First in vitro study of tricuspid valve mechanics uncovers causes for leakage

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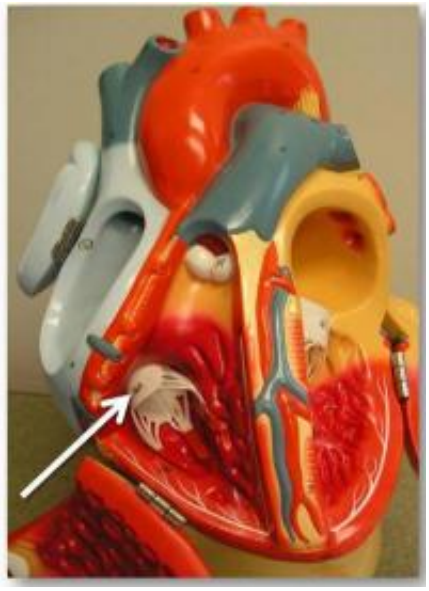


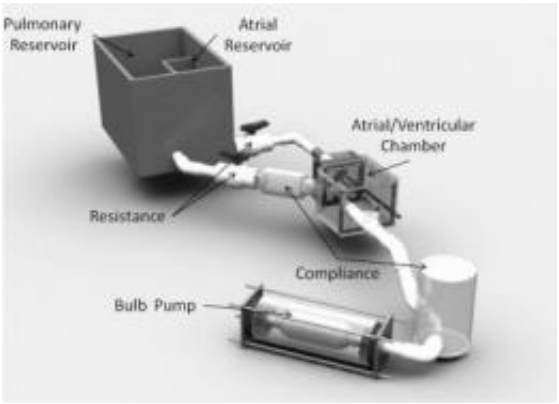
This is a heart model with an arrow pointing to the white tricuspid valve. A new study found that either dilating the tricuspid valve opening or displacing the papillary muscles that control its operation can cause the valve to leak. A combination of the two actions can increase the severity of the leakage, which is called tricuspid regurgitation. Credit: Robert Swatski

A new study into the causes of leakage in one of the heart's most complex valve structures could lead to improved diagnosis and treatment of the condition.

An estimated 1.6 million Americans suffer moderate to severe leakage

through their tricuspid valve, a complex structure that closes off the heart's right ventricle from the right atrium. Most people have at least some leakage in the valve, but what causes the problem is not well understood.

A new study, published online in the journal *Circulation* on August 1, 2011, found that either dilating the tricuspid valve opening or displacing the papillary muscles that control its operation can cause the valve to leak. A combination of the two actions can increase the severity of the leakage, which is called tricuspid regurgitation.



To determine possible causes of tricuspid regurgitation, Georgia Tech researchers placed tricuspid valves inside this right heart simulator, which is used to simulate physiological flow and pressure. Credit: Georgia Tech/Ajit Yoganathan

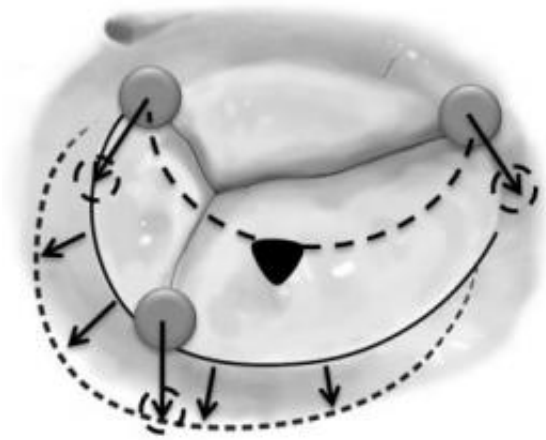
"We think this is the first in vitro investigation into the mechanics of the tricuspid valve, and that our findings into the mechanisms that cause tricuspid regurgitation could lead to improved diagnosis and treatment," said Ajit Yoganathan, Regents professor and Wallace H. Coulter Distinguished Faculty Chair in Biomedical Engineering in the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and

Emory University.

The tricuspid valve consists of three flaps that open to allow blood to flow from the heart's upper right chamber to the ventricle. To close the valve, the flaps re-cover the opening, keeping blood from flowing back into the chamber it just left. When the valve is leaky or doesn't close tightly enough, blood flows backward into the chamber just after the heart contracts.

Tricuspid regurgitation has been increasingly recognized as a source of disease in patients with chronic mitral valve regurgitation, but surgical repair of the tricuspid valve alone is recommended only in rare cases. If an individual suffers from severe tricuspid regurgitation, surgeons will sometimes repair the tricuspid valve during a surgery to repair other leaky heart valves.

"Standard clinical procedures that detail when and how tricuspid valve repairs should be performed need to be developed and this study suggests several items that should be considered," said one of the study's co-authors David H. Adam, chair of the Department of Cardiothoracic Surgery at Mount Sinai Medical Center in New York City. "Current repairs for tricuspid regurgitation focus mainly on remodeling the valve's opening to correct enlargement, but this study shows that it may also be important to restore the position of the papillary muscles, providing as much overlap as possible, in order to conduct effective and durable tricuspid valve repairs."



This drawing shows the mechanism of tricuspid valve regurgitation with dilation and papillary muscle (circles) displacement. The two flaps at the bottom move away from the center opening because of the dilation. When the flaps extend to cover the enlarged opening while being pulled away because of dilation, they are not long enough to cover the opening and leakage results. Credit: Georgia Tech/Ajit Yoganathan

With funding from the American Heart Association, Yoganathan and Coulter Department graduate student Erin Spinner conducted experiments with porcine tricuspid valves to determine possible causes of tricuspid regurgitation. The valves were attached to a plate designed to create physiological dilation and then placed inside a right heart simulator.

The researchers first investigated the effect of dilating the opening of the tricuspid valves. When the openings stretched to an area 40 percent larger than their normal size, a hole appeared in the central region of the valve. The hole caused leakage, and increased in size with further dilatation. This finding surprised the researchers because similar studies using the same method had shown that the heart's mitral valve could withstand dilation of 75 percent before leaking.

"These results tell us that the tricuspid valve is a much more complex valve than the mitral valve, which only has two flaps," explained Spinner. "Forming a proper seal over the valve opening might be more difficult with three flaps, which could be why such a large percentage of the population experiences some level of tricuspid regurgitation and why some individuals with annular dilation have tricuspid regurgitation and others do not."

The research team also investigated the effect of displacing the valve's three papillary muscles, which attach to the valve via threads. Contraction of the papillary muscles opens the valve and relaxation of the muscles closes the valve. The study showed that papillary displacement alone resulted in significant tricuspid leakage.

"While isolated displacement of the papillary muscles is rare, these results are relevant toward understanding what may happen if the size of the valve opening is repaired, but the papillary muscles are left displaced," noted Yoganathan.

The study also showed that higher levels of tricuspid leakage resulted when the researchers combined the conditions -- dilation of 40 percent or greater and displacement of all papillary muscles.

In their future work, the Coulter Department researchers plan to look at the effect of pulmonary hypertension on the tricuspid valve, because tricuspid regurgitation usually develops in association with pulmonary hypertension -- which is abnormally high blood pressure in the lungs. They also plan to work with their clinical collaborators to extend their findings to humans.

"In our in vitro study we were able to select specific porcine valves, but with human subjects there will be more anatomical variety. For example, two people may have valves of the same diameter, but one person may

have longer flaps that are able to compensate for dilation whereas the other might not," noted Yoganathan.

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