Health and Medicine | Dr Eric Stöhr

Bionic women and men

Heart failure and an artificial heart pump

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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 for example, the structure of our DNA, whirlpools, hurricanes, and the rotational patterns of our solar system and other galaxies. It is an anatomical feature that is found across the evolution of various animal species and has fascinated anatomists over the centuries.

Vortex patterns link two fundamental forms of motion that work in close balance with each other: an inner, rapidly ascending rotation and an outer, less rapid, descending rotation. Such motions produce energy-efficient suction and expulsion forces that have been exploited by humans in the design of propellers and turbines. In the heart, this helical shape helps the ejection of blood as the muscle twist (or "wrings") 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 left 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 distort 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-Sklodowska-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 warrant additional medical 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 2,800 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.

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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.

The 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 strong 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 monitor offers a good non-invasive method of measuring blood pressure in Heartmate II patients, and current efforts continue to increase its accuracy compared to the current non-invasive arterial readings from invasive arterial catheters.

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

Dr Stöhr’s research focuses on understanding the interaction between heart muscle dynamics and arterial function in health and disease.

Detail

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Bio

Eric Stöhr trained in exercise science and obtained his PhD in human cardiovascular physiology.

Funding

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- Prof Paolo Coombo. Director, Center for Advanced Cardiac Care, Columbia University Irving Medical Center, New York City, New York, USA.
- Dr William Cornwell. Assistant Professor of Medicine-Cardiology, University of Colorado.
- Dr Keichi Itatani. Cardiovascular Surgeon, Endowed chair, Department of Cardiovascular Surgery, Cardiovascular Imaging Research Center, Kyoto Prefectural University of Medicine.
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- Achim Schwarz. (www.alf-distribution.com/en/)

References


Personal Response

Prof Coombo, you have facilitated Dr Stöhr’s & Dr McDonnell’s work in New York – The HIT-LVAD trial is an exciting collaboration between leading researchers. What excites you most about this project?

First, because transatlantic collaborations like the HIT-LVAD trial are rare. Second, because LVAD is an exciting technology that is revolutionising the way cardiologists treat patients with advanced heart failure. LVADs have undergone tremendous improvements over the past decades, from bulky, noisy pumps with a limited durability of 1 or 2 years, to smaller, silent and more durable pumps with a durability of several years, even more than 10 years. Separate clinical studies in Europe and the US indicate that the recently developed HeartMate3 appears to overcome life-threatening complications because it does not clot. The collaboration between European and US researchers is therefore essential for further developments.