Simulation of Acoustically Excited Membrane Waves on an Eye

J. Mäkinen[1], D. Veira Canle[1], T. Ylitalo[1], R. Montonen[1], H. Malinen[1], S. Bäckroos[1], P. Ihalainen[1], E. Lampsijärvi[1], J. Heikkilä[1], T. Paulin[1], A. Salmi[1], A. Kontiola[1], I. Kassamakov[1], E. Hæggström[1]

[1]Department of Physics, Division of Materials Physics, University of Helsinki, Helsinki, Finland

Abstract

High intraocular pressure (IOP) is a risk factor for glaucoma, a condition that can cause blindness. Conventional ways of measuring IOP either require contact or can be uncomfortable for the patient. We have developed a method to measure IOP from the propagation time of a wave on the outer membranes of the eye, the cornea and sclera. A high IOP correlates with a high wave speed. To excite this wave noninvasively we use a shock wave that interacts with the eye. To understand the mechanics of wave propagation on a biological, membrane-like structure and the mechanics of acoustic wave coupling to such a structure, we have created a COMSOL Multiphysics® model. The model predicts wave propagation speed along the eye as a function of IOP value. The simulated predictions are then compared to measured results where a correlation between IOP and wave speed can be seen for both.

Our model uses the Pressure Acoustics interface in the time domain. The acoustic pulse is modeled with a non-linear profile resembling that of a shock wave. The actual shock wave was weak, it was less than 10% faster than the speed of sound in air. Hence we used the default implementation of the Pressure Acoustics interface to model the acoustic structure coupling. The acoustic wave is coupled to the Solid Mechanics interface which is used to model the cornea and sclera of the eye. The inside of the eye was also modeled and because it is mostly water, it was approximated to be homogeneous.

Figures used in the abstract

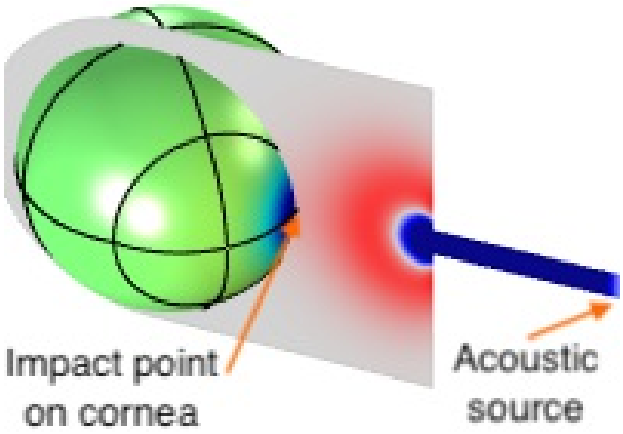

Figure 1: An acoustic wave from a tubular source impacting on the cornea, and exciting a wave on the surface of the eye.