Lung imaging research gets its second wind

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Computational fluid dynamics (CFD) provides a quantitative basis for predicting the pulmonary airflow patterns that carry inhaled materials inside the body. This is not only potentially useful for establishing safer exposure limits to airborne pollutants but also for improving targeted drug delivery in patients with pulmonary disease. One prerequisite is that simulated predictions be thoroughly tested in a living organism, where respiratory airflows depend not only on airway shape and curvature but also on local lung mechanics and associated differences between health and disease.

Until recently this level of testing has not been possible, but researchers at Pacific Northwest National Laboratory took an important step by making the first-ever comparison between CFD-predicted and measured airflow patterns in a live rat. Their findings highlight the practical use of advanced magnetic resonance imaging (MRI) methods that are not only appropriate for developing and assessing predicted airflow patterns within the breathing lung, but also for testing the mass-transfer models that are fundamental to gas mixing in respiratory physiology.

The work is featured on the August cover of the *Journal of Magnetic Resonance* where the team's pioneering MRI method for visualizing inhaled airflow was also a cover in 2008. The current effort is a logical extension to pulmonary CFD model development and testing.

"It basically took us 4 years to develop the underlying data processing and analysis necessary for direct MRI/CFD comparisons," said PNNL physicist Dr. Kevin Minard, who leads the research team. "To some, this might seem like a long time. The payoff is that we're now at the forefront of developing and testing pulmonary airflow predictions with noninvasive imaging. The team that made this possible is truly unique, and there's currently no equivalent capability elsewhere in the world."

Researchers employed high-resolution MRI with hyperpolarized 3He gas to accurately capture pulmonary airway structure for CFD. They also performed phase-contrast (PC) MRI for measuring 3He flow velocity, and developed data processing methods to fuse architectural and dynamic detail. The end result is an integrated platform that not only uses MRI to define pulmonary airway structure and specify CFD boundary conditions, but also provides experimental data for directly testing 3D airflow predictions.

Future research is aimed at understanding how pulmonary diseases like cystic fibrosis and emphysema affect local airflow patterns. Said Minard, "We also plan to improve our imaging techniques to visualize more detail in measured airflow patterns. We can then make finer comparisons between modeling and experiment to directly test how airflow is mediated by local disease."

Initial financial support in 2001 was through PNNL's Laboratory Directed Research and Development program. This was instrumental in growing the $20 million, 10-year project that is currently funded by the National Heart, Lung, and Blood Institute.

"We are seeing the fruits of the Lab's investment," said Dr. Richard Corley, PNNL Fellow and project lead. "Our initial goal was to test 3D models of pulmonary airflow in living organisms."

The PNNL research team includes Kevin Minard, Andrew Kuprat, Senthil Kabilan, Richard Jacob, Daniel Einstein, James Carson, and Richard Corley. The work was done at EMSL, a national scientific user facility at PNNL, sponsored by the U.S. Department of Energy Office of Biological and Environmental Research.

More information: KR Minard, AP Kuprat, S Kabilan, RE Jacob, DR Einstein, JP Carson, and RA Corley. 2012. "Phase-Contrast MRI and CFD Modeling of Apparent 3He Gas Flow in Rat Pulmonary Airways." *Journal of Magnetic Resonance* 221:129-138. DOI:10.101016/j.jmr.2012.05.007

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