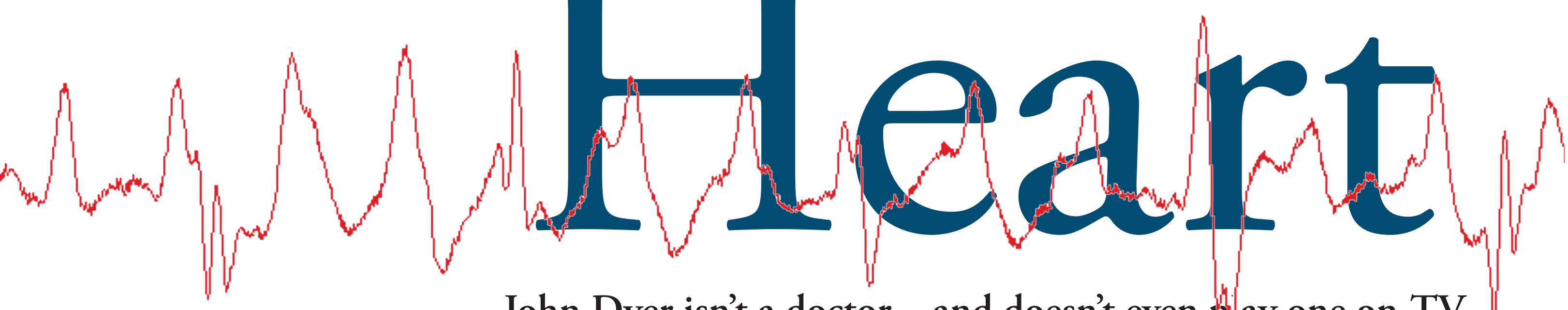
By Debra Levy Martinelli
Photos by Hugh Scott

Engineering a Healthy Heart



John Dyer isn't a doctor—and doesn't even play one on TV. He's an electrical engineer who is making important contributions to the research and treatment of heart patients at OUHSC.

Just as doctors and lawyers specialize within their respective professions—perhaps dermatology, pediatrics or neurosurgery for physicians, or criminal, corporate or family law for attorneys—so do engineers.

Electrical engineer John Dyer specializes in small signal processing, applying his expertise to a range of industries and fields that include aviation, navigation, energy production and arrhythmias associated with cardiac electrophysiology.

Small signal processing applied to therapies for the human heart?

continued

Electrical engineer John Dyer, left, and Warren "Sonny" Jackman co-founder and senior scientific adviser of the Heart Rhythm Institute at OUHSC work together to help patients with erratic heartbeats. Through recording catheters in the patient's heart, physicians like Dr. Jackman have become adept at identifying the source of the heart's incorrect electrical activity. The "bad" cardiac tissue is then removed or "ablated" or with the radio frequency (RF) current. Dr. Dyer's research in signal processing has improved ablation therapy by precisely targeting the millimeter-size tissue that can cause irregular heartbeats.

Dyer sits at the computer consoles in the "control room" outside the EP lab. From here doctors can monitor all the electrical signals from the body surface. Dyer's current work is to take the 12-lead ECG and analyze it in a way that will identify specific electrical behavior of the upper chambers of the heart.

It's a natural, Dyer says.

"The heart does two things: it's a mechanical pump, but there also is an electrical circuit that keeps it pumping in rhythm," explains Dyer, a research assistant professor in the University of Oklahoma College of Engineering and staff member of the Heart Rhythm Institute at the OU Health Sciences Center. "We can study both the proper and improper operation of that electrical circuit."

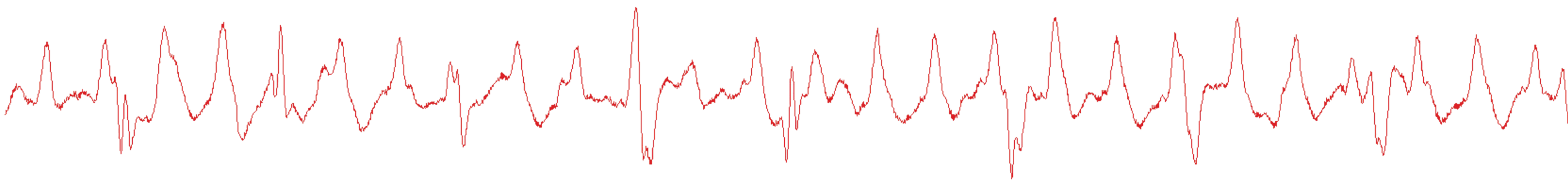
Think electrocardiogram, probably the most common procedure for recording electrical heart activity.

Supporting his colleagues at the HRI, Dyer has helped refine a procedure called ablation therapy that identifies and treats cardiac arrhythmias by destroying the millimeter-scale pieces of aberrant tissue that cause irregular heartbeats.

Dyer was recruited by HRI co-founder Warren "Sonny" Jackman, M.D., in the early 1990s, when Dyer was completing his bachelor's degree in electrical engineering at OU and working as a lab technician. Jackman was developing an ablation process for accessory pathways in the heart, using the same access technique cardiologists use for an angiogram: inserting an electrical catheter into an artery or vein in the groin area and guiding it to the heart.

"I went to one of Dr. Jackman's first ablation procedures," Dyer remembers. "The catheter went up into the heart, and when the doctors passed the ablation current through it, they had to unplug the catheter from the electrical recording system, which meant they couldn't see the signals from the catheter anymore. They were working on blind faith, hoping it was working."

It was working, he says, because Jackman has a gift for visualizing the movement of the electric circuit through the heart based on watching the electrical tracings on the recording system.



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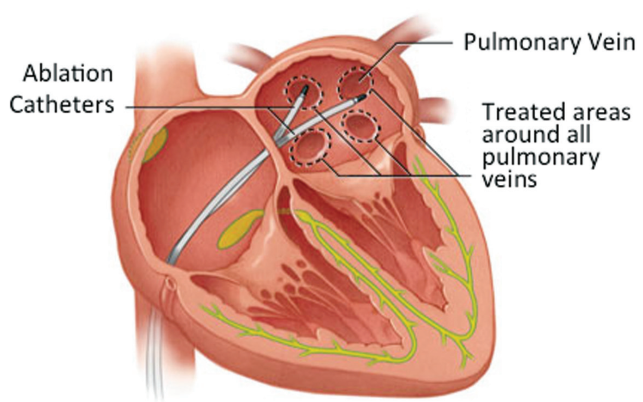


Catheter ablation introduces electrical catheters into the heart. The physician records electrical activity during atrial fibrillation and determines which tissue to ablate. The two main targets of ablation in atrial fibrillation are the tissue surrounding each pulmonary vein, and clumps of nerve cells called *ganglionated plexi*.

But Dyer immediately recognized how engineering could come to bear on improving the ablation process and came up with two solutions.

He first created a switchbox into which Jackman and his colleagues could plug both the catheter and the ablation unit and just flip a switch when they were ready to apply the ablation current without disconnecting any other equipment. Then he designed and built a filter for the surface leads—the electrodes attached to skin that record the electrical activity (electrocardiogram)—so that the doctors could still see what the heart was doing while they were ablating the small amount of target tissue.

With these improvements in place, the HRI team later tackled an ablation procedure to address atrial fibrillation, the most common cardiac arrhythmia. Atrial fibrillation occurs when the heart's upper chambers—the right and left atria—beat chaotically and out of coordination with the two lower chambers—the right and left ventricles.

"We're starting to understand that, like everything else in biology, there's a range of causes of atrial fibrillation, some of which are amenable to drug therapy and others that need ablation therapy," says Dyer, who, in addition to bachelor's, master's and doctoral degrees in electrical engineering also holds a bachelor of science degree in physiology.

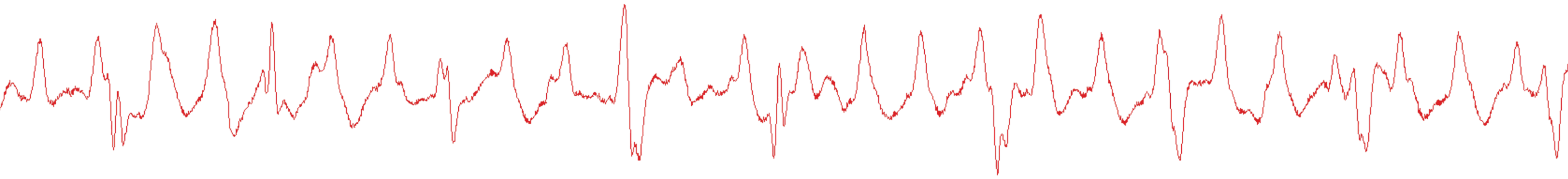
Darren Tepe was an atrial fibrillation patient who, over a period of years, required both.

"I had my first attack when I was 35," recalls Tepe, now a 54-year-old engineer at the Federal Aviation Administration in Oklahoma City. "My heart rate went up to 180 beats per minute. When that happens, you get a shot of adrenaline, so if you're in bed—which I was—you become wide awake. It's like you're running a marathon. I went to work the next day and felt good, even though I didn't get much rest the night before."

Still, he sought medical attention. Under the care of a cardiologist, Tepe took medication that managed the atrial fibrillation for several years. But then the attacks steadily became more frequent, often landing him in the emergency room.

"As time went on, after I had an attack I felt extremely nauseated and got a really bad headache," Tepe says. "It was pretty debilitating."

He researched his options, which ultimately led to Jackman, Dyer and the HRI. (Coincidentally, Tepe and Dyer worked together at Lucent Technologies in Oklahoma City years earlier.) Tepe had the ablation procedure in February 2011. *continued*



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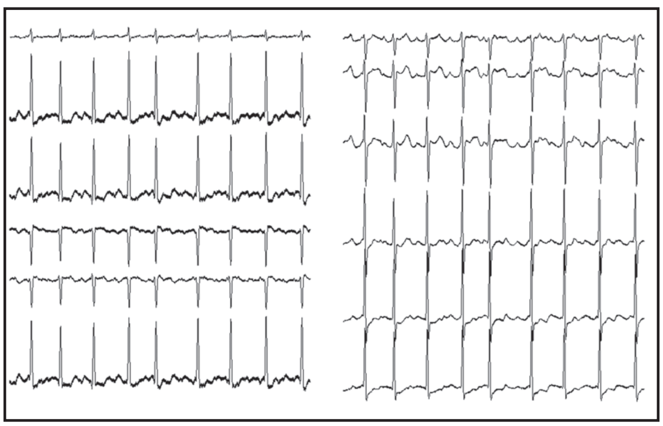

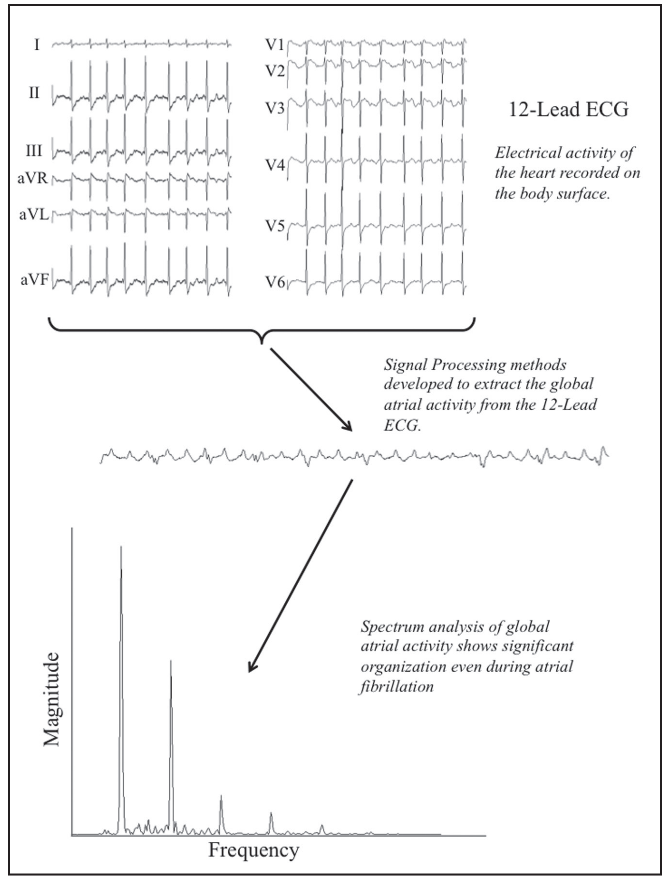

Dr. Dyer takes the tracings from the 12-lead ECG (electrocardiogram), upper right, and analyzes it in a new way that helps identify specific electrical behavior of the upper chambers of the heart. The recording catheters in the atria touch only some of the tissue, but Dyer gets better "global" information about the atrial electrical activity by using the surface leads to extract the total atrial activity.

"It gave me my life back," he says.

While a success for Tepe and many others, Dyer says ablation therapy still has a way to go.

"The current ablation method is to look for sites of aberrant electrical activity in the atria and ablate each one," he explains. "The difficulty is that there is no objective parameter that helps to determine when to stop looking for them. We use signal processing to try to acquire global electrical information from the atria and look at how structured the electrical circuit is. If it's working properly, the circuit should be very organized and structured; if it's not working properly, it's very chaotic.

"Our goal is to see if we can find a point in the spectrum where we can say, 'We've done enough ablation, now let's send the patient home. If he needs to be on an anti-arrhythmic drug for a little while to maintain sinus rhythm [normal heartbeat] until he gets better, that's OK.' "

Dyer says some recent research indicates that if a person can be kept in sinus rhythm for an extended period of time, atrial fibrillation starts to go away.

"If we can get someone to a point where he or she can stay in sinus rhythm with anti-arrhythmic medications, then over a year to a year-and-a-half the medications can be reduced and eventually eliminated. That's the goal. And then that person can live a normal life," he states.

A person like Tepe just a few years ago found that possibility hard to imagine.

"The ablation procedure changed everything for me," he declares. "I want other people with atrial fibrillation to have that opportunity, too. When you get a gift like that, you want it to be available for everybody."

Dyer, the self-proclaimed "small-signal guy," sees the potential for great progress in the treatment of atrial fibrillation.

"We're discovering there is a lot of interaction between the brain at the level that regulates body activity and the various organ

Dyer and Jackman stand next to the fluoroscopy—or live X-ray—equipment.The C-arm can be rotated so that the fluoroscopy is looking through the body at whatever angle is desired. This helps position catheters in the patient's heart. In the lower left is the table that the patient lies on. The table and C-arm are positioned so that the fluoroscopy passes through the chest region.

systems, including the heart," he says. "Our basic laboratory studies show that stimulating the vagus nerve [a major nerve that extends from the brain stem to the abdomen via the heart and other organs] may reduce the propensity for atrial fibrillation."

If his team's clinical studies currently underway clearly demonstrate that finding, they will better understand the condition's underlying mechanism.

Dyer and his colleagues also are exploring whether external oscillating magnetic fields—long used in orthopedics to help heal broken bones—might be beneficial in treating atrial fibrillation.

"As we gain a better understanding of the cause of atrial fibrillation, we can keep moving toward less invasive treatments that address the system as a whole and lead to better long-term results," he relates.

Still, Dyer is humble about his role.

"The physicians are the real pioneers in this field," he says. "But it's nice that I can bring to bear engineering tools to help them refine their technique."

Debra Levy Martinelli is principal of LevyMart Public Relations in Norman. She writes freelance articles for Sooner Magazine.