Predicting perilous plaque in coronary arteries via fluid dynamics

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Researchers at Emory and Georgia Tech have developed a method for predicting which areas of the coronary arteries will develop more atherosclerotic plaque over time, based on intracoronary ultrasound and blood flow measurements.

The method could help doctors identify "vulnerable plaque," unstable plaque that is likely to cause a heart attack or stroke. It involves calculating shear stress, or how hard the blood tugs on the walls of the arteries, based on the geometry of the arteries and how fast the blood is moving.

The results were posted online this week in the journal *Circulation*, published by the American Heart Association. The lead author is Habib Samady, MD, professor of medicine and director of interventional cardiology at Emory University School of Medicine.

Most people who have heart attacks do not have plaques in their arteries that bulge out and obstruct blood flow beforehand. Instead, the plaques in their arteries crack and spill open, leading to a clot. Samady says his team's ultimate aim is to try to figure out where that will happen.

Cardiology researchers studying arteries in isolation or in animals have long seen a link between branches in the arteries, disturbances in blood flow, and where atherosclerosis develops. The challenge was to translate observations from the laboratory to imaging the heart within a live person, he says.

"It's like looking at a river and predicting where sediment will accumulate," he says. "It sounds obvious, but it's hard to do it for every nook and cranny in the coronary arteries."

The Emory/Georgia Tech study was the largest published investigation of shear stress and plaque progression in humans so far, and the first to examine people with significant coronary artery disease. Doctors examined 20 patients in Emory University Hospital's catheterization laboratory between December 2007 and January 2009. They were being examined because they had abnormal exercise EKGs or stable chest pain. The patients' coronary arteries were examined by intracoronary ultrasound and Doppler guide wire before and after six months of therapy with atorvastatin (Lipitor).

To model shear stress, Samady, assistant professor Michael McDaniel, MD, and postdoctoral fellow Parham Eshtehardi, MD, teamed up with Jin Suo and Don Giddens, experts in fluid mechanics at Georgia Tech. The patients' arteries were divided into more than 100 segments each, and the shear stress was calculated for each one. Ultrasound allowed the researchers to estimate the size and composition of the plaques in each segment before and after the six-month period.

"Some atherosclerotic plaque appears to develop in a steady progression, and in other places, it develops in fits and spurts. These areas exist within the same patient and the same artery," Samady says. "Our thinking is that the places where plaque develops in more fits and spurts may lead to the rupture of plaque, leading to a clot that blocks blood flow. In contrast, the places where you have steady progression may be more stable, as long as there is a fibrous covering that is thick enough."

Analyzing each segment, the overall area of the plaque increased and the core of the plaque grew larger in places where shear stress was especially low. In places where the shear stress was high, there was shrinking of the

fibrous covering of the plaque and expansion of lipid necrotic core and dense calcified areas.

"High shear stress leads to regression, which you might think is good, but there are some bad actors that may lead to plaque rupture," he says. "What's new here is that we're seeing the detrimental effects of both low and high shear stress."

The data also shows that arterial plaques can grow despite anti-cholesterol therapy with statins, the current standard of care. To really gauge whether plaque in a certain spot is going to be dangerous, Samady says doctors would need to look at outcomes in more patients over a longer time frame.

"The dream is to predict which spot is vulnerable, and use that to guide treatment with drugs and interventions like stents," he says.

For the present, the shear stress-based method can be used to monitor patients' progress and determine how well treatment is working. Samady says ultrasound and blood flow measurements could be combined with a newer technique called optical coherence tomography for better resolution and more information.

Provided by Emory University