered the coup de grace given Aristole's hypothesis. In other words, it was revealed fluid in the ear, so Aristotle was wrong because he claimed that there is aerus innatus.

It is more than fully haste to deny and ignore the idea of a waist predecessor Aristotle. He guessed absolutely surprising the endogenous origin of air in the ear and made an assumption (hypothesis) that has passed as theory (the theory of analogy) for scientists for more than two millennia.

You can not claim from Aristotle to be known anatomical constitution and topographic distribution in the external ear, middle and internal, as long as it has established the Antonio Maria Valsalva (1666–1723) in 1700, so over 2000 years since Aristotle intuited that air exists in the generic ear and this vibrates and the vibrations somehow they reach the brain and thus auditory sensation arises. Aristotle does not say, because this was not even possible that exist innatus aerus in the inner ear.

However, the same scientists have recognized that there is air in the middle ear and instead marvel at the intuition of Aristotle looked suddenly him and fell into the illusion of discovery of the Eustachian tube ventilatory function. Apparently the first to do so was personal physician of King Louis XIV (1638–1715), Joseph Guichard Duverney (1648–1730) – Traité de l'organe l'ouie contenant la structure, les usages et les maladies de toutes les parties de l'oreille, Paris, E. Michallet, 1683 – the first treaty in the history of otology in which the ear anatomy and pathology have been addressed in a coherent and analytical manner.

Certainly, Antonio Maria Valsalva (1666–1723) professor of anatomy and surgery at the University of Bologna, who named the hearing tube in the name and in honor of the great teacher of anatomy in Rome and imagined the maneuver that bears his name, which is precisely the forced inflation of the middle ear trans-tubal (Tractatus de Aure Humana. Bologna, Typ C Pisarii, 1704), proceeded the same way as Duverney.

Some of those mentioned above tried to make the great Italian anatomist to be partaking at this illusion. Bartolomeo Eustachio (1510–1574) took all steps do not fall into this trap and he written that he can not to pronounce about the function of organ which was described by him as no one done before him and neither after him without evidence peremptory.

If it had not been pushed by the desire to contradict at all costs the Father of all sciences, but humbly would be bent over his writing and would be lingered over the idea of aerus innatus – which Aristotle said that the creator had placed it there – maybe today we would have enjoyed a better hearing preservation through a more rational treatment of middle ear disease.

PURPOSE

The purpose of this paper is to draw attention to the collective illusion which otologists live first and then all who accept without reservation that the origin of the so-called ‹‹middle ear air›› is from the ambient air and arrives here simply through the Eustachian tube (ET).

METHODS

We find the spirit of those scientists we were talking about in the introduction, who have researched the percentage compositions of ‹‹air›› in the middle ear, those of atmospheric air, the respiratory gases dissolved in arterial blood, venous blood, mixed venous blood.

And in these we see the same scientific bitterness in combating with any cost the Aristotelian idea of endogenous air. For the latter ones the combat at any price under discussion is indirect and in good faith as here it is about maintaining the line drawn by ancestors.

The collective illusion experienced as reality, about admitting that the air in the middle ear is exclusively via the Eustachian tube and stubbornness mentioned above, makes them wonder why there is a similarity between the partial pressure of dissolved gases in mixed venous blood and those of gas in the middle ear without a glimpse to the partial truth of the Aristotle's idea that this similarity at least attracts attention, otherwise the gas should demonstrates at least the common origin of the two locations listed.

Not even the obvious truth that the fundamental distinction between the composition of atmospheric air on one side and the gas mixture in the middle ear on the other hand, does not rise to the idea that the two have nothing in common. In other words there can be no causal relationship between them.

The illusion and stubbornness makes to imagine extremely complicated physiological mechanisms to explain what the common sense and the nature of things could not support, not to mention about contempt for the laws of physics. As happens with authors crucial scientific experiment among which we will mention below.(3)

If they give up the two psychological states criminalized above and spirit would be released from any preconception, it would be easy to imagine how the middle ear respiratory gases that make up a thermodynamic system perfectly defined, have the external environment another thermodynamic system perfectly defined that is compound of respiratory gases dissolved in total body water.

Interface between the two systems is unicellular epithelial layer of the middle ear mucosa.

The two thermodynamic systems are in thermal contact and thermal equilibrium, therefore in thermodynamic equilibrium, despite the pressure difference between them – in other words – despite the difference in internal energy between them.

At the interface of the two systems, there is exchanged mechanic work. This exchange explains achieving thermodynamic equilibrium, since there is no exchange of heat between them, as mentioned thermal contact and thermal equilibrium.

Between the two systems there is a perpetual exchanging gas mixing mass.

There are two types of phenomena at the interface between the two thermodynamic systems:

1. passive diffusion according to Fick's law for the purpose of pressure gradient;
2. intracellular metabolic energy pumping against pressure gradient.

All statements above have been proven experimentally a quarter century ago (1985), but the same psychological conditions mentioned above prevented the realization of this demonstration, both by those who conducted the experiment as well as by those who are called to do them.(3,2)

RESULTS

We reproduce (table no. 1.) the summary of data analysis from literature done by J. Sadé and M. Luntz in 1990, about the experimental measurements of partial pressures of respiratory gases and water vapour in the middle ear and mixed venous blood.(4)

In table no. 2, we have synthesized the data about partial pressures and volume percentage compositions of homogeneous mixtures of respiratory gases and water vapour, adding in plus to table no.1, expired air, arterial and venous blood.(5,6,7)

Table no. 1. Partial pressure of gases in atmosphere, middle ear and mixed venous blood as per J. Sadé and M. Luntz 1990.(4)

Gas type (species)	Partial pressure of gas species in the mixture [mm Hg]		
	Atmospheric air		Atmospheric air
Water vapour	3,7	Water vapour	3,7
Carbon dioxide	0,3	Carbon dioxide	0,3
Oxygen	159	Oxygen	159
Nitrogen	597	Nitrogen	597
Total pressure of the gas mixture [mm Hg]	760	Total pressure of the gas mixture [mm Hg]	760

Table no. 2. Partial and Total Pressure of gases in: inspired air (atmospheric); expired air; alveolar air; arterial blood; venous blood; mixed venous blood; middle ear

	Partial Pressure [mmHg] and Percentage composition [%]				Total Pressure [mmHg] [%]
	Molecular Oxygen O_2	Carbon Dioxide CO_2	Molecular Nitrogen N_2	Water Vapour H_2O	
Inspired Air (atmospheric)	158	0,3	596	5	760
	21%	0,04%	78%	0,7%	100%
Expired Air	116	30	575	39	760
	15%	4%	76%	5%	100%
Alveolar Air	105	40	568	47	760
	14%	5%	75%	6%	100%
Arterial blood	96	40	547	47	730
	13%	5%	75%	6%	100%
Venous blood	40	46	570	47	703
	6%	7%	81%	7%	100%
Mixed venous blood	40	47	574	47	708
	6%	7%	81%	7%	100%
Middle ear	43	49	621	47	760
	6%	7%	82%	6%	100%

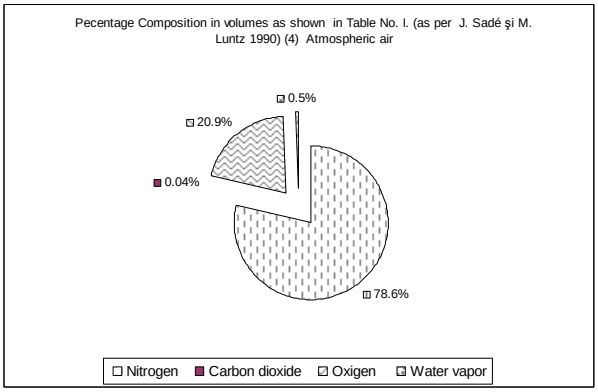
DISCUSSIONS

What we mean by air? Is a homogenous mixture of gases surrounding the Earth. Atmospheric air contains about 78 volumes percent of molecular nitrogen and 21 volumes percent oxygen molecular.

An oxygen-enriched atmosphere contains more than 23.5% oxygen by volume. An oxygen deficient atmosphere contains less than 19.5% oxygen by volume. An atmosphere immediately dangerous to life or health (IDLH) contains less than 18% oxygen. It can cause irreversible adverse health effects or may affect the ability of the individual to leave in time such an environment.

Therefore, looking at the percentage composition of ‹‹air›› in the middle ear, shown in figure no. 2. and table no. 2, we understand the need for quotes. When it is about the middle ear if it is called air (atmospheric) is inadequate. It is more correct to speak of a homogeneous mixture of respiratory gases saturated with water vapour at body temperature and normal pressure (760 mm Hg). For those who are hard to be convinced of the correctness of this perspective, Recalling the 6% value by volume of molecular oxygen concentration in the gas mixture of the middle ear and ask to review the lines above. Value of 6% stated previously justifies the air or atmosphere as immediately dangerous to life or health that we should label the air in the middle ear with.

Figure no. 1. Percentage composition of atmospheric air in volumes in normal condition as resulted from processing data in table no. 1

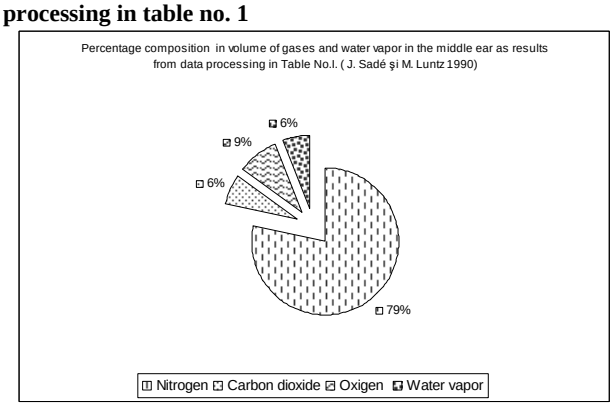


If the air in the middle ear could only come from the atmosphere directly, Percentage composition of volumes should reflect on the latter, where they originated.

If to be more precise, the middle ear ‹‹air›› would come from that found in the nasopharynx. If we consider that the cavum contains a mixture in equal parts of inspired air (atmospheric) and expired air, the percentage composition of oxygen in this mixture would be 18%, close to 21% (volume concentration of molecular oxygen in the atmosphere, or precisely speaking Fraction of oxygen in the atmosphere under normal conditions) but not any way by 6% (volume concentration of molecular oxygen in the gas mixture in the middle ear, measured experimentally).

The most difficult part to explain consistently is that the middle ear gas mixture saturated with water vapour and found at constant temperature of 37 ° Celsius (310, 15° Kelvin) is at constant pressure equal to barometric pressure or ambient pressure, which is generally considered to be at the value of 760 mm Hg.

Figure no. 2. Percentage composition in volume of gases and water vapour in the middle ear as results from data processing in table no. 1



Respiratory gases physically dissolved in the total body water have the partial pressures sum with less necessity than that of the ambient atmosphere, and this pressure difference is a function of the fraction of molecular oxygen in the air that lungs ventilate.(5) Under normal conditions this difference is 52 mm Hg.

Under these conditions, the middle ear gases diffuse into body fluids and pressure from the first would set out fluctuations of rhythmic opening of the Eustachian tube and inlet of atmospheric air, fluctuations that contradict the need for pressure consistency necessary for the proper functioning of ossicular chain.

What is even more difficult to explain and also more interesting to note is that a quarter of a century ago demonstrated experimentally on monkeys (Maccaca mulatta), that is the gas pressure in the middle ear remained constant and equal with barometric pressure (atmospheric–760 mm Hg) for periods more than 4 hours, while the eustachian tube was collapsed by relaxing the musculature which opens its lumen and the atmospheric air could not enter the middle ear to equalize pressure.(3,2)

Moreover, constancy of middle ear pressure was found not only at the difference of 52 mm Hg mentioned above, but also that of 610 mm Hg obtained experimentally by animal ventilation with pure molecular oxygen.(3,2) About all they talked at length about a decade ago.(2)

Which is not to say it is that if you imagine a material model of middle ear ventilation on its function, the most appropriate would be to choose a passenger plane from the field of modern technology.

More specifically, the middle ear is pressurized cabin of a Contemporary airplane passenger flying at 12,000 feet, and the body contains the ear is just earth's atmosphere with its pressure corresponding to this altitude.

Corresponding theoretical model is a thermodynamic model.[(2)] Percentage Composition of middle ear gas volume at 37° C and pressure of 760 mm Hg provided by the thermodynamic model are presented in figure no. 4. and in table no. 2 last line.

It is noted here that the numerical values go up to the experimental identification on mixed venous blood.

Figure no. 3. Percentage composition in volume of gases and water vapour in the mixed venous blood as results in processing data in table no. 1

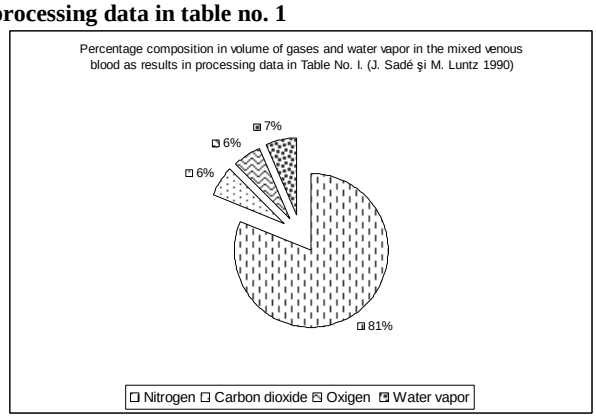
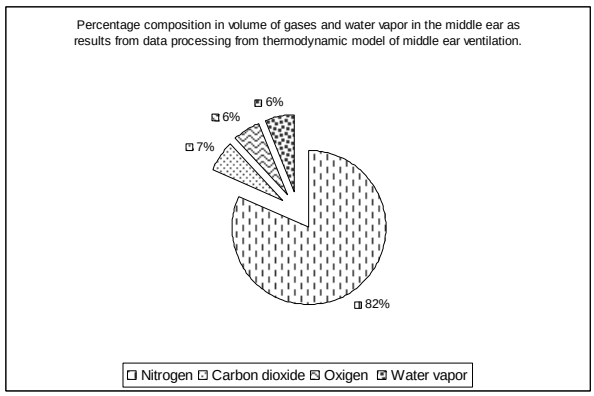


Figure no. 4. Percentage composition in volume of gases and water vapour in the middle ear as results from data processing from thermodynamic model of middle ear ventilation



CONCLUSIONS

When drastically analyzing, Eustachian tube with tympanic membrane proved to be the most misleading and ungrateful elements of otology content. The tube, by its accepted function is currently considered essential element explaining most of the middle ear pathology. As a result, it attracted the interest and focus of all generations of Otologists. That means middle ear pathology and clinical issues related all to it start and end with Eustachian tube. We must understand here it includes the treatment of middle ear diseases. It is fair and reasonable to recognize that the current state of the possibilities and therapeutic outcomes is particularly bleak. Collective effort of generations of Otologists to know about the Eustachian tube more, was not rewarded as it should be.

Middle ear gases originate from the internal environment of the body. More precisely, they come from physically dissolved gases in total body water. This endogenous origin was the brilliant and surprising assumptions made by Aristotle of Stagira about the Existence of endogenous air – aerus innatus or aerus implantus – Which exists per se in the ear, isolated from the outside air and the outer ear. The brilliant guess was supposed to be completed by mentioning that the air which was talked about is present only in the middle ear. In internal ear exists its liquids. Physiological hypothesis issued by Aristotle, the so-called theory of analogy, basically just needed to be completed and nuanced. Aristotle spoke exclusively about air vibrations. Today we also talk about vibration but we call them waves. In addition to the air, which Aristotle knew, today's

talk is about the labyrinthine fluids, basilar membrane, the sensory cell stereocilia.

Aristotle made an absolutely excusable mistake by looking at exclusively air vibrations in hearing theory. But he was right about the origin of endogenous air in the ear. It would be incredibly useful for Otology a return to Aristotle. Of course, a spiral return as it is in case of knowledge advancement. We must look for another way of understanding the pathology of chronic inflammatory middle ear diseases, so it will not disappoint us when we go through them. Not talking here about the way that can guide us on the right track flawlessly, as it was talked about this extensively since a decade ago. I argued then which is the accurate tool for diagnosis and rational treatment: mastoid radiography in comparative Schüller incidence. What we can say is that the lack of middle ear ventilation and inexorable evolution toward deafness can not be explained by the so-called tubal dysfunction. And we demonstrated this in a non-contradictory mode by the physics laws.(2,7,8,9,10)

REFERENCES

1. Bernard C. Sur le rôle de l'anatomie dans la découverte des fonctions. In: Rostand J editor. Claude Bernard – Morceaux choisis. Cap I, Leçons de Physiologie experimentale appliquée à la Medicine. Septième Édition, Paris: Gallimard; 1938. p. 37-48.
2. Rădulescu M. Organul D versus Trompa lui Eustachio în ventilaţia Urechii medii. Revista Română de ORL 2002;XXIV(2):72-78.
3. Yee AL, Cantekin EI. Effect of Changes in Systemic Oxygen Tension on Middle Ear Gas Exchange. Ann Otol Rhinol Laryngol. 1986; Jul-Aug 95(4,1):369-372.
4. Sadé J, Luntz M. Middle Ear as a Gas Pocket. Ann Otol Rhinol Laryngol 1990;99:529-534.
5. Piiper J. Physiological Equilibria of Gas Cavities in the Body. In: Fenn W O, Rahn H, Section 3 Editors. Respiration, Handbook of Physiologie, A Critical Comprehensive Presentation of Physiological Knowledge and Concepts. Washington DC: American Physiological Society 1965;2(48):1205-1218.
6. Guyton AC. Textbook of Medical Physiology. Eight Edition, Philadelphia: W B Saunders Company, Harcourt Brace Jovanovich Inc; 1991. p. 2,274,433-437,744,792.
7. Rădulescu M. Localizarea Organului D în Urechea medie. Revista Română de ORL. 2002;XXIV(3):152-159.
8. Rădulescu M. Organul D şi Conformaţia Radiografică Unilaterală a mastoidei în incidenţă Schüller. Revista Română de ORL 2003;XXV(1):7-13.
9. Rădulescu M. Organul D şi Conformaţia Radiografică Bilaterală a mastoidei în in-cidenţă Schüller. Revista Română de ORL 2003;XXV(2):78-83.
10. Rădulescu M. Organul D şi Boala inflamatorie cronică a Urechii medii. Spectrul audiometric şi formele clinice de gravitate–FCG. Revista Română de ORL. 2003;XXV(3):172-178.