HOW TO MAKE A HUMAN HEART

A pain in your chest that quickly spreads to your arm causes you to fall to your knees. Inside your body, oxygen-rich blood that normally flows to the heart muscle is suddenly blocked. If blood flow isn't restored quickly, your life hangs in the balance.

In the United States, someone has a heart attack every 34 seconds. While stents, transplants, angioplasty, by-pass operations, drugs and improved patient care have dramatically cut deaths from heart disease, it remains the number one killer. The World Health Organisation estimated in 2013 that the disease globally accounted for 17.8 million, or one in three, deaths.

But what if one day doctors could simulate an exact replica of your heart, imitating its unique electrical impulses, muscle fibre contractions and potential abnormalities? The model would not only allow doctors to observe how the heart had changed after the attack to help treatment, but might even have prevented it in the first place.

IMITATING LIFE

While computer simulation is already an important aspect of medical device development, it is only in recent years that the technology has been developed to such an extent that it can now simulate human biology.

Over the past few years technology companies have been teaming up with doctors and clinicians specialising in biomechanics to replicate individual hearts in a virtual reality. The idea is that when data received from this kind of technology is combined with patient's medical records, clinicians can more accurately diagnose and plan treatment for a whole series of illnesses without invasive procedures.

Global software company, Dassault Systèmes, which has been working on this kind of technology for the past three years, has developed the world's first realistic 3D simulation model of a whole human heart. Steve Levine, director of the Living Heart Project at the company believes the technology could be rolled out to medical device developers and to evaluate real patients by early next year.

"We can now [simulate] a basic heart beat in less than two hours on a workstation that sits by my desk," says Levine. Such a realistic model can quickly explore a variety of treatment options that can be evaluated by the simulation, and the software will identify the best ones to use. The doctors would then use their judgment to decide the ultimate course of action but the software would have filtered out 98% of options.

Scott Berkey, CEO of SIMULIA, a Dassault Systèmes brand that designs the software for the Living Heart Project, says this technology was once never thought possible.

"It's very emotional because we can see now that we might be able to have the ability to help patients that we were never able to help before."

SIMULIA modelled a structure of the heart but by collaborating with scientists and researchers, managed to simulate all the different components of the heart. "You're not seeing a graphic representation; you're seeing the actual physics. I think 10 or 15 years ago people thought we had just about discovered everything, but the truth is we're just scratching the surface of what we can simulate in general," says Berkey.

BEYOND THE HEART

Levine too believes that computational modelling will not stop at the heart, and will soon lead to better, more reliable, devices and procedures in other medical fields. "We're developing the foundation technology to fully simulate human biomechanics. Take knee implants, which are tested in a bending motion a

million times in a lab. We can do this on a computer in a matter of hours. However, we can also simulate other important movements—such as playing golf, getting in and out of a car, playing basketball—which can never effectively be tested mechanically to replicate how the joint is used."

He hopes that gradually, the whole body and all its organs will be simulated—even the brain. "We have already collaborated on brain/head injuries and looked at the physics of impact. We can do that today, although we're not yet able to look inside and understand the neural pathways," he says.

Professor Marco Viceconti, scientific director of the Insigneo Institute at the University of Sheffield, is part of a UK team currently building a fully computer-simulated replica of the whole human body. Just like Dassault Systèmes, the institute believes healthcare can be moved onto a more advanced level by simulating real biological processes in a virtual environment, what's known as ***in silico medicine***.

"These technologies are the core of the next major advance in medicine and our best hope to understand the body," says Viceconti.

According to Dr Keith McCormack at the Insigneo Institute, "we are fast approaching (indeed in some cases we have perhaps passed) the limit of current clinical mechanisms to provide adequately comprehensive care for some categories of patient.

"The more we know about the human body, the more difficult it is to integrate the totality of the information into a complete package of care and, as the population ages and the number of co-morbidities rises, it becomes impossible for any single clinician to offer adequately-comprehensive care,"says McCormack.

The Royal College of Surgeons can see the potential. "3D modelling provides a glimpse of what advances in new technology can potentially do for the future surgery," a spokesperson said. However, the college believes more data of its potential is needed, adding: "It is vital that we continue to provide the evidence for the successful application of new techniques like this so that they can be used to revolutionise care for patients."

NARROWING CHOICE

For Elazer Edelman, a consultant cardiologist based at the Massachusetts Institute of Technology, proving and applying these capacities is all the more vital "in a time of an abundance of potential therapies".

"This embarrassment of riches creates an interesting problem," he says. "There are more drugs than ever before and more devices available. The question is how does a clinician select the most appropriate?"

Edelman believes The Living Heart Project could soon be a tool that clinicians use to decide the optimal therapy for each patient and he predicts that not only will the technology be embedded in hospitals and labs within our lifetime, but it will also improve our knowledge of how substances and diseases affect different genetic subsets. This means that we will be able to identify those most at risk and prevent trauma from happening.

ANIMAL TESTED

3D computer modelling could also open up the prospect of doing research that might otherwise never be undertaken or only be done by using animals.

"Certainly we would like to believe over time our dependency on animal testing will go down as a result. We can't state animal testing will end, but this increases our ability to innovate and not at their expense," says Levine.

The VPH Institute for biomedical integrative research, of which the University of Sheffield is a supporting member, says: "In silico research provides enormous potential advantages for reducing, refining and replacing animal testing as well as translating the results of animal experimentation to humans."

According to UK Home Office statistics, in 2012 in Great Britain alone there were 4.11 million scientific procedures on animals, an increase of eight per cent or 317,200 procedures, compared with 2011. However, procedures specifically designed to test on living organisms or bodily part functions, dropped from 604,500 in 2011 to 430,500 in 2012.

Calls to reduce animal testing are already being ramped up by international science organisations and even governments. The UK government, for example, in 2010 publically announced it was behind developing mechanism-based devices that are more predictive of human biology and said it would "work to reduce" the use of animals in scientific research.

A delivery plan published in February 2014 shows how alternative methods such as tissue engineering, stem cells, and mathematical modeling, can deliver "fast, high-quality research that also boosts economic growth… Increasingly, attention has focused on non-animal technologies for solutions", it states.

The work Levine, Viceconti, Edelman and their teams are doing could therefore offer a third way—a way to take off the traditional constraints on research and allow innovative ideas to be virtually tested with no limits, saving lives and money. The technology could soon find it on the roll call of medical milestones such as vaccinations, sterilisation, x-rays, and MRI scans. Many millions of people's lives have been saved, and many millions could be thanks to a new era of technology.

"We are bringing this powerful technology to medicine, where machines that never sleep and never forget can process fully-personalised information on all the conditions from which a patient is suffering," says McCormack.

This article was first published as an Advertisement Feature on bbc.com running from 27th June 2014 to 5th September 2014, and was created by the BBC Advertising Commercial Production team in partnership with Dassault Systèmes