FLOW AND COMPRESSION IN ARTERIAL MODELS OF STENOSIS WITH LIPID CORE

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INTRODUCTION

High grade stenoses can limit blood flow and produce conditions in which the artery may collapse. This resultant compression may be important in the development of atherosclerotic plaque fracture and subsequent thrombosis or distal embolization [1]. We used experimental stenosis models that closely approximate the arterial disease situation where the entire stenosis is compliant [2, 3]. This paper was to examine the influence of lipid core in the stenosis on flow and compression under pulsatile flow

METHODS

The diseased carotid artery was modeled using an elastomer shaped in the form of a stenosis. Figure 1 illustrates the stenosis shape and pictures of sliced stenosis. The elastomer of lipid core model is inside of the stenosis part, and dyed in blue. The Young's moduli (for 40% stretch) of artery and lipid core models are 5.0×10^5 Pa and 4.2×10^3 Pa, respectively. The volume of lipid core model is 44% of stenosis part. Nominal stenosis severity (percent stenosis) and eccentricity of the stenosis model are given by:

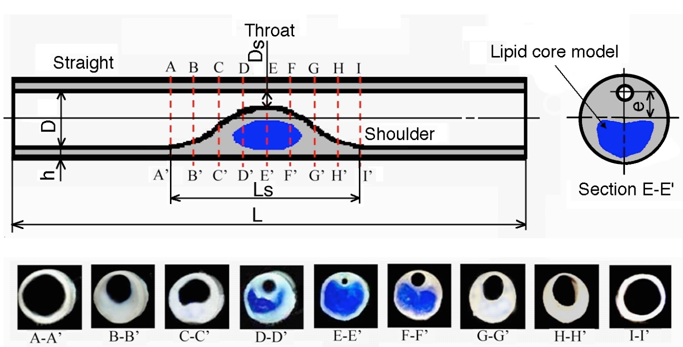


Figure 1: Schematic representation of the stenosis models and pictures of sliced stenosis *L*=110 mm, *Ls*=16mm, *D*=8mm, *h*=1mm.

$$St = (D - Ds)/D \quad \times 100 \ (\%) \tag{1}$$

$$Ec = e/((D-Ds)/2) \quad \times 100 \ (\%) \tag{2}$$

We used the model of 70-80% Stenosis and 100% Eccentricity.

The experimental flow loop is depicted in Figure 2. Pulsatile flow was perfused through the hydrogel stenosis model. The computer controlled gear pump which works as alternative current component, was connected to upstream tube. For the pulsatile flow, the upstream pressures were set as 100+/-30mmHg and downstream pressure was changed. Flow rate was measured by electromagnetic flow meter; pressures at the upstream and downstream were measured by pressure transducers. The working fluid used was water at room temperature. Sagittal section and cross-section ultrasound images of the stenosis were made from the B-mode of a Duplex ultrasound scan.

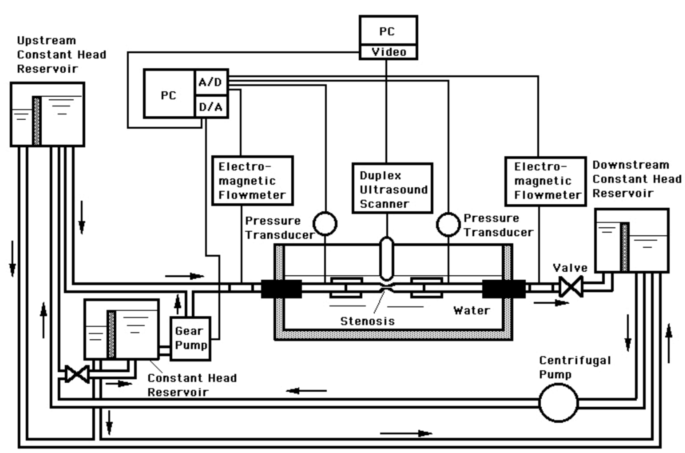


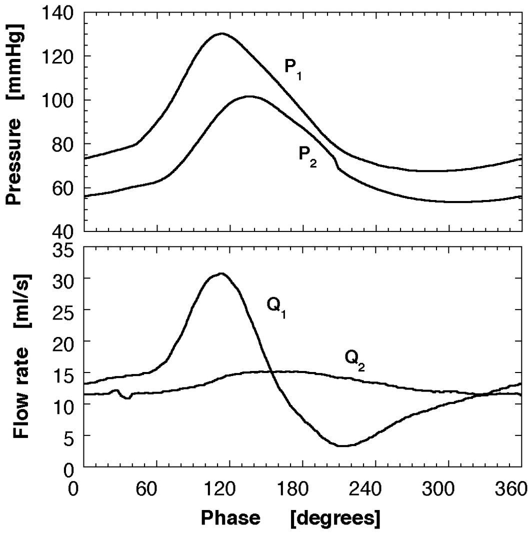
Figure 2: Experimental set-up for steady and pulsatile flow experiments in the compliant stenosis.

RESULTS

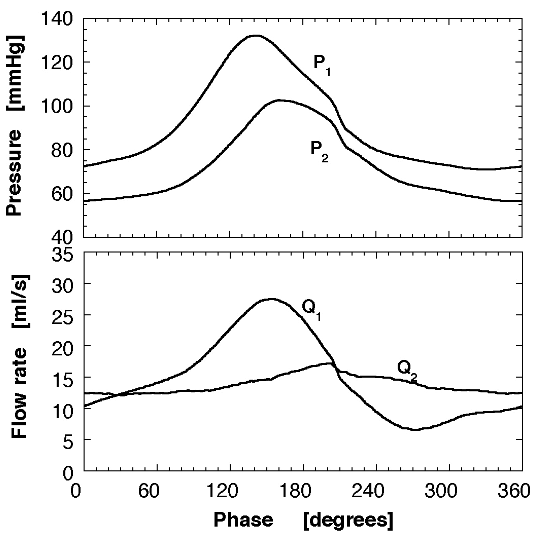
The pressure and flow rate through the compliant stenosis models are shown in Figure 3. The stenosis model caused a phase difference of flow rate and pressure between upstream and downstream. The phase difference in the stenosis model is accounted by the compliance of the straight portion (tube) of the stenosis model and the resistance of stenosis. There are no great differences between models of with or without lipid core. But the average down stream flow rate of with lipid core model was greater than that of without lipid core model.

Ultrasound images of sagittal section of stenosis model are shown in Figure 4. For the stenosis with lipid core, collapse is greater and location is closer to throat. Shape of stenosis with lipid core is slightly deformed to downstream side.

Table 1 shows the average downstream pressure (P_{2ave}) when the first outbreak of collapse is occurred. P_{2ave} of the models with lipid core is greater than that of without lipid core. This is explained that stiffness against collapse is reduced by the existence of lipid core. Besides, P_{2ave} increases with a decrease in stenosis severity. This is accounted by the geometrical stiffness against collapse. The phase of the first outbreak of collapse was generally around the end of systole (higher flow rate at post stenosis).

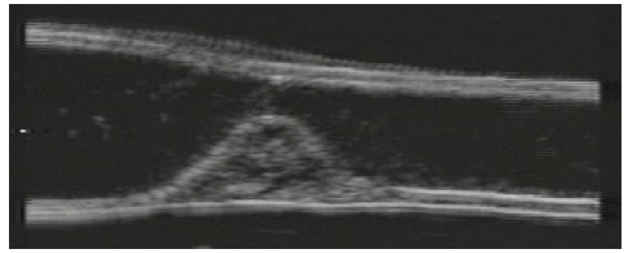


(1) *St*=70% *Ec*=100%, without lipid core

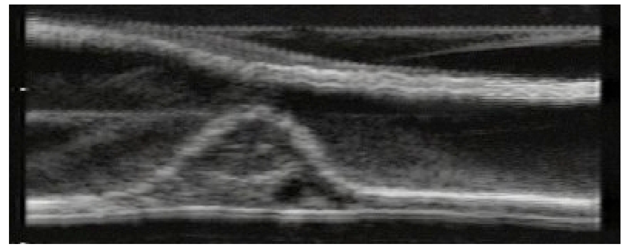


(2) *St*=70% *Ec*=100%, with lipid core

Figure 3: Measured upstream and downstream pressure for straight comliant tube. P_1, P_2: upstream and downstream pressure, Q_1, Q_2 : upstream and downstream flow rate.



(1) *St*=70% *Ec*=100%, without lipid core



(2) *St*=70% *Ec*=100%, with lipid core

Figure 4: Ultrasound images of the sagittal section of stenosis. (Upstream side; Left, downstream side; Right). Upstream pressure P_1=100+/-30mmHg, average down stream pressure P_{2ave}=10 mmHg, frequency=1.0 Hz, phase=168deg, axial stretch=36.5%.

Table 1: Average downstream pressure (P_{2ave}) when the first outbreak of collapse is occurred (*Ec*=100%)

St [%] \ Model	without lipid core	with lipid core
70	10	14
75	7	10
80	5	6

[mmHg]

DISCUSSION

This is a two component model, whereas diseased arteries may have complex plaque, fibrous cap and lipid core. The volume of lipid core is relative to stiffness of stenosis. These results may suggest that soft stenoses show collapse at higher average downstream pressures.

REFERENCES

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