Première rencontre CRM–INRIA–MITACS
5 – 9 MAI, 2008

MULTISCALE MODELLING OF THE RESPIRATORY TRACK

Céline Grandmont
Projet REO
INRIA Rocquencourt
BP 105
F-78153 Le Chesnay Cedex
FRANCE

celine.grandmont@inria.fr

Abstract

Our aim is to obtain a model that accurately describes the airflow in the proximal part of the respiratory track. The first two regions (the upper and medium parts) can be visualized by common medical imaging techniques, and direct 3D simulations based on the numerical approximation of the incompressible Navier-Stokes equations can be performed. Nevertheless, one cannot forget that this flow is dependent on the distal part and driven by the motion of the diaphragm and parenchyma. Thus these simulations require the specification of known boundary data on artificial boundaries or the coupling with simplified but representative models. The mathematical description of this geometrical multiscale modelling is a crucial issue since (a) the boundary data are not available from accurate measurements, (b) the distal part is the very pump, the driving force of the respiration. What we propose is a decomposition of the respiratory tree into three stages where different models will be exploited and in which the mechanical behaviour is quite different:

- the upper part (up to the 6th generation), where the Navier-Stokes equations hold to describe the fluid flow,

- the distal part (from the 7th to the 17th generation), where one can assume that the Poiseuille law is satisfied in each bronchiole,

- the acini, where the oxygen diffusion takes place and which are embedded in an elastic medium, the parenchyma.

We will assume that the pressure is uniform in the acini part and that they are embedded in a box representing the parenchyma. The motion of the diaphragm and the parenchyma is described by a simple spring model. We then obtain a sytem where the Navier-Stokes equations are coupled with an ODE. We shall present 3 dimensionnal computations based on this approach, and show how this approach makes it possible to investigate the

influence upon the overall flow of reduction of the diameter of branches in the zone which is not covered by the Navier–Stokes model or the influence of a change in the elastic behaviour of the parenchyma.