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INFLUENCE OF GUIDE WIRE CATHETER IN SIGNIFICANT CORONARY STENOSES BEFORE ANGIOPLASTY USING COMPUTATIONAL HEMODYNAMICS

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ABSTRACT

Hemodynamic interactions with smaller catheter-based pressure sensors evolving in clinical use was evaluated by Computational Fluid Dynamics (CFD) in human coronary artery stenoses before angioplasty procedures. The narrower flow cross-section with a guide wire present elevated the pressure gradient above that for physiologic flow by 180 % at basal flow.

INTRODUCTION

The development of small guide wire catheter sensors hold promise for reducing flow blockage effects in measuring mean transstenotic pressure gradients $\Delta\tilde{p}$ (e. g. Emanuelsson, et al. 1993), and velocities distal to lesions (e.g. Segal, et al. 1992). For critical minimal area coronary lesions of size ~ 1 mm, the ratio of guide wire size to minimal lesions size is about 1/2. A key to the evaluation of current clinical measurements is the determination of the lesion mean pressure gradient flow rate relation ($\Delta\tilde{p} - \tilde{Q}$) for two situations: physiologic flow, and with a catheter present which disturbs and changes the flow. In this investigation, computational hemodynamics is used to acquire numerical data on the flow field, phase relations, and the magnitude of phasic and mean pressure gradients in significant human coronary stenoses before angioplasty. For physiologic flow, the data set of Wilson et al. (1988), was used. The amount of shift in the $\Delta\tilde{p} - \tilde{Q}$ relation due to guide wire induced increases in flow resistance is evaluated by flow simulation. In the throat region, the ratio of guide wire size (presumed to be d_i = 0.46 mm) to minimal lesion size (d_m = 0.95 mm) was 0.48. Wilson and Laxson (1993) note that the specific effects of changes in hemodynamic conditions on pressure gradient measurements are not well described in the human coronary circulation.

METHODS

The *in vivo* data set of Wilson et al. (1988) in a 32 patient group undergoing percutaneous transluminal balloon coronary angioplasty (PTCA) was used. The patients had single-vessel, single-lesion coronary artery disease. Dimensions and shape of the coronary stenosis before angioplasty were obtained from biplanar angiograms. The average minimal diameter d_m = 0.95 mm (A_m = 0.7 ± 0.1 mm^2). Average proximal diameter was d_e = 3 mm, producing a 68% mean diameter stenosis before PTCA. Dimensional data on the shape of a similar size lesion are from Back and Denton (1992). Before angioplasty, the length of the constriction region was l_c = 6 mm, the narrow throat length was l_m = 0.75 mm, and the divergence length l_r = 1.5 mm. Average distal diameter $d_r \simeq d_e$. Measurements of coronary flow reserve by Wilson et al. (1988), with a 3F pulsed Doppler Ultrasound Catheter ($d \simeq$ 1.0 mm) with tip positioned proximal to the coronary lesions (with minimal blockage) was 2.3 ± 0.1 in the abnormal range for the patient group before angioplasty.

The coronary flow waveform used in the flow simulations was obtained in our laboratory from *in vitro* calibration (Cho et al. 1983), smoothing the fluctuating Doppler signal, and phase shifting the normal pattern for the proximal LAD. The spatial average velocity across the flow $\bar{u}(t)$ needed for flow simulations, is similar to that from Doppler catheter measurements in patients where normal peak diastolic flow is reduced by significant lesions (e. g., Wilson et al. 1988; Segal (*Cardioimetrics*) 1992). The ratio of relative peak diastolic to peak systolic velocity was 0.4 .

The flow simulations were carried out by solving mass and momentum equations using a Galerkin finite element method. The Carreau model was used for shear rate dependent non-Newtonian viscosity of blood. In the proximal vessel the spatial velocity profile was taken to be the usual Poiseuille profile for physiologic flow, and the analogue profile with the catheter (assumed to lie concentrically in the lesion). The calculations were initiated a distance proximal to the lesion to allow the pulsatile non-Newtonian blood velocity profile to develop before the stenosis inlet, and extended a distance distal to the lesion to allow for separated flow reattachment processes in the distal vessel. The calculations were for two consecutive pulse cycles in order to compare them and to obtain accurate results; the results for the second pulse cycle are calculated in continuation of the first one. Heart rate was 75 beats/min (period of a heart beat T = 0.8 s) and the density of blood ρ = 1.05 gm/cm^3. The finite-element code FIDAP, Sun Ultrasparc2 computer was used. Reported pressure drops $\Delta p(t) = p_r - p_e$ are instantaneous pressure differences between the stenosis inlet and distal region, thereby including pressure recovery therein. These are referred to as pressure gradients in the literature.

RESULTS AND DISCUSSION

Values of calculated $\Delta p(t)$ are shown in Fig. 1 for physiologic flow, and Fig. 2 (guide wire present) during the cardiac cycle at a basal time average (mean) flow rate $\tilde{Q}$ of 50 ml/min. For physiologic flow, the corresponding mean Reynolds number $\tilde{\mathrm{Re}} = 100$ and frequency parameter $\alpha_e = 2.25$. The shape of Δp with time is generally similar to the waveform velocity $\bar{u}$ in either case. Inertial effects and momentum changes are significant, however, and there is a phase lag in the $\Delta p - \bar{u}$ relation. Time average (mean) $\Delta\tilde{p}$ are shown by the dotted lines in Figs. 1 and 2. With the guide wire present, values of $\Delta\tilde{p}$ increased by 180 % above that for physiologic flow.

The results of the computations over a range of mean flow rates including hyperemic response will be reported at the conference.

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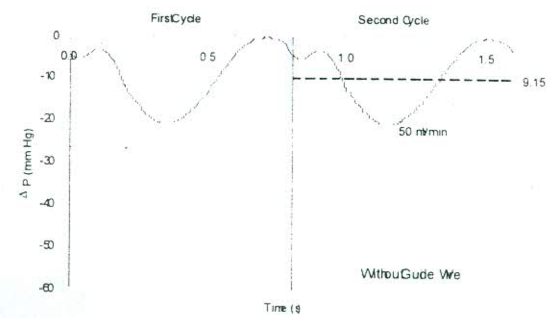

Fig 1: Pulsatile pressure drop Δp(t) across the stenosis during cardiac cycle before angioplasty for physiologic mean flow rate (without the catheter) Q = 50 ml/min.

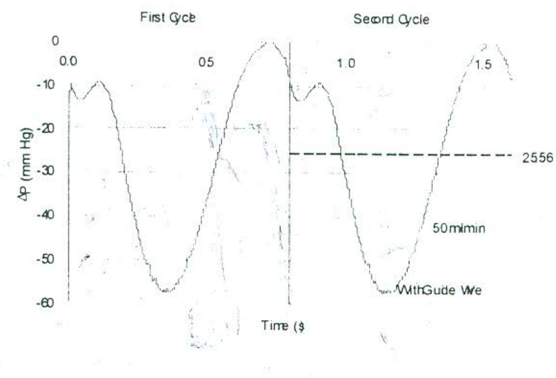

Fig 2: Pulsatile pressure drop Δp(t) across the stenosis during cardiac cycle before angioplasty with the catheter present; mean flow rate Q = 50 ml/min.