ANALYSIS OF A DYNAMIC RESPONSE OF A COCHLEA USING FLUID-STRUCTURE INTERACTION MODEL

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1. Introduction

The work presents the results of our research on human inner ear modeling. The human inner ear consists of two parts: the semicircular canals (responsible for the sense of balance) and cochlea (responsible for the hearing). The cochlear macro-mechanics is not fully understood yet. The experiments are extremely difficult to conduct because of (a) the fact that the cochlea is a hidden cavity carved in solid bone (temporal bone), (b) the small size of the cochlea, and (c) the even smaller scales of the oscillatory displacements of the sensory membranes. It is almost impossible to measure the basilar membrane displacements or flow fields within the cochlear compartments without disturbing the dynamics in the cochlea. Therefore, the simulation methods create the possibility to answer these open questions. Unfortunately, most current models of cochlear fluid dynamics are far from being able to answer these open questions. Our FSI model answers many opened questions regarding the inner ear operation, taking into account the interaction between the soft tissues and pressure distributions in the cochlea.

2. Model of the cochlea

A 3D Fluid-Structure Interaction (FSI) model (Figure 1) of the uncoiled cochlea was built and validated based experimental data. The model consists all meaningful geometrical features of the biological cochlea like oval and round windows, and the basilar membrane. The frequency - dependent displacement amplitudes of the stapes footplate were used to excite the model [2]. The displacement function in reference to the time is described by Equation 1:

(1) $$d_x(t) = A \times sin(2\pi f t),$$

where: $d_x(t)$ - displacement of the stapes footplate in direction perpendicular to the stapes, A - amplitude, f - frequency, t - time.

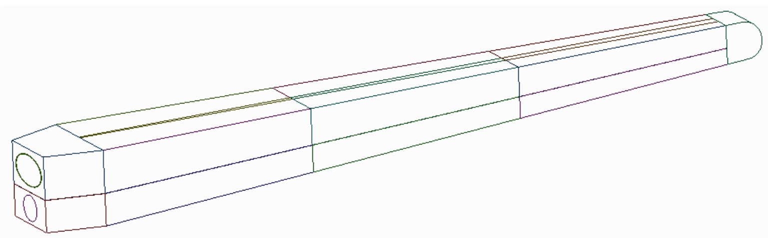

Figure 1. Uncoiled model of the cochlea.

3. Results

The Fluid-Structure Interaction model was used to study basilar membrane deflections and pressure levels in the cochlea at three excitation frequencies: 2.5, 5 and 10kHz. The model was validated against experimental data in terms of the frequency - position data [1], the round window amplitude vibrations [2] and the pressure amplitudes in the scala vestibuli and in the scala tympani [3]. The model gives interesting information which can be helpful in the inner ear mechanics study. Example results are show in Figure 2.

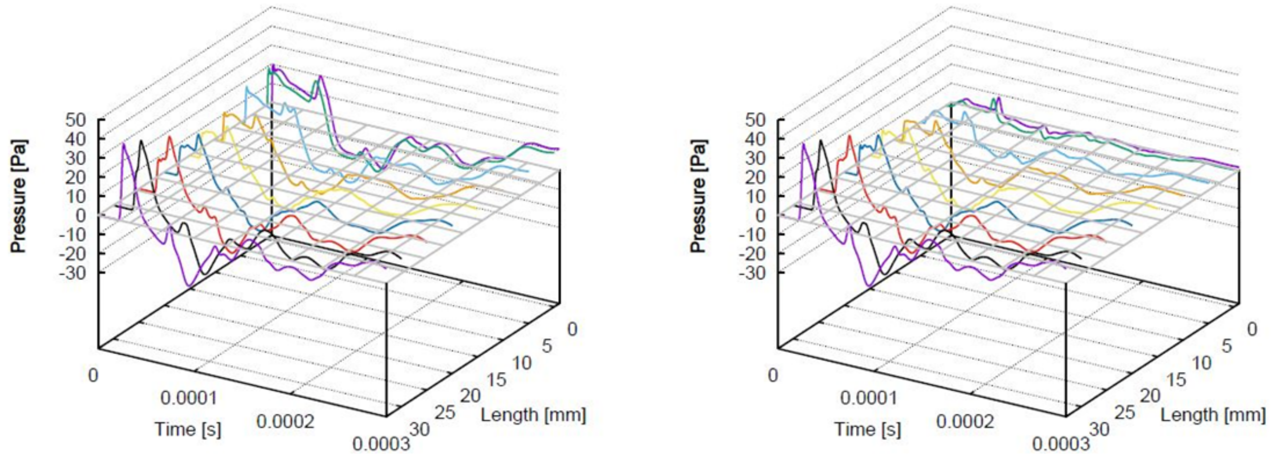

Figure 2. Pressure distribution in the scala vestibuli (left panel) and in the scala tympani (right panel) of the cochlea measured on points placed along the scalas. Length on the charts is measured in reference to the basilar membrane base.

4. Conclusion

The cochlea physiology can be well simulated by our FSI model. Cochlear hydrodynamics, especially the differential perilymph pressure, derived from the FSI model may be used to analyse the effectiveness of cochlear stimulation by various middle ear prostheses or by round window.

5. References

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