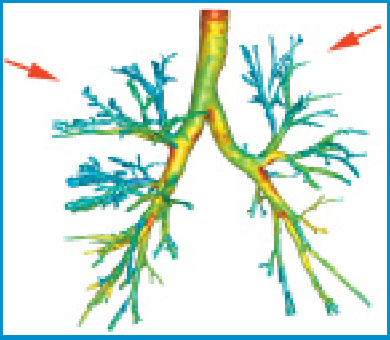
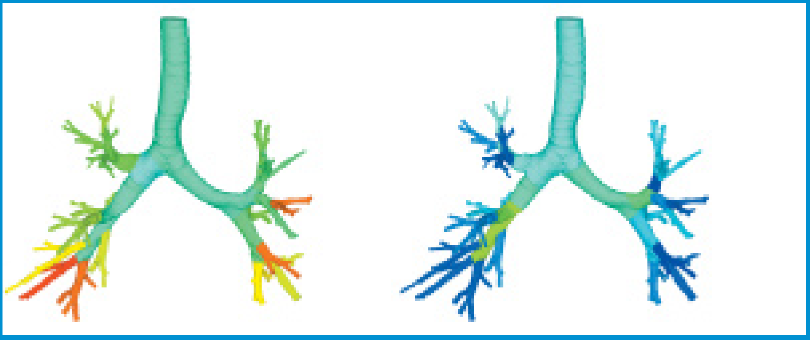
Going with the Flow

Functional biomedical imaging through CFD provides a new way of looking at pathological lungs.

By Jan De Backer and Wim Vos
FluidDA nv, Antwerp, Belgium



Reconstructed airway of a patient with cystic fibrosis: The red arrows indicate regions in which inflammation has restricted the airways.



Contour plots show the effect that the use of a bronchodilator has on the local values for airway volume (left) and resistance (right); red indicates high values and blue indicates low values.

Diseases such as asthma, chronic obstructive pulmonary disease (COPD) and cystic fibrosis can have a significant adverse impact on the structure and integrity of the lungs' airways. While functional magnetic resonance imaging (MRI) allows for measurement of air flow, computational fluid dynamics (CFD) provides highly detailed information of local flow characteristics and resistances. The first requirement of a patient-specific analysis is knowledge of the bounding walls of the patient's flow domain — their lung geometry. This type of information usually comes from computed tomography (CT), a scan that indicates detailed information about lung geometry because of the natural contrast between air and the lung walls. The main drawback of CT is that the resulting scan is a static image. Coupling computational analyses of air flow with the lung scan has the potential to provide significant added value to the clinical evaluation of lung function.

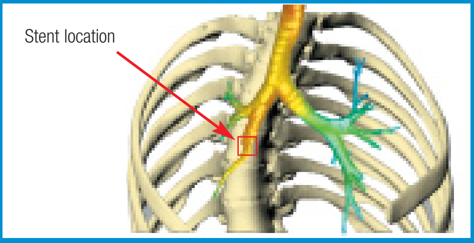
FluidDA, a spin-off of the Antwerp and Ghent universities in Belgium, has successfully developed a workflow for predicting air flow in healthy and diseased lungs using CFD. The fluid and structural dynamics company combines clinical experience and capabilities with numerical simulations to offer a variety of services to the healthcare industry.

The workflow process begins with the conversion of CT scan data into a 3-D computer model of the airway, performed with the Materialise product Mimics. FluidDA then uses TGrid software to create surface and volume meshes and FLUENT technology to simulate and examine the air flow. Flow patterns, relative pressure drops and drug delivery profiles are readily extracted from the simulation results. The resistance distribution — defined as the total pressure drop over various lung segments — also is available.

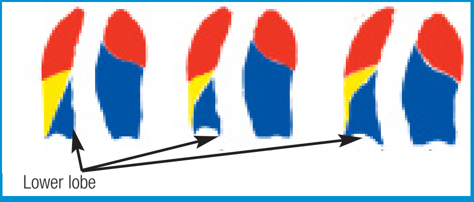
The pharmaceutical and medical device sectors also can benefit from patient-specific flow analysis as a way to evaluate performance and efficacy in a virtual patient population. In clinical studies, it is possible to analyze the effect of bronchodilating medication, which widens lung air passages and relaxes bronchial smooth muscle to ease breathing, on airway volume and flow resistance. A researcher then can begin to establish correlations between drug deposition patterns and clinical outcomes, thereby providing an indication as to why the drug does or does not work. Functional imaging also can be used to assess the placement of intrabronchial devices such as stents and valves.

Coupled with CFD, such imaging can dramatically increase insight into medical assessment and improve the accuracy of medical interventions. ■

For patients with deformation of the spinal column (kyphoscoliosis), simulation can be used to determine the site of obstruction and/or respiratory function.



Obstruction site (and subsequent location) of an intrabronchial stent, which re-inflated the blocked lower right lung lobe. Pressure contours are plotted in the airway.



An increase in the volume of the lower lobe is clear in time following insertion of a stent.