EXPERIMENTAL STUDY OF THE FLOW FIELD IN PATIENT SPECIFIC LOWER AIRWAYS

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Abstract

In this study Particle Image Velocimetry (PIV) is used to visualize and measure airflow in the lower airways. Using Rapid Prototyping Manufacturing (RPM) technology, a hydraulic in vitro model was developed and constructed. Preliminary 2D PIV measurements compared successfully to Computational Fluid Dynamics (CFD) results.

1 Introduction

Chronic Obstructive Pulmonary Disease (COPD) is in the United States (US) the 4th leading cause of death [1]. More than 12 million people are diagnosed with COPD and it is estimated that another 12 million people have COPD without knowing. More than 20 million people in the US are diagnosed with asthma [2]. The influence of air pollution by particulate on public health is still insufficiently known. Fine particles may settle deeply into the human airways or even diffuse into the blood. This study aims to investigate experimentally the air flow in the lower airways.

2 Materials and methods

A hydraulic in vitro model was designed taking into account the main requirements for PIV. High resolution CT-scans were taken with a multi-slice scanner (GE VCT Lightspeed). Image segmentation and subsequent 3D reconstruction was performed with commercially available software (Mimics 10.0, Materialise). The trachea until the third bifurcation was extracted from the original STL file to develop the physical model. The kernel of the airway model was printed with Fused Deposition Modeling (FDM, Stratasys Inc.) in WaterWorks®, a water soluble material. Using vacuum casting, transparent silicone (Dow Corning, Sylgard 184) was poured around it. The silicone allows for optical access and matches the refractive index of the working fluid (water/glycerin mixture) [3]. After curing, the WaterWorks® kernel was washed out with sodium hydroxide. An image of the model is shown in figure 1 right.

3 Results

Steady flow experiments were performed with a Reynolds number of 1450 based on the hydraulic diameter of the trachea. The velocity profile was measured in the midplane of the trachea under normal breathing conditions at rest. A preliminary PIV result is shown in figure 1 left.

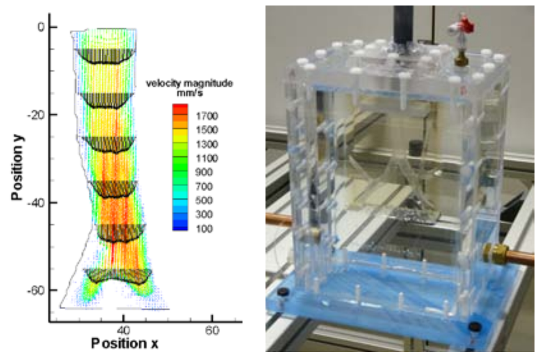

Figure 1: *left:* Flow velocities during inhalation, Re = 1450; *right:* the experimental model

A visual comparison between PIV and CFD result is presented in [4].

4 Conclusion & future

An experimental platform for investigating air flow in the lower airways was developed. PIV measurements in multiple planes will be performed soon. On a longer term, this platform aims to analyze particle distribution to help improve therapies like aerosol spray and to assess the impact of today's air pollution on public health.

References

[1] National Heart, Lung and Blood Institute. Fact sheets: COPD, 2009

[2] National Heart, Lung and Blood Institute. Fact sheets: Asthma, 2009

[3] Hopkins L. M. et al., 2000, “Particle Image Velocimetry Measurements in Complex Geometries,” *Exp. Fluids*, 29, pp. 91–95.

[4] Van Holsbeke C. et. al. Functional Imaging on Patient Specific Lower Airways Using Computational Fluid Dynamics. *Belgian Day on Biomedical Engineering 2009*