Characterization of Ear-Canal Feedback Pressure due to Umbo-Drive Forces: Finite-Element vs. Circuit Models

Morteza Khaleghi
Kevin N O’Connor
Sunil Puria
Characterization of Ear-Canal Feedback Pressure due to Umbo-Drive Forces:
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Morteza Khaleghi, Kevin N. O’Connor, and Sunil Puria
Earlens Corporation, Menlo Park, CA 94025, USA

Background: Hearing-aid users often complain of poor sound quality and difficulty understanding speech in noisy situations. One of the main reasons for this is that the microphone in a hearing aid is typically located above the pinna, rather than inside the ear canal, in order to minimize feedback. This, in turn, reduces the subject’s ability to perceive the acoustic pinna cues above about 4 kHz that are needed for sound localization. Various strategies for minimizing the feedback pressure (thereby increasing the Maximum Stable Gain, MSG) of a wide-bandwidth non-surgical Tympanic Lens are investigated numerically to facilitate placement of a microphone in the ear canal.

Methods: The ear-canal feedback pressure due to mechanical stimulation of the tympanic membrane (TM) was calculated using a 1D circuit model representing the TM as a distributed-parameter transmission line and the ossicular chain and cochlea as a network of lumped elements (O’Connor and Puria, 2008), and using a 3D finite-element model (FEM) representing the human middle ear (Puria et al., 2014). In both cases, the ear canal was terminated with an impedance boundary condition of \( \rho \times c \) for air. Circuit-model and FEM responses to umbo-force stimulation are compared with experimental data from four human cadaveric temporal bones (Puria et al., 2015).

Results: The MSG calculated from the two models and TB measurements decreases from about 40 dB at 0.1 kHz to about 15 dB at 1 kHz. Between 1.5 and 4 kHz the MSG is about 10 dB. As the frequency increases above 4 kHz, the MSG of the FEM, in agreement with experimental data, increases to 40 dB at 8 kHz. However, the MSG of the circuit model only reaches a maximum of 10 dB at 6 kHz. Furthermore, the direction of the force vector at the umbo can be optimized to increase the MSG by up to 10 dB in the 1–4 kHz range.

Conclusions: While the feedback pressure in devices that mechanically stimulate the umbo is significantly lower than in acoustic hearing aids, it is still not zero, and this limits the placement of a microphone in the ear canal for patients with significant hearing loss. Attempts at reducing the feedback pressure by altering the umbo-force vector have been studied using two computational models. While both of the models predicted the feedback pressure precisely below about 4 kHz, only the FEM results come close to the measurements at higher frequencies.
Abstract Text

Title: Characterization of Carotid Feedback Pressure due to Umbilical Cord Pulsations: Finite Element vs. Circuit Models

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Keywords: Pulsation, Umbilical Cord

Abstract Body

Background: According to some reports, umbilical cord pulsation can result in aortic arch compression and potentially lead to cardiovascular complications. One of the main reasons for this is the interaction of a radiating blood jet and a jet from the umbilical cord. This interaction can cause turbulence and feedback that can impact the cardiac function.

Methods: The study was conducted using a 1D aortic arch model simulated using a computational fluid dynamics (CFD) approach. The model incorporated the anatomy of the aortic arch and the umbilical cord pulsations, which were modeled as a source term at the umbilical end. The model was validated against experimental data from real human umbilical cord samples.

Results: The model accurately predicted the pressure waveforms and flow patterns observed in the experimental studies. The umbilical cord pulsations were found to significantly contribute to the overall pressure gradients in the aortic arch.

Conclusions: The umbilical cord pulsations play a crucial role in the hemodynamics of the aortic arch. Understanding these interactions is essential for the development of new therapies and the prevention of cardiovascular diseases.

Research Funding

Supporting Files

First Author

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Sex:

First Name:

Middle Name:

Last Name:

Credentials:

Job Title:

Institution:

Department:

Mailing Address:

City:

State/Province:

Postal Code:

Country:

Email Address:

Phone:

Marital Status:

Gender:

Academic Rank:

Role:

Co-Authors

<table>
<thead>
<tr>
<th>First Name</th>
<th>Last Name</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kevin</td>
<td>DCarter</td>
<td>Co-author</td>
</tr>
<tr>
<td>Alex</td>
<td>Pilla</td>
<td>Co-author</td>
</tr>
</tbody>
</table>