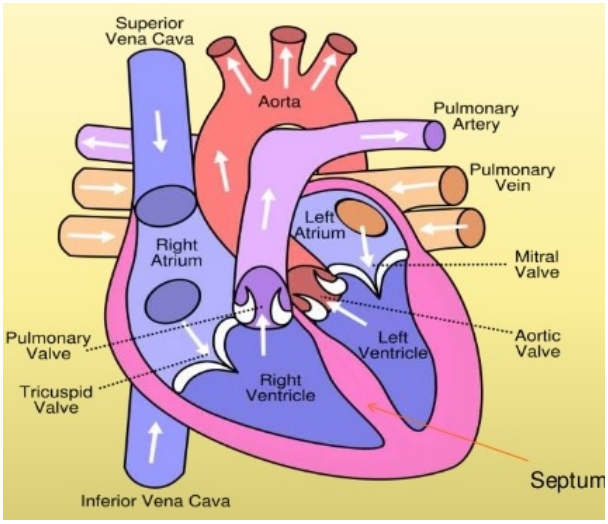
MRI imaging & 3D modelling prior to Surgery by Dr David Nordsletten on 16th March 2018

Dr Nordsletten said the heart was an electrophysiological pump, operating about once a second for one's entire life. During that time it is subject to many stresses, with heart failure a possible outcome.

Many factors can affect the heart: obesity makes it have to work harder, smoking too much alcohol and a lack of exercise do not help (nor does too much exercise). Arteries harden and blood vessels stiffen with age, so the heart has to pump harder to maintain blood pressure. It can be viewed at many scales: from individual cells, its nerve connections, valves, to the blood vessels; small scale changes can affect the function of the whole organ.

The muscle fibres of the heart are in two layers which surround the ventricles helically.



Some Heart diseases:

Dilated Cardio Myopathy (DCM) is a disease of your heart muscle where it becomes stretched and thin, so that it is unable to pump blood efficiently. The usual, but not only, cause is a defective gene. It worsens with increasing fibre stiffness

Hypertropic Cardio Myopathy (HCM) is an inherited disease of heart muscle, where the muscle wall of the heart becomes thickened.

Another condition is where fibres separate, so that propagation of an electrical signal between them is compromised and affects synchronism of the heartbeat.

There are about ten genes which control the formation of the heart's mitochondria – which can go wrong.

The heart needs to keep beating – it does not stay still while one scans it. Investigative methods include:

- Wire Test - A wire (a catheter with a pressure sensor at the tip) is threaded through an artery up to the heart. It can identify a narrowed section in a coronary artery and measure blood pressure either side of the narrowed area. Comparing the two measurements can show how much the narrowed area is limiting blood flow.
- Doppler Echo – An ultrasound beam directed to the heart creates an image of it, while the Doppler effect is used to assess the direction and velocity of blood flow at points within it.
- MRI Scanning - where the person being scanned is inside the machine - is able to show abnormal heart operation. Several techniques are available. Phase-Contrast velocity imaging and Virtual Work Energy Relative Pressure calculations show how much energy is expended to create the observed flow. Elastography uses a high (between 50 and 150 Hz) vibration frequency to measure myocardial tissue stiffness (it is also used for other organs such as liver, breast, brain, kidney, prostate).

These methods can be used together, for instance the location of a Wire can be seen in in an MRI scan.

Translational Cardiac Modelling - Dr Nordsletten is primarily concerned with designing mathematical models of heart operation to match what is seen in MRI scans. He uses the models to see how well their predictions agree with reality and adjusts for an optimum match. One method he uses to test a model is to add noise to it – if this has little effect on the correlation with the results from a patient, then it gives confidence in the model.

The models use estimates of material stiffness and density; they incorporate Navier-Stokes equations for the motion of viscous fluids – these are complex, though some variables can be approximated by constants. The challenges in modelling come from the limitations of the hardware

- but also the behaviour of the heart which includes non-linear dynamic motion; dynamic stiffness; and differences between intrinsic and apparent properties.

In a study a group of 20 healthy people (up to the age of 50) and another, older, group with DCM were scanned – twice, each scan lasting 3 hours! The first group gave a set of normal results to which the second group could be compared.

Outlook - Dr Nordsletten said modelling accuracy will improve with better understanding of the parameters involved. and be able to focus on individual patients.