3-D simulations reveal synergistic mechanisms of the human heart

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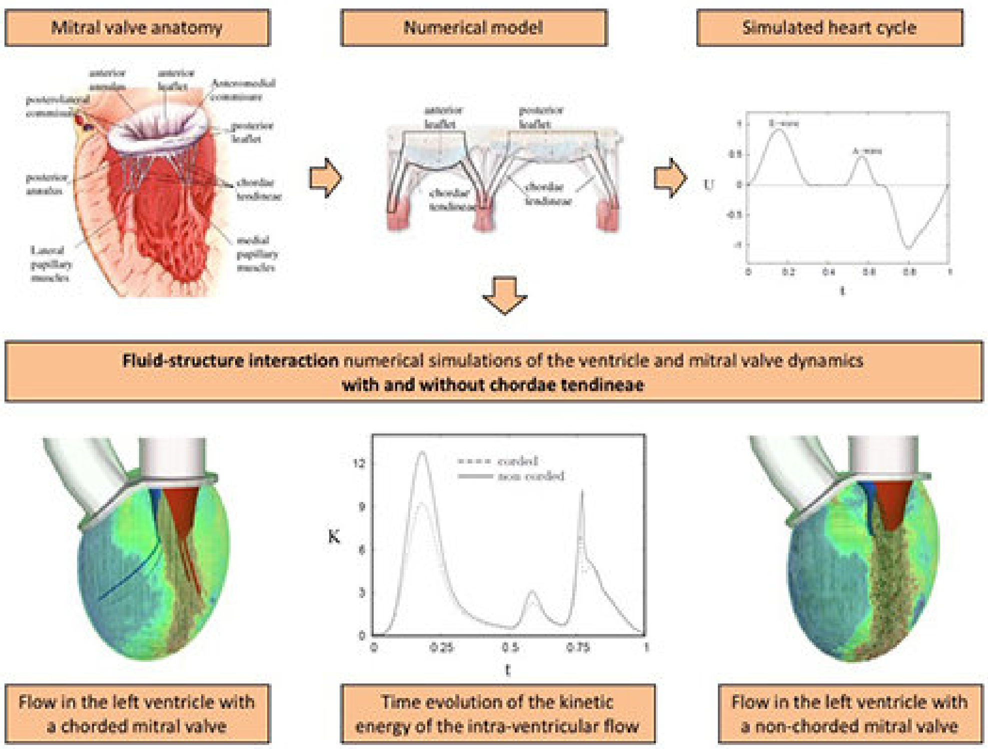

Credit: Springer

Understanding how the blood flow within this part of the heart affects the way it works could help prevent cardiac problems. In a new study in the European Physical Journal E (EPJ E), published by Springer, EDP Sciences and Società Italiana di Fisica (SIF), Valentina Meschini from the Gran Sasso Science Institute, L'Aquila, Italy and colleagues introduce a model that examines the mutual interaction of the blood flow with the individual components of the heart. Their work stands out by offering a more holistic and accurate picture of the dynamics of blow flow in the left ventricle. The authors also perform some experimental validations of their model.

The left side of the heart is the part that is most vulnerable to cardiac problems. Particularly the left ventricle, which has to withstand intense pressure differences, is under the greatest strain. As a result, people often suffer from valve failure or impairment of the muscle tissue known as myocardium.

In this 3-D numerical simulation study, the authors develop a mathematical model taking into account the fact that parts of the left side of the heart, including the left ventricle, the mitral valve and the heart strings, are coupled in a twofold manner with the blood flowing through the heart. The mitral valve has two flaps and lies between the left atrium and the left ventricle, while the heart strings are cord-like tendons that connect the heart muscles to the heart valves.

Until now, most cardiac models have considered separate components of the heart, either the ventricle or the mitral valve. But they have never approached the whole combination as a synergistic system. Another key shortcoming of previous models was their failure to take into account either the interaction between the blood and the heart structure, which can lead to deformation of the heart, or the structure of the heart chambers under the load of the passing blood flow.

"The inclusion of a chorded mitral valve in an already complex system like the left ventricle is a challenging step forward to an uncompromised computational model of the heart," says Meschini.

The authors conclude that the effects of the heart strings on the mitral valve are more complex than initially assumed. They also reveal the importance of the effects of blood dynamics and a different type of ventricle deformation caused by the pulling action of the heart strings on the myocardium.

"The next step in this work would be to replace the imposed flow-rate with an active contraction/relaxation of the ventricle. This could be achieved by coupling the fluid-structure interaction model with an electrophysiology model able to provide the propagation of the electrical stimulus through the whole ventricle. This additional feature will make the computational model much more realistic and reliable," says Meschini.

Meschini explains that the final goal is to simulate the whole heart, so that the right ventricle and the two atriums in the system work synergistically.

"We believe that coupling this with the electrophysiology model is key, and would give us a reliable tool which can be used for virtual checks, to test new medicine or different intervention measures and avoid in vivo experiments with animals or real patients," she says.

More information: Valentina Meschini et al. Effects of mitral chordae tendineae on the flow in the left heart ventricle, *The European Physical Journal E* (2018). DOI: 10.1140/epje/i2018-11634-7

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