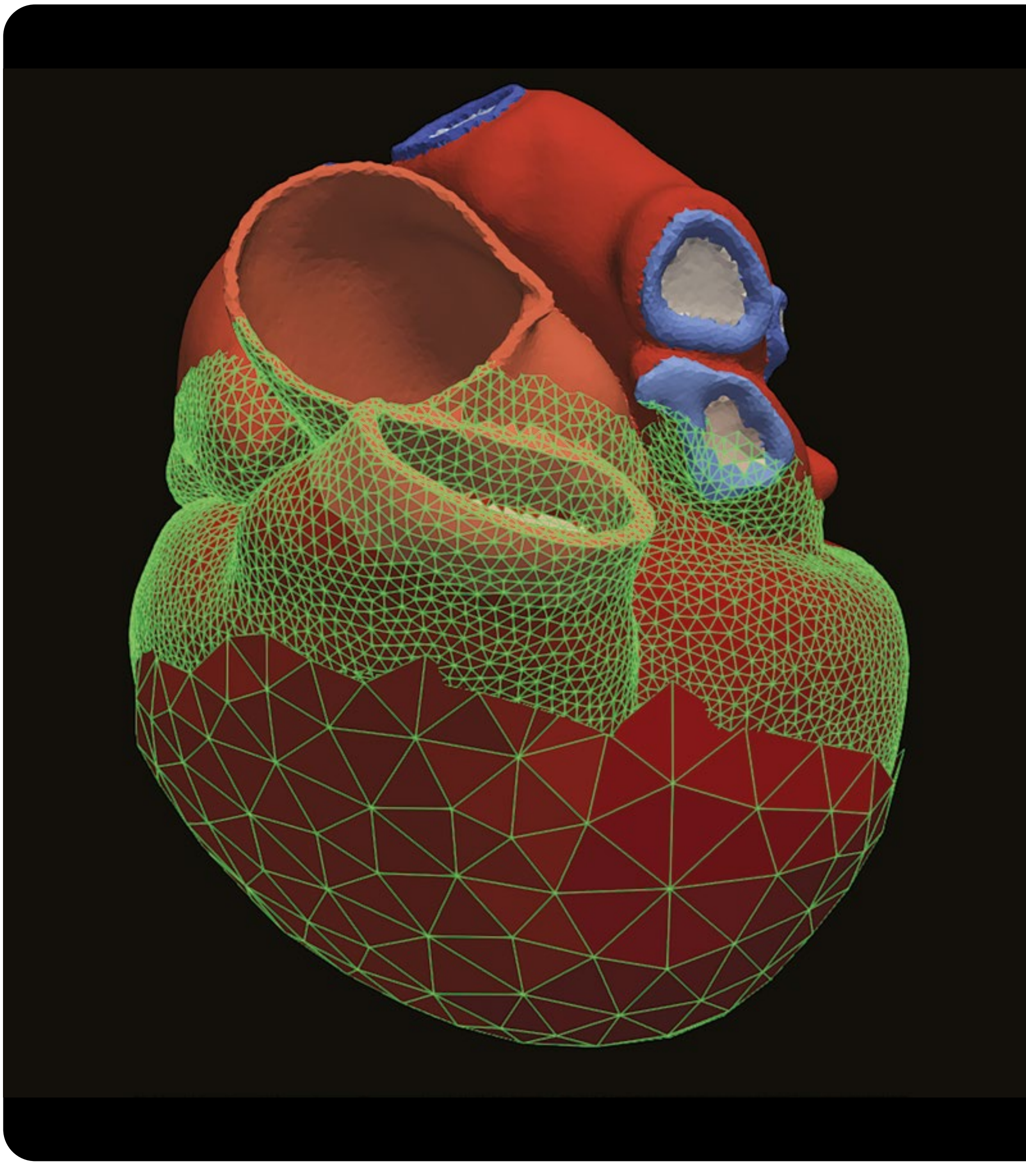
archer2

Cardiac digital twin to improve patient therapy

Currently, 7.6 million people in the UK are living with heart conditions, with a person dying every three minutes because of a heart disease (bhf.org.uk). Most cardiac patients suffer from poor quality of life, despite being treated with the best available therapy, and often need multiple hospital visits.

This causes a strain on the NHS and puts patients at an increased risk of complications due to unnecessary procedures. Therefore, novel methods are needed in order to better understand cardiac function, diseases, and treatment that can help to improve patient therapy.



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With each heartbeat, thanks to complex chemical reactions, each cell in the heart is electrically excited and contracts. Because of the very organised structure of the cells within cardiac tissue, these cell processes translate into a synchronous and efficient electrical activation and mechanical contraction of the whole heart.

The heart then pumps oxygenated blood to different parts of the body, ensuring that all organs function properly. The blood then returns back to the heart, is re-oxygenated in the lungs and redistributed to the body with each heartbeat. This whole process happens approximately every second, pumping around 9000 litres per day.

Cardiac digital twins, e.g. computer models of the heart that can replicate a real patient's cardiac function, are a powerful tool that can be used to non-invasively investigate treatment outcome. This approach has the potential to save costs of cardiac patient care, to reduce the number of unnecessary invasive procedures, and to ultimately improve patient outcome.

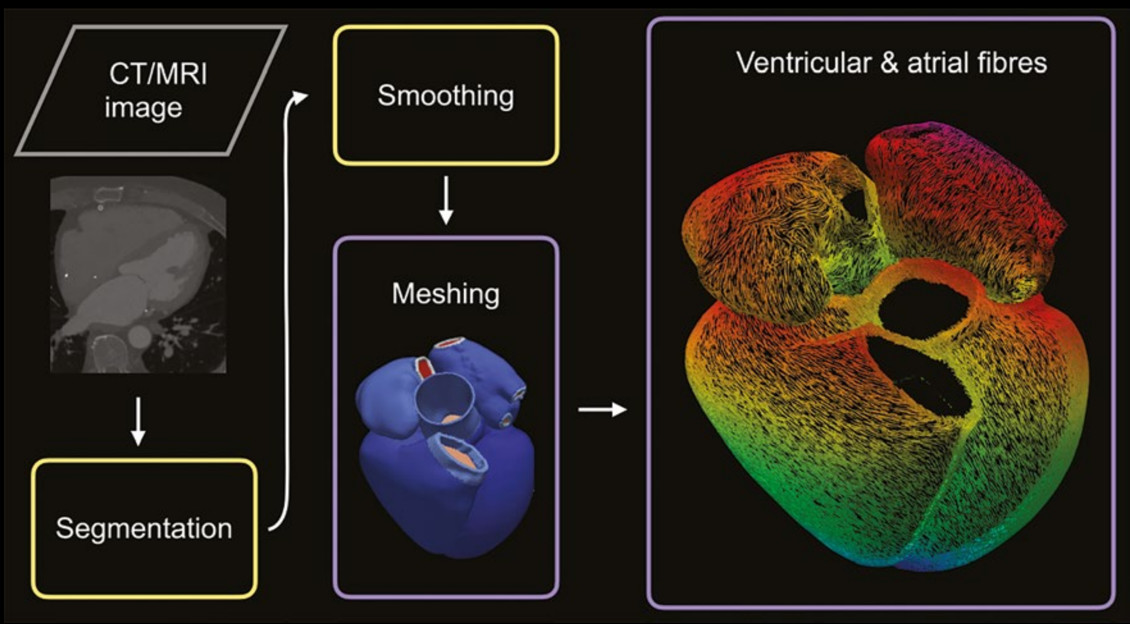

Figure 1: Workflow for patient-specific anatomical models.

Figure 1 Workflow for patient-specific anatomical models. The computed tomography (CT) acquired from the patient was segmented to select the cardiac structures of interest, smoothed to remove artefacts, and meshed to create a discretised geometry needed for the simulations. Ventricular and atrial cell orientation was defined to represent the highly organised structure of cardiac tissue.

To create cardiac digital twins, anatomically accurate heart models are generated from patient computed tomography (CT) data (Figure 1). The electrical activation and mechanical contraction of the heart are simulated with the cardiac arrhythmia research package (CARP).

Our simulation framework, able to simulate the multi-scale processes leading to heart function, from single protein to whole organ scale, represents one of the most complex heart models to date. However, this model complexity comes with high computational demands. The large number of cores available on ARCHER2 makes the development of such models possible. Furthermore, thanks to the continuous support of EPCC, we have been able to achieve parallel efficiency to up to 4096 cores for our multi-scale and multi-physics whole heart simulations [PMID: 26819483].

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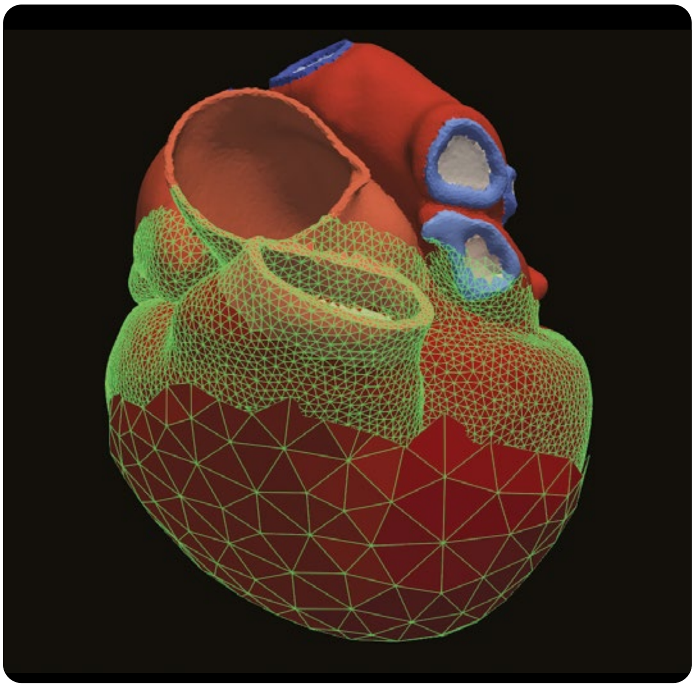

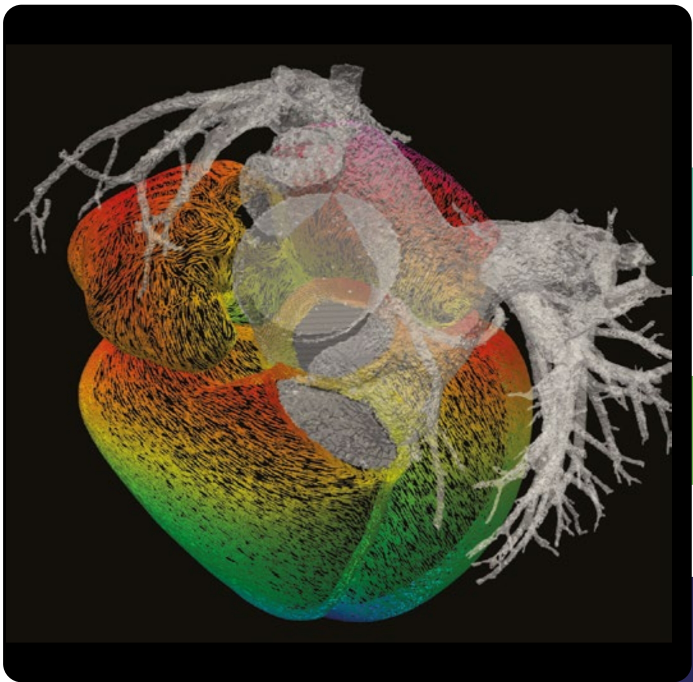
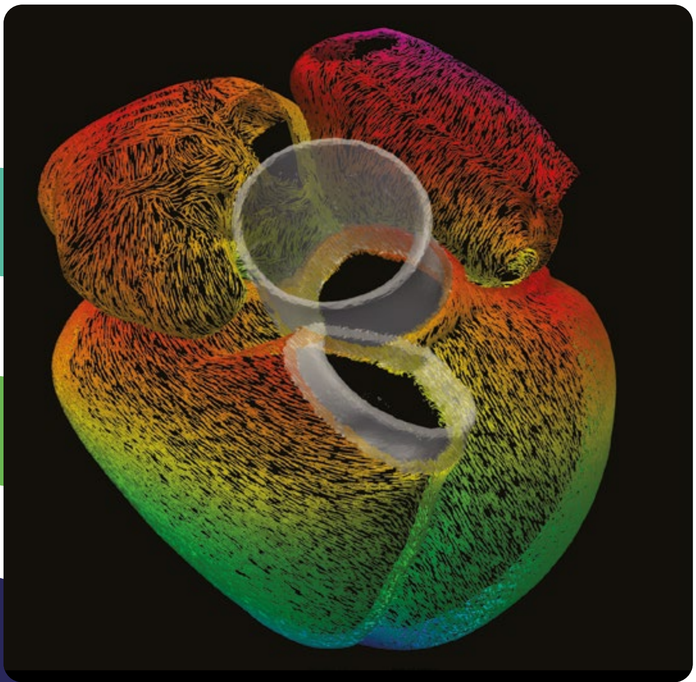

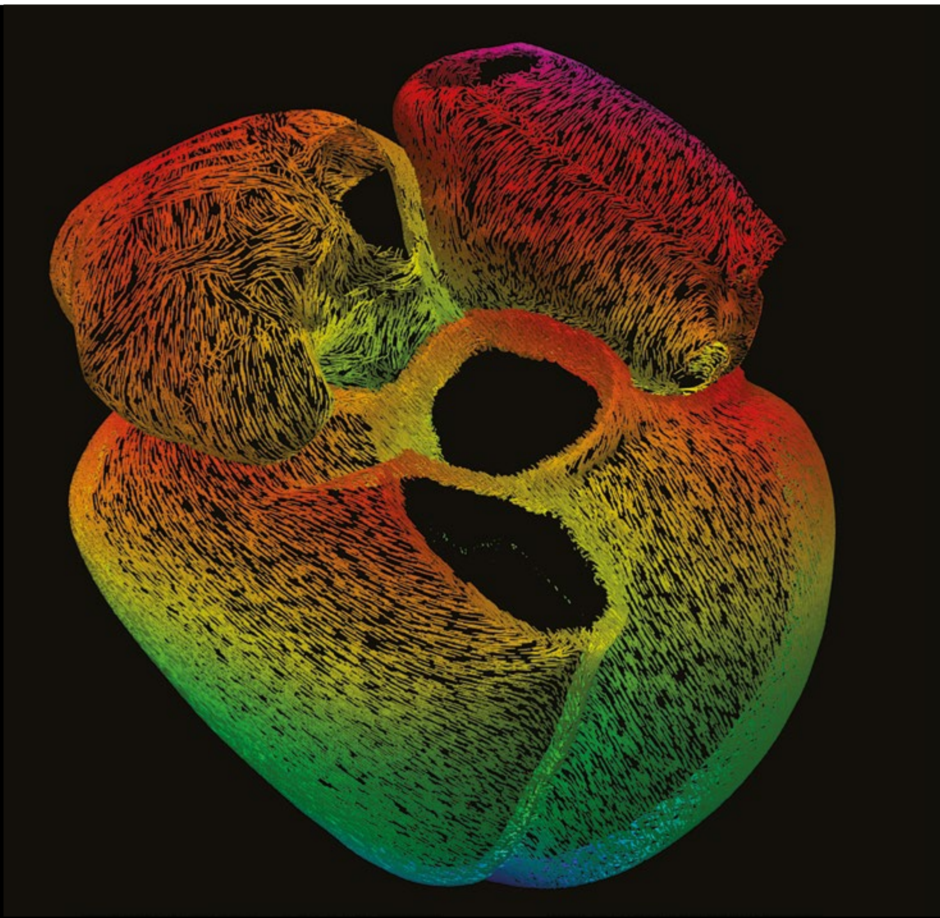

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About ARCHER2
ARCHER2 is the UK's National Supercomputing Service, a world class advanced computing resource for UK researchers. ARCHER2 is provided by UKRI, EPCC, HPE and the University of Edinburgh. ARCHER2 is the latest in a series of National Supercomputing Services provided to UK researchers.