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RECONSTRUCTING BABY HEARTS, AIR IN OPERATING ROOMS, SOLVING THE MYSTERIOUS SHAPE OF RED BLOOD CELLS

Medical Highlights of the Fluid Dynamics Conference
Minneapolis, Nov. 22-24, 2009

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FOR IMMEDIATE RELEASE

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WASHINGTON, D.C., November 24, 2009 -- Fluids are a central part of human biology -- from the liquefied food in our gut that we digest, to the nourishing blood in our veins, the protective fluids in our spine, the liquid in inner ears required to hear, and the oxygen we inhale when we breath*. Next week scientists at the largest scientific meeting of the year devoted to the fluid dynamics will present the latest research in this field and its potential impact on medicine.

The 62nd Annual Meeting of the American Physical Society's (APS) Division of Fluid Dynamics takes place from November 22-24 at the Minneapolis Convention Center. This meeting brings together researchers from around the globe to present work with applications in engineering, energy, physics, astronomy, medicine, and mathematics.

Reporters are invited to attend the conference free of charge. Registration instructions and other information may be found at the end of this news release.

MEDICAL HIGHLIGHTS IN THE SCIENTIFIC PROGRAM

The following is a brief sampling of some of the medical highlights from among the 1,611 abstracts to be presented at the meeting.

1) PEDIATRICS: New Tool for Helping Pediatric Heart Surgery
2) STERILIZATION: Cleaner Air in Operating Rooms
3) THROAT SURGERY: A Mechanical Model of Vocalization
4) MALARIA: Measuring and Modeling Infected Cells
5) BLOOD: A Puzzling Aspect of Red Blood Cell Shapes, Explained

1) NEW TOOL FOR HELPING PEDIATRIC HEART SURGERY

A team of researchers at the University of California, San Diego and Stanford University has developed a way to simulate blood flow on the computer to optimize surgical designs. It is the basis of a new tool that may help surgeons plan for a life-saving operation called the "Fontan" surgery, which is performed on babies born with severe congenital heart defects.

The babies who get this surgery have a developmental disease where one of the chambers -- or ventricles -- of the heart fails to grow properly. This leaves their hearts unable to properly circulate blood through their lungs and starves their bodies of oxygen. The lack of oxygen turns their skin blue, a condition sometimes referred to as "blue baby syndrome" for that reason.

The Fontan surgery is one of three surgeries performed immediately after birth to replumb the circulation of children born missing their left ventricles. The operation essentially connects the veins that would normally bring blood into the right side of the heart with the pulmonary arteries. The aim is to redirect the blood flow so that it becomes properly oxygenated, allowing the patient to survive with only one functional pumping chamber. Before the advent of this type of surgery in the early 1970's, these sorts of heart conditions were uniformly fatal.

There are still risks, including exercise intolerance, blood clot formation, and eventual heart failure requiring transplantation. Doctors mitigate this risk by carefully planning the surgery, starting with images of a baby's heart and then sketching out their plans. UCSD's Alison Marsden has been working with surgeons at Rady Children's Hospital and Stanford University to develop a new computational tool to assist in this process. In addition, Dr. Marsden and cardiologist Jeff Feinstein have developed a new Y-graft design for the Fontan surgery that is expected to be put into clinical use within a few months.

"Our ultimate goal is to optimize surgeries that are tailored for individual patients so that we don't have to rely on a "one-size fits all" solution," says Marsden.

The tool first uses imaging data to construct a model of an individual baby's heart and then allows doctors to input their surgical designs. The computer can then systematically explore different potential designs using powerful optimization algorithms, similar to those used in the aerospace industry for aircraft design. It then applies fluid dynamics to simulate the blood flow after reconstruction. This way, says Marsden, surgeons can test their plans and evaluate blood flow patterns before operating.

The talk " Analysis of Alternative Polling Strategies for Derivative-Free Optimization of the Fontan Surgery" by Weiguang Yang, Jeffrey Feinstein, and Alison Marsden is at 12:06 p.m. on Tuesday, November 24, 2009.
Abstract: http://meetings.aps.org/Meeting/DFD09/Event/112194

2) CLEANER AIR IN OPERATING ROOMS

Hospital-acquired infections cause more than two million cases of sickness every year in the United States. One way of cutting down on the spread of these infections, says Jean Hertzberg of the University Colorado, Boulder, is to improve the air circulation inside of operating rooms.

The air flow systems that keep operating rooms sterile are based on “clean room” designs for fabricating microchips from the 1960s, in which sterilized air is supposed to flow smoothly from vents in the ceiling, over the patient and then to the exhaust. But according to Hertzberg and her colleagues James McNeill and John Zhaiin which air is supposed to flow smoothly from the ceiling to the room. But according to Hertzberg, this smooth flow -- which is also predicted by modern computer models -- isn't what actually happens.

"It doesn’t take into account the actual dynamic nature of a modern operating room in which doors are flapping open and closed, people are running in and out, and a giant light is shining down on the patient adding heat,” says Hertzberg.

With funding from ASHRAE - the technical society that sets operating room air standards - Hertzberg and her colleagues have recreated a mock operating room to observe how air actually flows. The room is staffed by manikins, with a dummy on an operating table heated to the temperature of a human patient. Air flow is visualized with techniques originally developed to study the flows produced by rocket engines.

The team's findings, to be presented at the DFD meeting, suggest that "things are not the way the models say they should be." The heat given off by the patient, for example, does not cause air to rise and deflect away dirty air, as the models have predicted. Because the air flow is turbulent, not smooth, new systems may need to be developed to keep patients undergoing surgery infection-free.

The talk "Flow visualization of sterile air flows in surgical environments" by James McNeill, Jean Hertzberg, and Zhiqiang Zhai is at 12:45 p.m. on Tuesday, November 24, 2009.
Abstract: http://meetings.aps.org/Meeting/DFD09/Event/112197

3) A MECHANICAL MODEL OF VOCALIZATION

When people speak, sing, or shout, they produce sound by pushing air over their vocal folds -- bits of muscle and tissue that manipulate the air flow and vibrate within it. When someone has polyps or some other problem with their vocal folds, the airflow can be altered, affecting the sound production.

"Voice disorders affect 30 percent of the general population and up to 60 percent of educators," says Plesniak. "The objective of our work is to develop a detailed understanding of the phonation process, which will enable the development of computational models."

Wanting to better characterize the physics of this process, George Washington University professor Michael Plesniak and his doctoral student Byron Erath teamed up with speech pathologists a few years ago, while Plesniak was at Purdue University, to investigate the velocity field and flow structures in the airflow that occur when a person speaks.

Plesniak and his students constructed a mechanical model of the vocal folds that had motorized, programmable components that can alter their shape and motion in various ways to mimic vocal folds. By placing this model in a wind tunnel, they examine normal vocalization and common pathologies like the formation of polyps and cysts.

An important feature of the model, says Plesniak, is that it is seven-and-a-half times larger than the actual physiology, which allows the dynamics to be studied in greater detail. The ultimate goal, he adds, is to create tools to help surgeons make preoperative assessments of how a vocal tract surgery will affect an individual's voice.

The talk "The development of supraglottal flow structures during speech" by Byron Erath and Michael Plesniak is at 4:14 p.m. on Monday, November 23, 2009.
Abstract: http://meetings.aps.org/Meeting/DFD09/Event/111753

4) MEASURING AND MODELING BLOOD FLOW IN MALARIA

When people have malaria, they are infected with Plasmodium parasites, which enter the body from the saliva of a mosquito, infect cells in the liver, and then spread to red blood cells. Inside the blood cells, the parasites replicate and also begin to expose adhesive proteins on the cell surface that change the physical nature of the cells in the bloodstream.

Experiments show that infected red blood cells are stiffer and stickier than normal ones -- in the later stages of the disease, up to 10 times stiffer. They also tend to adhere to the endothelial cells lining the vasculature, affecting the normal blood flow. This explains some of the common symptoms of malaria, such as anemia and joint pain.

Sticking to the walls of blood vessels is a survival mechanism for the parasite. In order to develop completely, it needs several days inside a red blood cell. Even though parasitized cells are nearly invisible for the immune system, they may be destroyed in the spleen while circulating freely in the bloodstream.

Doctoral student Dmitry Fedosov and Brown University professor George Karniadakis are studying how malaria infections affect the physical properties of red blood cells, and alter normal blood flow circulation. In particular, they examine an increase in blood flow resistance, and dynamics of infected cells in the bloodstream.

They also monitor the mechanical properties of infected red blood cells by measuring membrane temperature fluctuations, and through the response of a "microbead" that is attached to the cell and twisted. The measured properties are then used in modeling the flow of red blood cells in people infected with malaria. They also collaborate with the group of professor Subra Suresh at MIT, who obtain experimental measurements of the properties and the flow of healthy and infected cells.

"Our model predicts the dynamics of malaria-infected RBCs in the bloodstream, which anticipates the possible course of the disease," says Fedosov.

Recently they found that temperature fluctuations of infected red blood cell membranes measured in experiments are not directly correlated with the reported cell properties, hence suggesting significant influence of metabolic processes. They measured an increase in resistance to blood flow in the capillaries and small arterioles during the course of malaria and found that parasitized red blood cells have a “flipping” motion at the vessel wall that appears to be due to stiffness of the infected cells. The developed models will aid to make realistic predictions of the possible course of the disease, and enhance current malaria treatments.

The talk "Multiscale modeling of blood flow in cerebral malaria" by Dmitry Fedosov, Bruce Caswell, and George Karniadakis is at 6:12 p.m. on Sunday, November 22, 2009.
Abstract: http://meetings.aps.org/Meeting/DFD09/Event/111038

5) A PUZZLING ASPECT OF RED BLOOD CELL SHAPES, EXPLAINED

Computer simulations from groups in France and the United States have revealed the secret behind the slipper-like shape adopted by red blood cells flowing in micro-vessels. This is an important step toward understanding red blood cell physiology and its implication for blood flow.

Red blood cells are one of the most abundant components of blood, constituting up to 45 percent of the blood volume. Two million of them are produced every second in the bone marrow, and they live for nearly 120 days. Their main task is to supply oxygen, delivered by the lungs, to the living tissues in the body. Red blood cells are the simplest cells in the body since they don’t have a nucleus. They are filled with hemoglobin proteins, which carry oxygen from the lungs.

At rest, healthy red blood cells adopt a bi-concave disk-like shape -- sort of like a donut with a coin in the middle. Once they move with the blood flow, however, their shape changes and deforms, adapting to the surrounding flow. Scientists have observed that red blood cells adopt a symmetric parachute-like shape or an asymmetric slipper-like shape. The enigma is that both shapes coexist under the same experimental conditions -- both in the test tube and in actual flowing blood.

"The parachute shape, we can understand," says Badr Kaoui from the Universite Joseph Fourier-Grenoble in France. "It is the natural shape that a single red blood cell will adopt when moving in a Poiseuille flow -- a flow with a parabolic velocity profile that develops in micro-vessels."

But what about the slipper-like shape? The question of why red blood cells sometimes exhibit asymmetric shapes even in a symmetric flow has been a longstanding mystery in blood research for the last 40 years.

Now Kaoui and Chaouqi Misbah from the Universite Joseph Fourier-Grenoble in France in collaboration with George Biros from the Georgia Institute of Technology in the United States have found an answer to this old question by performing numerical simulations using a simple model for red blood cells. The appearance of the slipper shape, says Kaoui, is due to the loss of stability of the parachute shape when the applied flow is weak and when the degree of deflation of the cells is higher.

They found that the slipper-shaped red blood cells move faster than the parachute-shaped ones under the same applied flow conditions. This may explain why red blood cells prefer to adopt a slipper-like shape -- especially in the tiny vessels of the microvasculature. With such asymmetric shapes, the cell moves faster through the bloodstream, and thus the transport of oxygen throughout the body is enhanced. The results have implications for helping scientists sort blood cells in the laboratory, potentially enabling them to perform medical diagnoses on a very small quantities of blood.

“We know that some diseases like Malaria affect the mechanical properties of the red blood cell membrane," says Kaoui "So our ultimate goal is to take advantage of this principle and study how red blood cells move and deform in an external applied flow in different diseases.”

The talk "Why do red blood cells have asymmetric shapes even in a symmetric flow?" by Badr Kaoui, George Biros, and Chaouqi Misbah is at 4:28 p.m. on Sunday, November 22, 2009. Abstract: http://meetings.aps.org/Meeting/DFD09/Event/112213

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MORE MEETING INFORMATION

The 62nd Annual DFD Meeting will be held at the Minneapolis Convention Center in downtown Minneapolis. All meeting information, including directions to the Convention Center is at: http://www.dfd2009.umn.edu/

PRESS REGISTRATION

Credentialed full-time journalist and professional freelance journalists working on assignment for major publications or media outlets are invited to attend the conference free of charge. If you are a reporter and would like to attend, please contact Jason Bardi (jbardi@aip.org, 301-209-3091).

USEFUL LINKS

Main meeting Web site: http://meetings.aps.org/Meeting/DFD09/Content/1629
Searchable form: http://meetings.aps.org/Meeting/DFD09/SearchAbstract
Local Conference Meeting Website: http://www.dfd2009.umn.edu/
PDF of Meeting Abstracts: http://flux.aps.org/meetings/YR09/DFD09/all_DFD09.pdf
Division of Fluid Dynamics page: http://www.aps.org/units/dfd/
Virtual Press Room: SEE BELOW

VIRTUAL PRESS ROOM

The APS Division of Fluid Dynamics Virtual Press Room will contain tips on dozens of stories as well as stunning graphics and lay-language papers detailing some of the most interesting results at the meeting. Lay-language papers are roughly 500 word summaries written for a general audience by the authors of individual presentations with accompanying graphics and multimedia files. The Virtual Press Room will serve as starting points for journalists who are interested in covering the meeting but cannot attend in person. See: http://www.aps.org/units/dfd/pressroom/index.cfm

Currently, the Division of Fluid Dynamics Virtual Press Room contains information related to the 2008 meeting. In mid-November, the Virtual Press Room will be updated for this year's meeting, and another news release will be sent out at that time.

ONSITE WORKSPACE FOR REPORTERS

A reserved workspace with wireless internet connections will be available for use by reporters. It will be located in the meeting exhibition hall (Ballroom AB) at the Minneapolis Convention Center on Sunday and Monday from 8:00 a.m. to 5:00 p.m. and on Tuesday from 8:00 a.m. to noon. Press announcements and other news will be available in the Virtual Press Room.

GALLERY OF FLUID MOTION

Every year, the APS Division of Fluid Dynamics hosts posters and videos that show stunning images and graphics from either computational or experimental studies of flow phenomena. The outstanding entries, selected by a panel of referees for artistic content, originality and ability to convey information, will be honored during the meeting, placed on display at the Annual APS Meeting in March of 2010, and will appear in the annual Gallery of Fluid Motion article in the September 2010 issue of the journal Physics of Fluids.

This year, selected entries from the 27th Annual Gallery of Fluid Motion will be hosted as part of the Fluid Dynamics Virtual Press Room. In mid-November, when the Virtual Press Room is launched, another announcement will be sent out.

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ABOUT THE APS DIVISION OF FLUID DYNAMICS

The Division of Fluid Dynamics of the American Physical Society exists for the advancement and diffusion of knowledge of the physics of fluids with special emphasis on the dynamical theories of the liquid, plastic and gaseous states of matter under all conditions of temperature and pressure. See: http://www.aps.org/units/dfd/

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