Heart and Medicine | Dr Eric Stöhr

Bionic women and men

Heart failure and an artificial heart pump

Left ventricular assist devices (LVADs) have been developed for heart failure patients when medicine does not work and a transplant is unavailable. These devices provide a continuous flow of blood around the body, creating ‘humans without a pulse’, and thus presenting a unique opportunity to examine blood flow and heart function in relation to overall health. Dr Eric J. Stöhr, of Cardiff Metropolitan University, UK, and Columbia University, USA, is a key member of the HIT-LVAD trial team (led by Dr McDonnell in Cardiff and Prof Colombo in NYC), a research project aiming to understand the biology of LVAD patients and using the insights to benefit the patients’ health and the general public.

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The left ventricle is the most muscular, the most electrically active and the most intelligent of all the heart’s muscle fibres. It pumps blood through the pulmonary circuit, returning low-oxygen blood to the lungs to replenish the blood with oxygen. The left-hand side is larger, as it has the harder job of pumping oxygen-rich blood through the high-pressure circuit around the body to cells, tissues and organs.

An examination of the anatomy of each of the four chambers reveals interesting differences, with the left ventricle – the largest chamber – the most complex of all. In a healthy person, it is comprised of a muscle fibre arrangement that represents a wound, double helix. A helix can be best imagined as a mechanical spring, with the interesting property of being either right- or left-twisting, no matter which way you turn it; a right-handed helix cannot be superimposed over a left-handed one. The left ventricle has two opposite helices arranged over these layers. The inner layer, the subendocardium, is arranged as a right-handed helix, which transitions to the middle circumferential layer. In turn, this transitions to the subepicardium, the surface layer, which is arranged as a left-handed helix. This anatomy gives the left ventricle the property of twisting when it contracts, a motion that is comparable to the wringing of a towel.

The efficiency of the helix twist

The helical arrangement of muscle fibres in the left ventricle is reminiscent of spiral and vortex patterns in nature, which can range from the small to the astronomical. In the heart, this helical shape helps the ejection of blood as the muscle twist (or “wring”) during contraction. Experimental and mathematical modelling of the clockwise and anticlockwise spiral loops of muscle fibres in the left ventricle has shown that it is also an efficient way of distributing stresses and strains across the chamber. When the heart muscle relaxes, a rapid ‘untwisting’ occurs, which is thought to help with the refilling of the chamber.

Evaluating a normal twist

The relationship between systolic twist (contraction) and diastolic untwisting (relaxing) of the heart, and how they relate to cardiovascular health and disease is not clearly understood. What we do know is that people with chronic heart disease can have significantly altered left ventricle twist mechanics, with several factors contributing to this. High blood pressure, congenital heart conditions or diseases affecting the valves in the heart can all increase blood pressure and volume, causing injury to the heart. In turn, this can change its shape, size and structure, leading to a progressive decline in left ventricular performance. Reduced blood flow to the heart from blocked arteries can also disturb the efficiency of the filling and emptying dynamics, as can an alteration to the electric pulse controlling the contraction of the heart’s muscle fibres.

In a recent review of research assessing left ventricle dynamics in both healthy people and those with cardiac issues, Dr Eric J. Stöhr, a Marie-Skłodowska-Curie Fellow of the European Union and lecturer in Cardiac Physiology and Health at Cardiff Metropolitan University, UK, highlights evidence to show that left ventricle twist dynamics can also alter with ageing, as well as through exercise. However, these effects have received much less attention than those from cardiovascular disease. He argues that understanding the left ventricle twist response to normal physiological challenges is essential for interpreting the effects of heart conditions. Essentially, we need to fully understand normal cardiac function to appreciate the influence of cardiovascular diseases. Research is ongoing to understand why and how left ventricle twist is altered in various cardiac conditions and across the age and health range of the general population.

LEFT VENTRICULAR ASSIST DEVICE

Unfortunately, an increasing number of individuals do not have normal heart function, including twist. This globally growing prevalence of heart failure can be attributed to the combination of an ageing population and substantial improvements to medicines prolonging the life of people with heart disease. In America alone, over 5 million people suffer from heart failure and there is a significant proportion – 150,000 to 250,000 – whose condition will worsen despite medicinal advancements. Currently, the optimal treatment for these patients is a heart transplant, but with a shortage of donors, this is not always possible. In 2016, only 2800 patients underwent a heart transplant operation in the USA. To fill this gap, a mechanical pump, the left ventricular assist device (LVAD), has been developed to support the failing muscle tissue of the heart.

The LVAD works by sucking blood out of the sick heart and moving it back to the normal circulation, generating enough cardiac output to service the cells, tissues
Researchers have the opportunity to study blood flow in a way that has not been possible to date.

The aim is to better understand the risks and causes of adverse effects associated with patients fitted with continuous-flow LVADs. It will be the first time in human history that researchers have the opportunity to study blood flow in a way that has not been possible to date.

**A UNIQUE OPPORTUNITY**

The second and third generation LVADs have improved the longevity of heart failure patients, but people who live with the aid of some of these machines have the peculiar characteristic of being left without a pulse. This has raised several intriguing questions about our physiology. Do we really need a pulse? If so, what are the effects of short- or long-term loss or reduction in arterial pulse pressure? The HIT-LVAD trial hopes to apply insight from research on this area, using the LVAD patient population, to increase our understanding of more general cardiovascular disease such as high blood pressure.

A stepping stone towards this goal is the development of a reliable method of monitoring blood pressure. Elevated blood pressure has been associated with continuous-flow LVAD-related complications. Since LVAD patients do not have a heart pumping pulse or none at all, normal blood pressure measurements are very difficult to assess, being limited to hospitalised patients whose readings are taken via an invasive arterial catheter. The Heartmate 3 system offers an additional challenge since it incorporates artificial pulse technology and therefore interrupts the regular flow in an unpredictable manner. Together with collaborators from industry and academia, Dr Stöhr has confronted this challenge by testing and validating a new machine, the Mobil-O-Graph system. The Mobil-O-Graph system monitors a non-invasive method of measuring blood pressure in Heartmate II patients, and current efforts continue to increase its accuracy compared to the invasive arterial pressure readings from invasive arterial catheters.

Further HIT-LVAD research will measure the blood flow and pulse in different LVAD patients in the aorta, the neck (carotid arteries), the eye (retinal arteries) and brain arteries, with the aim of increasing our understanding of which machine and machine settings are best for the health of the LVAD patient.

The cutting-edge research will be used to improve the lives of heart failure patients undergoing LVAD implantation all over the world, and ultimately, increase our knowledge of optimal blood flow and heart function in relation to overall health for the whole population.
Dr Stöhr’s research focuses on understanding the interaction between heart muscle dynamics and arterial function in health and disease.

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**References**


