LES of Physiological Blood Flow in Diseased Basilar Artery: Semi-Patient Specific Model

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SUMMARY

Large Eddy Simulation (LES) is applied to study physiological pulsatile spiral and non-spiral blood flow through a model of an irregular stenosis with an adjacent post-stenotic fusiform irregular aneurysm in basilar artery. The stenosis and the aneurysm are of 75% area reduction and 126% area enlargement, respectively, at their centres [1]. Numerical results of various important physical quantities are presented to particularly investigate the transition-to-turbulence nature of the pulsatile flow with their relevant clinical implications.

Key Words: *LES, arteriosclerosis, blood flow, turbulence, wall shear stress, aneurysm.*

1 INTRODUCTION

Atherosclerotic artery rarely has both stenosis and aneurysm in the same arterial segment. Until recently no reports on intracranial stenoses associated with adjacent aneurysms have been found [1]. In *et al* [1] reported the existence of a severe stenosis with an adjacent (pre-stenotic 'saccular' or post-stenotic 'fusiform') aneurysm in basilar artery. They defined a 'saccular' aneurysm as an aneurysm which has a smooth berry-shaped body and a neck; and an 'atherosclerotic fusiform' aneurysm as an aneurysm having a dilated arterial segment without definite neck formation.

Aneurysm has the potential for rupture of the vessel wall, which may lead to haemorrhage, complications to local organ function, and even death as aneurysm ruptures have high mortality and morbidity rates [2]. Hence, like severe stenosis, aneurysm could prove fatal if left without taking any therapeutic measures. The objective of this work is to study the transient blood flow through a semi-patient specific model of an arterial stenosis with an adjacent (post-stenotic) aneurysm in the same arterial segment giving particular focus on the relevant pathophysiology associated with the cardiovascular diseases.

2 NUMERICAL MODELLING AND RESULTS

Figure 1(a) depicts the model geometry resembling a section of basilar artery with stenosis and aneurysm. The diameter of the undiseased section of the model is taken as $D = 8$ mm [3]. The stenosis is centred at $z = 0$ and of length $2D$ while the adjacent aneurysm is taken of length $= 4D$ and centred at $z = 3D$. The cross-sections of both the stenosis and aneurysm are shifted a maximum of 0.25 mm randomly to either x or y-direction (positive or negative) to generate the irregular shape with a cosine function. Governing equations of flow are solved by LES [4] with physiological and pressure pulses employed at the inlet and outlet, respectively. Spiral velocity

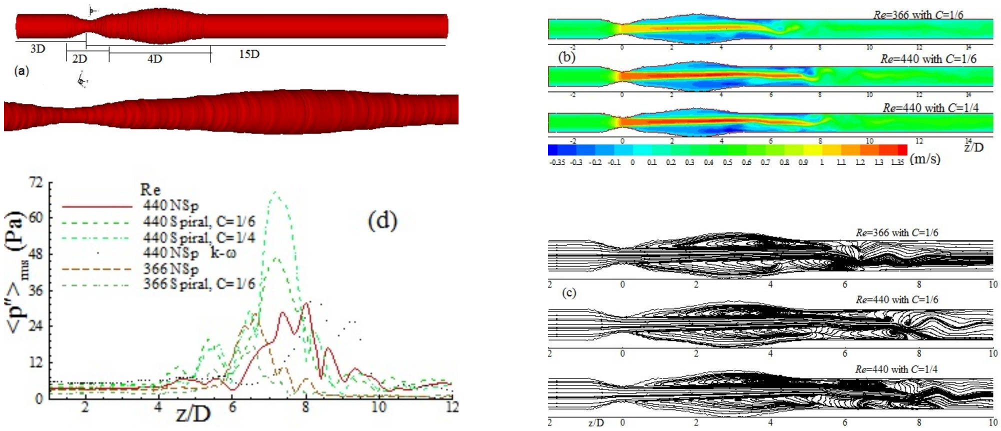

Figure 1: Irregular model artery having stenosis with adjacent aneurysm (a); Instantaneous streamwise velocity (b), streamlines (c) and rms of wall pressure fluctuations (d) at different Re and spiral speed. The Womersley number is fixed at 6.92.

at the inlet is introduced by taking the magnitude (C) of the pulsatile bulk velocity as tangential velocity [5]. A no-slip condition is applied to the rigid wall and the results presented are almost mesh independent. The Reynolds numbers (Re) investigated, based on the bulk inlet velocity, are 366 and 440 corresponding to the respective peak Re of ≈ 1000 and 1200. Due to the absence of any experimental or 'in-vivo' data, the simulation for $Re = 440$ was run with the two-equation k-ω Transitional model to crudely assess the LES results.

Fig. 1(b) shows that the flow reverses near the wall from the centre of the stenosis to the immediate downstream region of the aneurysm. The stenotic jet becomes weaker at around the post-lip of the aneurysm, i.e. at $z \approx 5D$, and starts to break down. The flow streamlines (c) towards the downstream of aneurysm appear to be very chaotic due to the presence of turbulence. Where the rms of the wall pressure fluctuations, $\langle p'' \rangle_{rms}$ (d), are found strongly oscillating with their peaks generally rising due to the spiral velocity which, associated with the extreme pressure fluctuations, usually causes arterial murmurs.

3 CONCLUSIONS

Transition process of the blood flow through a model of stenosis-aneurysm in basilar artery has been studied by LES. Strong turbulence influenced by the spiral flow was predicted in the aneurysm downstream and the turbulent energy spectra showed a large range of frequencies making up the inertial subrange region. Extremely large recirculation regions found are very harmful in the pathological context since they increase the blood residence time with potential risk of stroke and blood clot or thrombosis inside the aneurysm. The turbulent wall shear stresses around the diseased section also reaches clinically dangerous level for both the Reynolds numbers.

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