NON-INVASIVE MEASUREMENT TECHNIQUES APPLIED TO BIOLOGICAL FLOWS STUDY OF MULTIPLE LUNG BIFURCATIONS

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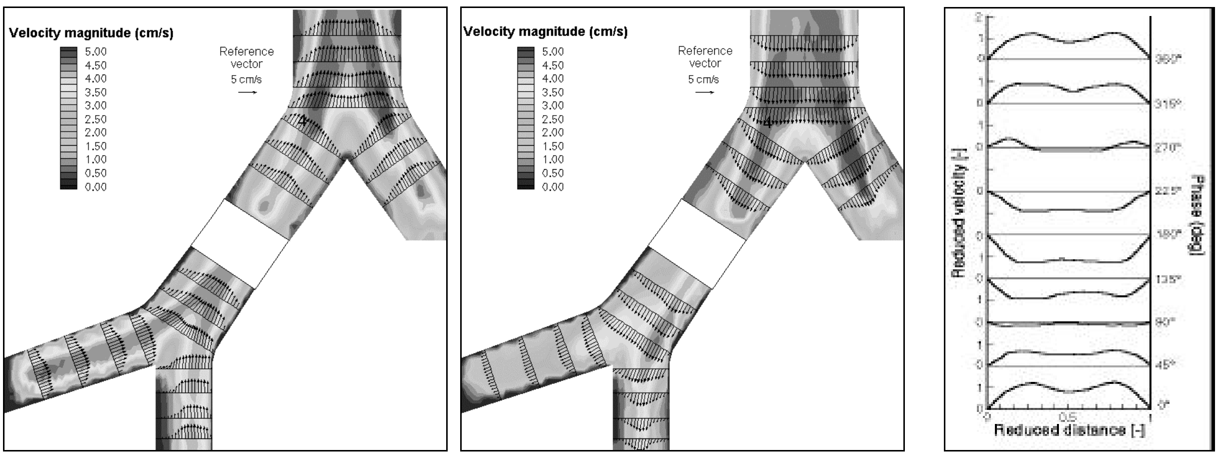
Fluid mechanics is one of the approaches in the field of biomechanical engineering, which allows, thanks to the study of physiological flows, to get a better understanding of biological systems. This research is divided into 2 parts. The first one consists in establishing a general review of three advanced non-invasive measurement techniques: laser Doppler velocimetry, particle image velocimetry (PIV) and magnetic resonance phase velocity mapping techniques. In this section, two studies dealing with blood flows are presented: flow downstream of a heart valve and flow in a total cavo-pulmonary connection.

The second part of this research deals with the study of steady and oscillatory flows in a network of pulmonary bifurcations. The pulmonary zone under investigation corresponds to generations 5, 6 and 7 of the bronchial tree, the zone in the conducting part of the respiratory tract where the flow is laminar.

Steady inspiratory and expiratory flows were investigated with laser velocimetry techniques. At inspiration, it is shown that the bifurcations cannot be considered independent from each other, for Reynolds numbers varying between 400 and 1500. At expiration, some visualisations show that secondary motions, which are flow rate dependent, induce the deformation of the axial flow.

For the study of oscillatory flows, a system of four pistons was placed at the outlet of each branch of the model. The system controls the flow in imposing a sinusoidal flow rate around a mean value equal to zero, to simulate the inspiratory and expiratory phases. The measurements were performed using a time resolved PIV technique in order to understand and assess the flow fields in successive bifurcations. The time-development of the velocity through successive bifurcations is presented for different Reynolds and Womersley numbers.

The effects of both the Reynolds and Womersley numbers on the flow structure and in particular on the boundary layer development in function of time were highlighted (see figure). The quasi-steadiness of the flow as the frequency of oscillation decreases was also investigated. Moreover, this investigation demonstrates that, in certain conditions, the structure of the flow can repeat itself from one bifurcation to the other one, despite the presence of strong secondary motions. Finally, the phenomenon of Steady Streaming Displacement, that concerns the displacement of a fluid element during a complete period, is illustrated as a way to estimate the particle transport during a complete breathing cycle.



a) Maximum expiration ***b) Maximum inspiration*** ***c) Time evolution at station 4***

Figure 1: Flow in the 3D bifurcation model for Re = 1000, a = 8.1