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DEVELOPMENT OF A NUMERICAL MODEL TO SIMULATE PRESSURE DISTRIBUTIONS IN ULTRASOUND ANGIOPLASTY

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INTRODUCTION

Ultrasound Angioplasty has been shown to be effective in the removal and re-canalising of blockages in arteries (Siegel RJ, 1993). The ultrasound is delivered via a wire waveguide to the lesion location.

The wire, generally, has a ball-tip at the distal end to increase transmission of the ultrasound to the surrounding fluid by causing the ball-tip to oscillate between 20– 45kHz and with displacements of up to 100μm peak-to-peak (Atar, 1999 and Yock, 1997). Pressure waves, micro streaming, cavitation and direct contact with the oscillating ball-tip affect the blockage.

Most work to date has concentrated on a spherical ball-tip geometry at the distal end of the wire waveguide, with the ball-tip diameter between 1-2mm (Steffen, 1994 and Rosenschein, 1996).

METHODS

To simulate the interaction between the ball-tip and surrounding fluid a Finite Element Acoustic Model using fluid-solid interaction and acoustic elements was developed.

In order to validate the FEA model a pulsating sphere was simulated and compared with the analytical solution, given in Equation 1.

The radial displacement and frequency were the input loads on the solid ball tip, while outputs included maximum nodal pressures at points in the acoustic field.

EQUATIONS

Equation 1 gives the solution for the maximum pressure at a distance $r = 1$ due to a pulsating sphere in a fluid (Burdic, 1991):

$$\frac{\varepsilon_m(a)}{p_m} = \frac{\lambda \left[1 + \left(\frac{\lambda}{2\pi a} \right)^2 \right]^{\frac{1}{2}}}{2\pi a \rho c^2} \tag{1}$$

P_m= Peak Pressure Amplitude at the range r=1, ρ = fluid density, λ= wavelength, $\varepsilon_m(a)$ = displacement at distance r = a, a = radius of sphere, c= speed of sound in the fluid medium.
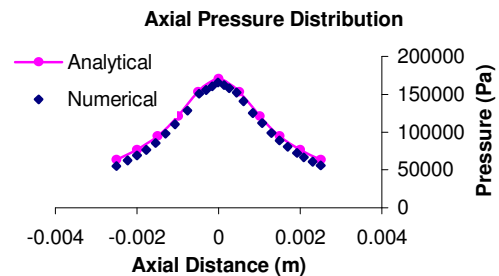
FIGURES AND TABLES

Figure 1: Plot of maximum pressure distribution axially parallel to pulsating spherical ball-tip. d_0= 15μm, f= 22.5kHz, a= 0.00075m, c=1580m/s

DISCUSSION

The correspondence between the finite element solution and the analytical solution for a pulsating sphere is shown in Figure 1. This is a plot of the maximum pressures at points axially parallel to the tip at a distance of 1mm. This location is similar to that of the arterial wall, although the presence of the wall is ignored here.

Areas of cavitation activity may be identified where the maximum pressure amplitude exceeds ambient fluid pressure. This information may aid in the design of the devices.

In future work the validated model will be used to simulate an oscillating sphere. This is more representative of actual tip movement during ultrasound angioplasty.

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