Heart holograms may advance cardiac care

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Holograms have become a source of entertainment in the last decade, with Tupac Shakur and Michael Jackson appearing on stage to perform long after their deaths. But how can this technology be translated and used in medical practice? Through meticulous research, Partho Sengupta, MD, has developed a cardiac visualization hologram that is transforming our ability to detect early stages of cardiovascular disease.

“The heart is basically a pump. We know that. Or at least we think we do,” said Dr. Sengupta, director of interventional echocardiography and cardiac ultrasound research at Mount Sinai Hospital in New York. “What if I told you that there are at least eight different models of cardiac muscle architecture even today?”

Scientists and cardiologists have visualized the heart muscle arrangement as bundles, layers, bands and many other shapes. Historically, the inner workings of the heart were a mystery, but with modern visualization techniques, there is greater opportunity to see the heart in new ways.

An eventful trip to the butcher

Dr. Sengupta, speaking at TEDMED in Palm Springs, Calif., shared his personal journey of trying to understand the heart’s form and function and what new technology could mean for health and treatment. In 2003, he traveled from India to the United States “seeking new knowledge,” he said. “I hit a few speed bumps on the way. I did not know that a formal research approval would require several months.”

Instead of taking that path, Dr. Sengupta did what only a cardiologist would think to do—he went to a local butcher shop and placed an order for animal hearts.

“Now ordering for animal hearts would not require any source of approval,” he said, “but the butcher was extremely surprised. I ordered cow heart, pig heart, goat heart, all kinds of hearts and the next day they all arrived frozen, neatly wrapped in a delivery box."

Over the next week, Dr. Sengupta used a microwave in his break room to thaw the hearts, then, with the help of his pathology professors, carried out meticulous dissections.

"What we saw was intriguing. The muscle fiber geometry in the heart was swirling complexly and soon we realized why we had so many different perspectives," he said. "You could dissect the heart, unwrap the fibers and assign it a shape depending on how you viewed the muscle works."

So Dr. Sengupta decided to take a different approach. He put an entire, undissected heart in a water bath and used a high-resolution ultrasound probe to get a panning, cross-sectional view of the entire heart from top to bottom.

The reflections from the inner and outer side of the wall were swirling in two different directions resembling galactic spiral arrangements, Dr. Sengupta said. "I spent some time trying to link the counter-directional, unique spiral arrangement to the twisting motion of the heart."

He then tried to connect that spiral arrangement to blood flow. And with new visualization techniques, was able to conceptualize that the heart muscle action is not just a simple squeeze, but a much more evolved design.

"As the blood flow changes its direction inside the heart chambers, you'll see there's an intervening phase where it starts rotating," Dr. Sengupta said. "This rotational flow is called a vortex formation and allows conservation of energy and momentum."

This knowledge helped Dr. Sengupta and his colleagues create new holographic ultrasound technology. They were able to visualize the swirling flow inside the heart with two-dimensional images. But the heart is a three-dimensional structure and there had to be a better way to show it.

Inspired by Hollywood, stage and music, Dr. Sengupta started looking for holography medical presentations and found that it would be too expensive. He crowd-sourced his idea to raise the funding and, with a team from India, Europe and Canada, cost-effectively developed the technology. He was able to perform a successful holographic presentation at the annual convention of the American Society of Echocardiography (ASE), where his mentor appeared on stage as a holographic avatar (see the 11-minute, 32-second mark).

The medical community has shown great enthusiasm about using ultrasound for diagnosing cardiovascular problems, Dr. Sengupta said. "It is cost-effective, the machinery is small and getting smaller, it's portable and can be taken into communities."

Holograms, ultrasound in practice

Following his successful presentation to the ASE, Dr. Sengupta wondered how a practicing cardiologist could use this new technology in day-to-day practice. He investigated technology that converts desktop computers into a holographic suite and found a program from the Massachusetts Institute of Technology that allows users to communicate and exchange three-dimensional objects.

Dr. Sengupta showed the audience a video clip of the holographic program in use. It is a flat board tilted at a shallow angle, like a writing desk or an easel. The hologram is lifted from the screen with a stylus and can be rotated in its entirety. The example presented was a sub-mitral valve. “You can see it has a saddle-shaped geometry, which is much better appreciated when you lift the image off the screen and [rotate] it in the air as a hologram,” he said. Then he showed an example of an abnormal valve. “You can see it has got irregular heights and as it closes, the irregularity causes a wide gap in closure which makes the valve leak,” he said.

“Details like these are extremely crucial for surgical planning,” he said, “and can be obtained directly from ultrasound.”

In 2012, with the help of the ASE, Dr. Sengupta and his colleagues traveled to northern India for a humanitarian mission. In less than two days, they performed over a thousand scans and uploaded them to a cloud-storage service. Seventy-five institutions around the world read the reports and sent back results. Dr. Sengupta and a colleague wrote an editorial, published in the *Journal of the American Society of Echocardiography* in 2015, on potential clinical uses of holography as well as three-dimensional printing.

Could ultrasound be used for mass screening? Dr. Sengupta wondered. “What if we had something like the passport kiosk units you see [in] airport terminals, which allow speedy immigration of thousands of passengers daily?”

A patient would walk in front of the kiosk, have their picture taken and then a thermal scan would detect any abnormalities in the skin circulation, he said. The patient would then place a finger in the monitor to characterize the pulse dynamics and a microwave would take a sample of the cardiac motion proving cardiac function information.

“If any abnormality is detected at this stage, it would trigger the need for further evaluation like performing a high-sensitivity electrocardiogram,” he said. If the patient needs an ultrasound examination, the data would be transmitted and a physician at another location could perform a long-distance examination using a robotic arm to visualize the blood vessels and the heart, he said.

“And after all this data is collected it would be funneled into an intelligent system, which would have a computational algorithm that would integrate the electrical, the structural, the functional data together so that we can quickly discover the medical problem and design the solution, which would be personalized,” Dr. Sengupta said. “This technology is already here—ready for testing. Some of it’s already been tested and is ready for translation.”

So why do we need such visualization for screening heart disease? The answer, Dr. Sengupta said, “is cardiovascular disease is the leading cause of death in the United States … technologies like this can help us stop this.”

“Eventually [this technology] may become so affordable that you find such kiosks in community outlets and drug stores,” he said. “And that would go a long, long way toward universal, early detection of cardiovascular disease.”