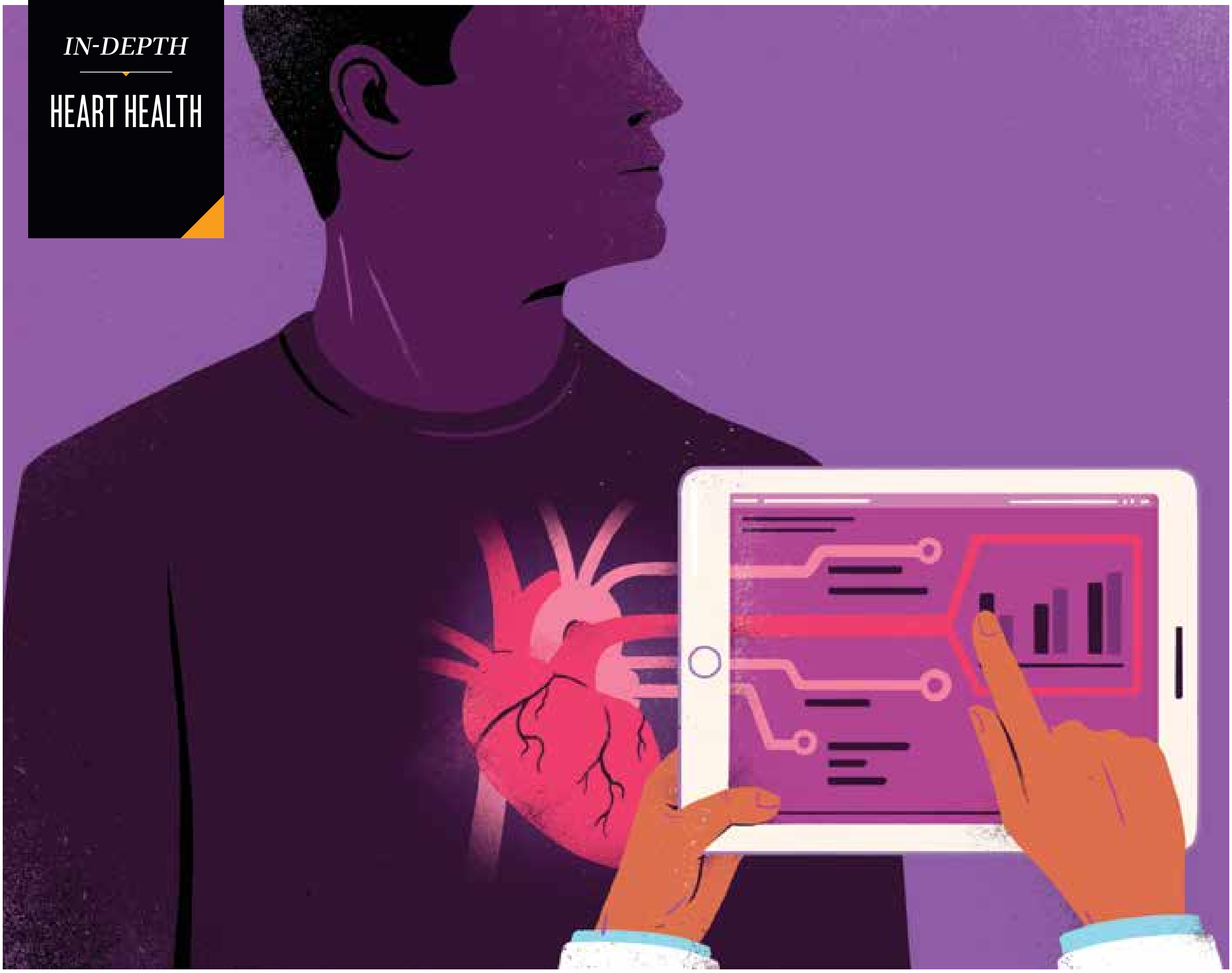

High-tech Heart Care

Exciting advancements in technology—from AI to 3D printing—are driving cardiology into the future.
BY KAMALA THIAGARAJAN

Our heartbeat marks the rhythm of our lives. Yet, for so many, that rhythm may be unexpectedly and prematurely disrupted.

Every year, according to the Centers for Disease Control and Prevention, 1 in 4 Americans dies as a result of a heart disease—that's 610,000 people. The World Health Organization reports that an estimated 17.9 million people around the globe died from cardiovascular diseases in 2016, accounting for 31 percent of all global deaths.

Medical innovation has done much to detect anomalies earlier, reduce suffering and expand lifespans and quality of life after a cardiac event such as a heart attack. Here are some of the cutting-edge treatments that have transformed cardiac care in recent years.

CARDIAC MAPPING

The human heartbeat is a result of a series of electrical impulses. These impulses begin in the sinoatrial node, a cluster of cells situated in the upper wall of the right chamber of the heart. The SA node is known as the heart's natural pacemaker, because it regulates the heartbeat and forces blood into the lower chambers of the heart, causing them to contract and pump blood throughout the body.

A healthy heart beats 60 to 100 times per minute when you are at rest. When you're engaging in any

ILLUSTRATION BY SÉBASTIEN THIBAULT

kind of physical exercise or if you're going through anxiety, fear or stress, the rate increases. However, imagine a condition in which your heart rate fluctuates wildly, beating too quickly or too slowly, for no apparent reason at all. If the body's natural pacemaker doesn't work right, it can lead to atrial fibrillation or arrhythmia—an erratic heartbeat— which is a condition that can create complications such as blood clots, heart failure and stroke.

According to the American Heart Association, at least 2.7 million Americans live with atrial fibrillation. As this can be a completely silent condition causing no symptoms, some people may not even know they're suffering from it. Others experience dizziness, heart palpitations and shortness of breath. Atrial fibrillation is the leading cause of stroke and hospitalization in the United States.

A procedure called cardiac mapping has widely been used to detect the abnormal heart rhythms found in these conditions. It involves inserting an electrically sensitive endocardial catheter—a long, flexible thin tube—into the heart via an artery or vein in the groin. This allows a physician to locate the origin of an erratic heartbeat and to use electrical impulses to eliminate errant tissue and possibly correct it.

Advances in cardiac mapping technology are now reducing both the time and discomfort of this procedure, making it more effective and less invasive. Launched in the United States in 2017, CardioInsight technology is making inroads into clinical practice, giving physicians the ability to noninvasively map patients' irregular heart rhythms.

"CardioInsight technology provides a means of mapping abnormal heart rhythms noninvasively and identifying the region or areas responsible for the abnormal rhythm. We currently have the most experience with it in the United States," says J. Michael Mangrum, M.D., a cardiac electrophysiologist and associate professor at the University of Virginia Medical Center. "It is transforming the quality of care for patients with persistent forms of atrial fibrillation—the most common abnormal heart rhythm—and PVCs, which are premature ventricular contractions or premature contractions of the lower chambers of the heart," says Mangrum.

All a patient would need to do, Mangrum adds, is wear a disposable, single-use vest. The vest, consisting of 252 electrodes that map the heartbeat, is connected via cables to a computer processing unit to analyze the information.

"The electrical information is collected through the vest. The patient also undergoes a CT scan of the heart with the vest in place and a 3D rendering of the heart is constructed," says Mangrum. "The electrical information is then projected back onto the 3D image of the heart with the areas of interest identified."

This detailed and noninvasive twist to cardiac mapping has the potential to save more lives. In order to detect the origin of an irregular heartbeat, the patient must be experiencing the condition while wearing the vest. However, the CardioInsight vest gives the physician flexibility to observe the patient's heart rhythm while in the hospital for up to eight hours, allowing the condition to be detected with improved accuracy. Patients wear the vest prior to cardiac ablation, a procedure that involves a surgical procedure to eliminate the tissue in your heart that is triggering or sustaining an abnormal heart rhythm, thereby stopping the arrhythmia.

Electrophysiology is seeing some of the most advanced technologies available in medicine, Mangrum says. The greatest advancements are in being able to improve the ablation procedure that can eliminate atrial fibrillation successfully. These include advances in 3D navigation while moving catheters in the heart, catheters that can measure the degree of contact pressure inside the heart to optimize the ablation, ultrasound that can see within the heart and new energies used to ablate the tissue. "Some very exciting technologies are in development now that may help improve the procedure even more," he says.

INNOVATIONS IN THE MAKING

Are adhesive heart patches a Band-Aid for broken hearts?

Can you mend a broken heart by literally patching it up? We soon may be able to put a bandage on the heart, just as we would any other damaged part of the body.

After a heart attack, it takes at least eight weeks for the scarred heart tissue to heal. However, the heart still has to pump blood. Scientists at Brown University in Providence, Rhode Island, Fudan University in Shanghai and Soochow University in Suzhou, China, have joined efforts to create and test (on rats) a new type of heart adhesive that is made out of a water-based hydrogel material and biological substances that are flexible enough to act as a patch on scarred tissue, allowing it to heal even while the rest of the heart works to pump blood. In a study published in the April 2019 issue of *Nature Biomedical Engineering*, this new type of adhesive patch was shown to be effective in rats, reducing the muscular damage after a heart attack. It remains to be seen how this innovation would work in the human heart.

"WE ARE LEARNING MORE AND MORE ABOUT THE GENES THAT AFFECT OUR RISK OF DEVELOPING HEART DISEASE AND OUR RESPONSE TO THERAPY. BY BETTER UNDERSTANDING THESE FACTORS, IT ALLOWS US TO TAILOR OUR TREATMENTS TO THE INDIVIDUAL—OFFERING TRULY PERSONALIZED MEDICINE."

—THOMAS RYAN, M.D., DIRECTOR OF THE OHIO STATE UNIVERSITY HEART AND VASCULAR CENTER

WEARING YOUR HEART ON YOUR SLEEVE

Today, many health tech devices promise to monitor your heart 24/7 without disrupting your daily routine. The FDA-cleared AliveCor KardiaMobile is one such consumer device. It works like a portable echocardiogram and can detect various kinds of arrhythmia. Compatible with most iOS and Android phones, the device can stick to the back of a mobile phone or its cover. It has two metal pads and works by communicating wirelessly with the free Kardia app. Once it is synced and positioned in front of the patient's phone, the patient places two fingers of each hand on the device's metal sensors and waits 30 seconds for an ECG reading.

"AliveCor is more useful in patients with palpitations that occur more irregularly," says Alejandra Miyazawa, M.B.Ch.B., M.R.C.P., a cardiologist at the Imperial College Healthcare NHS Trust in London. "When patients are symptomatic, they can put their fingers on the device and obtain an ECG trace."

Fitbit and the new series of Apple Watches also promise to monitor heart rates. The Apple Heart Study, conducted by Stanford University researchers (and sponsored by Apple) evaluated the accuracy of the Apple Watch in detecting atrial fibrillation in more than 400,000 participants in 2017. The researchers reported that wearable technology can safely identify irregularities in heart rate, which was subsequently confirmed as atrial fibrillation. In a widely publicized tweet last year, Apple CEO Tim Cook noted how the device helped save the life of an 18-year-old by detecting her arrhythmia. But physicians warn that the results can't always be trusted.

"Automated interpretations can be wrong," says Miyazawa. "ECGs reported by a machine should be reviewed in the context of the patient's clinical history and presentation. Most clinicians would not rely on a machine interpretation alone."

AUTOMATING ECG READINGS WITH AI

Machine interpretations using algorithms are being employed in many other ways in cardiac care—and automated ECGs are one such development.

An ECG recording is one of the most common components of heart examinations. Ten electrodes are strapped to a patient's body, recording 12 different views of the electrical activity of the heart. ECG analysis is a critical first step to help diagnose and predict cardiovascular disorders. A physician usually reads the results of an ECG. But by automating the process, a computer can be trained to detect heart issues with greater speed and accuracy.

For automation, a patient's ECG must be fed into specialized data acquisition software to make a digital record, says Miyazawa. As more ECGs are digitized, a pattern recognition system sets in and the software begins to recognize and flag problem areas. It can identify possible ischemic changes (a reduction in the blood flowing to the heart), atrial arrhythmias (atrial fibrillation or flutter of the heart), left ventricular hypertrophy (an enlargement or thickening of the left ventricle) and axis deviation (a deviation in the direction of the overall electrical activity of the heart), among other complications, says Miyazawa. These readings are then corroborated by a physician.

"Although both are liable to misinterpretation, mistakes are often reduced with a combination of the two," says Miyazawa. "Artificial intelligence in cardiology, beyond diagnosis of ECG readings, is still in the early stages." The results produced by AI and the technology itself still need to be validated through extensive clinical trials.

Deep machine learning requires large amounts of information to be processed before it can be used, and it is only as good as the information that physicians feed into these systems. "AI has shown promise in diagnosing patients earlier than physicians, which has the potential to reduce hospitalization and improve patient outcomes," Miyazawa adds. "The benefits of incorporating AI in the field of cardiology are tremendous, particularly with the aging population and its strain on clinical services. It would certainly improve patient experience, workflow, productivity and, ultimately, patient outcomes."

LVADS AND QUALITY OF LIFE

The first generation of the modern version of the left ventricle assist device was operational in the 1990s. The LVAD is a surgically implanted, battery-operated, mechanical pump that can assist a failing heart. These devices were first used as a bridge therapy—to prolong the life of a patient whose heart had failed, so that they could possibly stay alive long enough to receive a transplant once a donor heart became available. In 2010, the LVAD was approved by the FDA as a destination therapy—for use in patients who were not candidates for heart transplant surgery. The LVAD assists the functioning of the heart, allowing patients to have a better quality of life.

The most advanced LVAD—HeartMate3—was released in 2018. The devices are substantially smaller now and fit pediatric patients, says James Bergin, M.D., cardiologist at the University of Virginia Medical Center.

All of these devices require an external source of power, Bergin adds. The pumps are attached to a cable that passes from the device through the skin of the abdomen and to the controller, a small computer held outside of the body. The controller runs the pump and provides messages and alarms to help operate the system that is inside the body.

It's a complicated setup: The line crosses through the skin into the body, and infections can occur at that site. The battery pack, which is outside of the body, needs to stay charged. The batteries "used to be charged through a cord that is plugged into an electrical socket. But today, battery packs are getting more sophisticated," says Bergin. "As the companies move towards transcutaneous recharging, that will help out dramatically."

Rather than providing a pulsatile flow, LVADs are now continuous-flow devices. This allows them to be much smaller and use much less energy. The current-generation devices have the potential to last a very long time. The HeartMate3 is fully magnetically suspended. Another device called HeartWare is mostly magnetically suspended; both may last at least 10 to 15 years. What prevents these devices from completely replacing heart transplantation is the risk of stroke, bleeding and infection, Bergin says.

But each generation of LVADs is a constant improvement on the last, affording a better quality and length of life for patients with heart failure. Even exercising is possible once the procedure is complete and the patient has healed.

THE LEADLESS PACEMAKER

A traditional pacemaker is a small electronic device that is implanted in the chest with leads running to the heart to help control abnormal heart rhythms. It was first introduced in the late 1940s and has been critical to heart care since then, especially in the correction of arrhythmia. Today, a less invasive version called the leadless pacemaker is now implanted directly into the heart, minimizing scarring.

"Because the pacemaker is not sitting in the upper chest, people can move their arms sooner and more safely and they don't have to worry about damaging [it]," says Mangrum of the University of Virginia Medical Center. "With traditional pacemakers, there is increased risk of problems such as infections in the chest pocket, bleeding or a collapsed lung during implantation. As the leadless pacemaker is inserted from the groin, these risks either don't exist or are minimized. Leads that connect traditional pacemakers to the heart undergo significant wear and tear over time, and although they are resilient, they can fracture and fail to function. These problems are not seen with the Micra TPS," he says, referring to Medtronic's leadless pacemaker, marketed as the "world's smallest pacemaker."

FROM TRANSPLANTS TO 3D PRINTING: HOW HEART CARE IS EVOLVING

Thomas Ryan, M.D., is the director of The Ohio State University Heart and Vascular Center and a professor of cardiovascular medicine at The Ohio State Wexner Medical Center. Co-author of *Feigenbaum's Echocardiography*, the leading textbook in the field of cardiovascular ultrasound, he's also the former president of the American Society of Echocardiography. Here, he discusses the latest heart care advancements with *Sky*.

Tell us about a cardiac care technology that both intrigues you and is saving lives.
One area that continues to evolve is transcatheter valves. This has been the most dynamic, rapidly changing area in cardiology the past decade and shows no signs of slowing. In a few short years, it has revolutionized how we care for patients with valve diseases, reducing the need for open-heart surgery for many patients.

Is this linked to cardiac tissue engineering—the 3D printing of the heart?
At Ohio State, we are actively involved in 3D printing research and we are using this technology in patients with heart valve disease. The heart has four valves that may malfunction for many different reasons. The transcatheter valves are animal valves, such as from a pig or cow, sewn on to an alloy frame. Sizing this artificial valve correctly is very important. The 3D reconstruction is derived from a CT scan of a patient's heart. By creating a 3D model of their heart and blood vessels, we can better understand the risks and benefits of transcatheter valve implantation for the patient. Our research work in this area not only helps us in patient selection, but also allows us to pick the right type and size of valve for the individual and to reduce the risk of a complication.

How have organ transplant procedures advanced in recent years?
Organ transplantation is a special gift, different from everything else we do. For patients with a failing heart, transplantation can be both a life-saving and a life-changing event. At The Ohio State Wexner Medical Center, we have a robust and growing heart transplant program, offering many years of quality life for select patients with heart failure. It can make a huge difference in our most seriously ill patients. We have had patients run a marathon a few years after receiving a heart transplantation.

Are there any advancements in your field that you're particularly excited about?
Definitely genetics. We are learning more and more about the genes that affect our risk of developing heart disease and our response to therapy. By better understanding these factors, it allows us to tailor our treatments to the individual—offering truly personalized medicine.

Should cardiac care be different for men and women?
We now know that there are many aspects of heart disease—risk factors, symptoms, response to therapy and outcomes, to name a few—that differ between women and men. Because of these important differences, at The Ohio State Wexner Medical Center we established a women's heart program more than a decade ago. Our women's heart team focuses on those aspects of cardiovascular diseases that differ for women and men: premium on prevention and early detection, providing a personalized approach to both diagnosis and treatment.

PUZZLE ANSWERS

Easy KENKEN

4	1	2	3
1	2	3	4
3	4	1	2
2	3	4	1

Hard KENKEN

5	2	3	1	6	4
6	4	1	3	5	2
3	1	5	4	2	6
2	5	4	6	1	3
1	3	6	2	4	5
4	6	2	5	3	1

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Easy Sudoku

9	4	1	2	5	3	8	6	7
2	6	7	9	1	8	4	5	3
3	5	8	6	4	7	1	2	9
5	3	4	1	8	6	7	9	2
7	2	6	5	9	4	3	1	8
8	1	9	7	3	2	6	4	5
6	7	5	3	2	1	9	8	4
4	9	3	8	6	5	2	7	1
1	8	2	4	7	9	5	3	6

Hard Sudoku

2	1	6	4	5	7	8	9	3
8	7	4	1	3	9	5	2	6
9	5	3	8	2	6	1	7	4
4	9	5	6	7	3	2	8	1
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7	3	1	5	8	2	6	4	9
3	6	7	2	9	5	4	1	8
1	4	9	7	6	8	3	5	2
5	8	2	3	1	4	9	6	7

D	R	O	S	S		A	C	T	S		A	S	S	A	D
A	I	S	L	E		P	L	O	W		U	T	E	R	O
T	A	C	I	T		H	O	M	E		R	U	L	E	R
E	T	A	T	S		I	D	E	A		I	B	E	A	M
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M	A	E		S	E	A	C	R	E	S	T		R	A	E
S	T	A	S	H		T	H	E	Y		S	A	T	Y	R
	A	L	L	A	N					V	A	L	E	S	
O	B	L	I	Q	U	E	R	E	F	E	R	E	N	C	E
R	O	T	C		K	R	O	N	E	R		P	D	A	S
B	R	I	E		E	T	U	D	E	S		P	E	L	T
S	E	E	D		S	E	E	S	T	O		O	D	E	D