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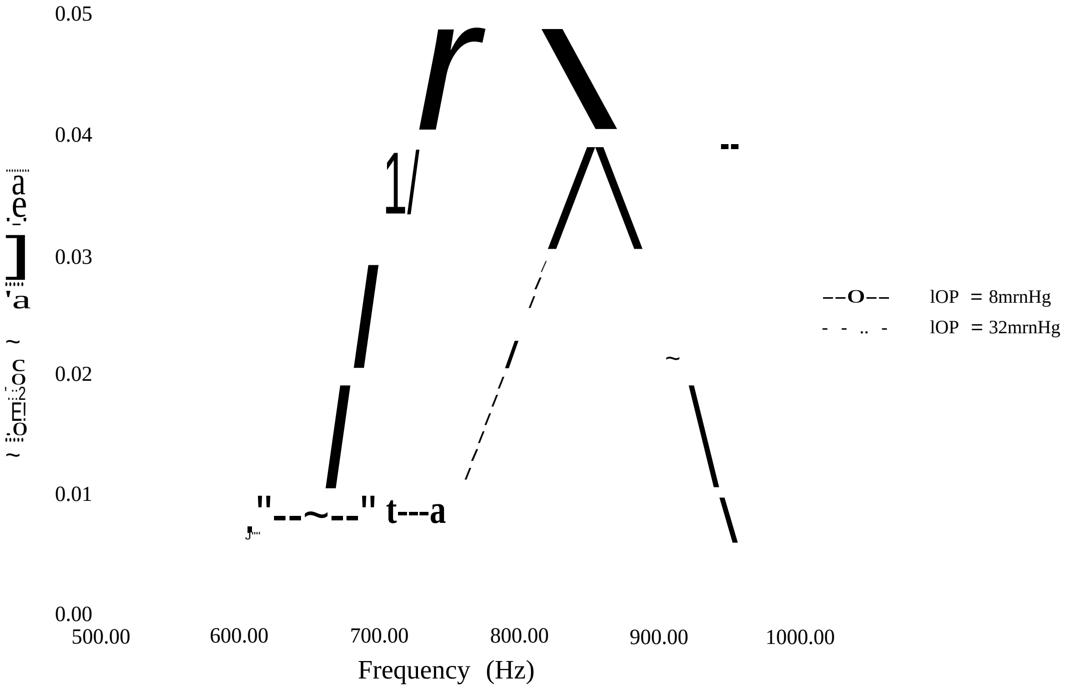

Fig. 3. *In vitro* response of a human eye-bank eye with shift in intraocular pressure (IOP). Vertical scale: estimated radial vibration amplitude. Horizontal scale: vibration frequency.

approximately one third of the Young's modulus, and thus, for the sclera, we took $\mu \sim 1000$ kPa. To see how the resonance shifts with changing rigidity, we evaluated the resonance frequencies for μ = 100, 300, 1000, 3000 and 10,000 kPa. The resonance is seen to shift significantly for these changes, as shown in Fig. 1, which gives the larger real positive frequency solutions to the first three resonance modes (n = 1, 2, 3). We see that all resonances increase with the increase in rigidity. Thus, we expect the resonance frequencies to shift upward as IOP increases. This hypothesis is supported in the detailed analysis in Coquart et al. (1992) for both the *in vitro* (eye being out of the socket) and *in vivo* (eye being inside the socket) cases.

Estimating the vibration amplitude

When a scattering object vibrates in a manner to produce a wavelength much larger than the geometric dimensions of the scatterer itself, the Doppler spectrum of the signals returning from sinusoidally oscillating structures is similar to that of a pure tone frequency modulation process (Holen et al. 1986).

The received or scattered wave can be written as (Carlson 1986; Huang 1990):

$$s_r(t) = A\cos\left\{2\pi f_0 t + \frac{2\pi \Delta f_m}{2\pi f_L}\sin(2\pi f_L t + \varphi)\right\}, \quad (3)$$

where A is the amplitude of $s_r(t)$, f_0 is the center frequency, f_L is the vibration frequency, φ is the vibration phase and

$$\Delta f_m = \frac{2 v_m f_0 \cos\theta}{c_0}, \quad (4)$$

where $v_m = 2\pi f_L \xi_m$ is the vibration amplitude of the velocity field, ξ_m is the vibration amplitude, f_0 is the propagation speed of the waveof is the human

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Parker, K. J.; Huang, S. R.; Musulin, R. A.; Lerner, R. M. Tissue response to mechanical vibrations for sonoelasticity imaging. Ultrasound Med. Biol. 16:241–246; 1990.

Parker, K. J.; Lerner, R. M. Sonoelasticity of organs: Shear waves ring a bell. J. Ultrasound Med. 11:387–392; 1992.

Taber, L. A. Large deformation mechanics of the enucleated eyeball. J. Biomech. Eng. 106:229–234; 1984.

Woo, S. L.-Y.; Kobayashi, A. S.; Schlegel, W. A.; Lawrence, C. Mathematical model of the corneoscleral shell applied to intraocular pressure relations and application tonometry. Ann. Bio-