World's most detailed 3-D computer model of heart chambers

April 4 2013

Researchers from The University of Auckland have developed the world's most detailed 3D computer models of the heart's upper chambers.

Previous models have only been able to reproduce the shape and wall thickness of the heart's upper chambers (or atria).

University of Auckland research fellow Dr Jichao Zhao spent the past two years processing data from 700 extremely thin image 'slices' of the atria to use in his new computer model.

He's now able to show, for the first time, a detailed and realistic 3D image of the arrangement of muscle fibres throughout the heart's atrial chambers, right down to the cellular level.

To achieve this, Dr Zhao and his colleagues at the University's Auckland Bioengineering Institute (ABI) developed a suite of new image processing tools. These tools allowed Dr Zhao to extract structural information from the images, enabling him to examine the effects of the arrangement of muscle fibres on electrical signals in the atria.

This work is part of a recently-completed programme funded by the Health Research Council of New Zealand (HRC) and directed by Professor Bruce Smaill and ABI director Professor Peter Hunter.

Dr Zhao's atria model is being used to examine the mechanisms behind persistent atrial fibrillation, a debilitating heart condition that causes a completely irregular heartbeat which doesn't go away.

"In New Zealand, about a quarter of the population who are older than 40 will develop atrial fibrillation in their lifetime, putting them at higher risk of not only heart failure, but also thrombosis and stroke," says Dr Zhao.

Patients with persistent atrial fibrillation commonly undergo treatment to remove the tissue thought to be causing the atria's electrical signals to go haywire. The method that clinicians currently use to map these electrical signals has serious shortcomings, including being very time consuming and not particularly reliable.

Dr Zhao has been working with clinician Dr Nigel Lever from Auckland City Hospital to develop a new method that can record electrical signals simultaneously across the inner surfaces of both atrial chambers.

"By combining novel multi-site mapping catheters with state-of-the art imaging, it will be possible to get a snapshot of what's going on in real-time and with much greater anatomical precision than is currently achievable," says Dr Zhao.

The HRC-funded programme has also achieved another world-first. Following a heart attack, the area in the heart affected develops scar tissue that butts up against normal tissue forming what's known as the 'infarct border zone'.
With input from Associate Professor Ian LeGrice and Dr Gregory Sands at the University's School of Medical Sciences, the ABI's cardiac electrophysiology group has used advanced confocal microscopy techniques to develop the first high resolution computer model of this area.

ABI senior research fellow Dr Mark Trew says the new model shows how structural remodelling in this area can give rise to potentially life-threatening heart rhythm disturbance.

"We first had to differentiate between surviving heart muscle cells in the border zone that could conduct electricity and scar tissue that couldn't. Once that was done, we needed to determine the links between different parts of tissue to work out the surviving electrical circuits," says Dr Trew.

"Looking at the images of the border zone, you can see where the surviving muscle cells are being pushed apart and the spaces filled up with fibrous material which changes the electrical properties of the heart. This rewiring happens because the electrical conducting cells have separated and are now forming different pathways."

After building a network representation of the tissue, the group took the mathematics that describe the physics of electrical current movement and put that into the network. From there they used computer modelling to stimulate different parts of the model.

"We've been able to show that rhythm disturbances, which give rise to very rapid heart rates and increase the risk of sudden death, are caused by abrupt changes in the arrangement of the surviving heart muscle cells in the border zone affected by a heart attack," says Dr Trew.

Provided by The University of Aukland-New Zealand