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A hydrodynamic model of human cochlea. (Russian, English) Zbl 1177.74285

Summary: A two-compartment model of the human cochlea is proposed. When stretched out, the bony spiral tube looks like two chambers separated by a membrane. Both chambers are filled with viscous fluid called perilymph; they communicate with one another via a canal. Sound vibrations enter the cochlea through the oval window and cause periodic change of pressure in the perilymph, which, in turn, causes the membrane to vibrate. The motion of the fluid is described by hydrodynamic equations, which are supplemented with the membrane vibration equation. The equations are linearized in the amplitude of the vibrations, and their solution is sought in the form of Fourier harmonics with a given frequency. To determine the harmonics, a system of linear boundary value problems for ordinary differential equations with variable coefficients is obtained. The numerical solution of this system using finite difference method fails because it involves a large parameter and the problem is close to a singular one. We propose a novel numerical method without saturation that enables us to obtain solutions in a wide range of frequencies up to an arbitrary and controllable accuracy. The computations confirm the Bekesy theory stating that high frequency sounds cause the membrane to bend near the apex of the cochlea, and low frequency sounds cause it to bend near the base of the cochlea.

MSC:

74L15 Biomechanical solid mechanics
76Z05 Physiological flows
92C10 Biomechanics

Keywords:
basilar membrane; cochlea; perilymph; endolymph; vibrations; frequency; Chebyshev polynomial; linear boundary value problems; system of ordinary differential equations; variable coefficients; numerical method without saturation

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