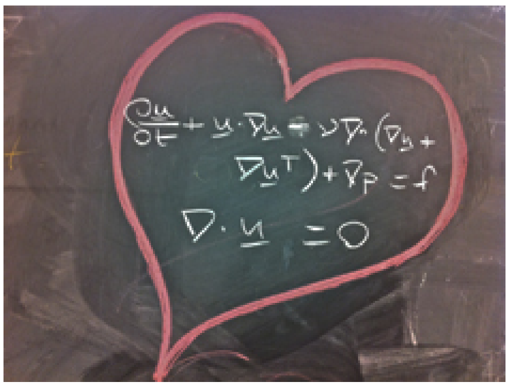
Hepling the heart with math

December 15 2010, By Carol Clark



When it comes to analyzing blood flow problems, you can't beat math. Credit: Carol Clark.

The science of cardiovascular mathematics dates at least to the 1700s, when the pioneering Swiss mathematician Leonhard Euler developed a model for fluid dynamics while studying blood flow in arteries.

“The love between math and medicine goes back a long time,” says Emory mathematician Alessandro Veneziani.

But it was not until the past decade or so, he adds, that advances in computing and diagnostic imaging put fluid dynamics at the cutting edge of medicine.

“My dream is that medical simulation will become part of the daily routine of medical doctors,” he says.

Veneziani's lab uses math and computer simulations to investigate blood dynamics, and support physicians in the diagnosis and treatment of cardiovascular diseases.

"Blood flow problems are really difficult, so we need sophisticated mathematics to solve them," Veneziani says. "Like weather forecasting, which is also based on mathematical models of fluid dynamics, we are creating models to forecast outcomes for patients."

His research has helped improve the odds for babies with a heart defect known as left-ventricle hypoplasia. Through computer simulation, surgeons can now predict the optimal size and placement of the artificial aorta needed to keep a newborn alive while awaiting a heart transplant.

Modeling aneurysms

A recent grant from the Brain Aneurysm Foundation is supporting Veneziani's research into the tears in neural blood vessels that create balloon-like bulges. Using complex equations to predict the likelihood of rupture in aneurysms could help doctors determine whether to operate, or forego the risky surgery and simply monitor the patient.

The mathematical engineers in Veneziani's lab work closely with physicians in the Emory School of Medicine and other institutions to develop the cardiovascular models. Some of the problems they are working on include bicuspid aortic valve defects in newborns, atherosclerosis and ventricular dissynchrony.

The process begins with differential equations to describe the blood dynamics. Medical images from individual patients are then pixelated into geometric representations. Finally, computer software is used to simulate the flood flow, and all of the data is merged.

“Now we are providing the medical doctors not just an image, the situation at a given instant, but a dynamical image, including the simulation of blood inside,” Veneziani says. “We can compute the stress of the blood on an arterial wall and a lot of relative indexes for providing the medical doctors with a better picture of the situation.”

The image processing software used in the process, the Vascular Modeling ToolKit (VMTK), was developed by the M. Negri Institute in Bergamo, Italy, and Emory. The simulation software, LifeV, was developed by the EPFL (the Ecole Polytechnique Federale of Lausanne, Switzerland), the Politecnico di Milano in Italy and Emory.

Both VMTK and LifeV are open-source, available free for download from the Internet.

“We want other researchers to use the software to solve blood flow problems, and to give us feedback, so we can keep refining and improving the code,” Veneziani says.

Provided by Emory University