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Keynote Lecture

Middle ear static pressure: measurement, regulation and effects on middle ear mechanics
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The middle ear (ME) is a rigid biological gas pocket which is closed most of the time. It is believed that the pressure in the ME is regulated by a complex combined action of the Eustachian tube muscles, eardrum deformation and gas exchange through the blood circulating in its walls. External changes can cause abrupt pressure variations, and sudden pressure variations of thousands of kPa occur in everyday situations. To understand the mechanisms and effects involved with quasi-static high amplitude pressure variations, we need to know how ME pressure varies in normal circumstances, investigate both fast and slow regulation mechanisms, and determine the effect of such pressures on middle ear mechanics. We will introduce some recent work performed in these three fields, which will be discussed further by other contributors, and discuss in more detail some recent results we obtained on mechanics of ossicle motion induced by static pressure. To determine the normal variations in ME pressure, we developed a monitoring system which is used in ambulant patients. We will show some results from direct measurements in intact ears. To investigate a possible fast regulation process, we performed measurements of eardrum deformation in gerbils. We found that volume displacement of the pars flaccida is small compared to middle ear volume, so the its fast pressure regulating function is limited to a very small pressure range. As to slow regulation processes, we will introduce a new technique for measuring rates of gas exchange in rabbit ears. The method works at constant pressure, so no baroreceptors are triggered which may influence the process. The method allows to determine the “pumping” rate at which the blood constantly removes gas from the ME cavity. In more detail, we will discuss some recent results, obtained in rabbits, of the effect of static pressure variations on middle ear ossicle motions. With heterodyne interferometry, we measured motions of umbo and stapes at pressure change rates between 200Pa/s and 1.5kPa/s. We will show that hysteresis in these motions increases as pressure change rate decreases, quite in opposite to the common notion that such hysteresis is mainly caused by visco elasticity. We conclude that static and dynamic friction are important aspects of ossicle motion at slow pressure variations, new aspects which should be taken into account when trying to model quasi-static ossicle mechanics. Finally, we will introduce some 3-D measurements of ossicle displacement, measured with X-ray tomography.