Dangerous arrhythmia analyzed in a heartbeat

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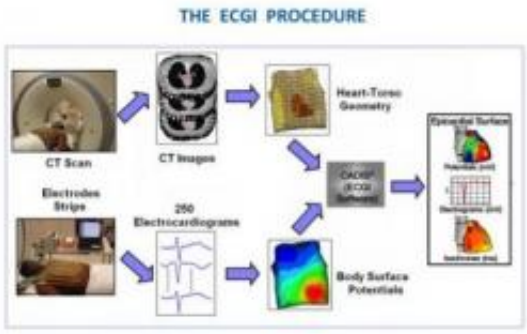

Electrocardiographic Imaging (ECGI) can map a life threatening cardiac arrhythmia noninvasively, during a single heart beat. Credit: WUSTL

Just one second, one heartbeat. That's what is needed for a new, noninvasive functional imaging technology to record data for locating the source in the heart of a dangerous cardiac arrhythmia called ventricular tachycardia (VT).

VT is an abnormal, fast beating of the heart, which, if ignored, can lead to ventricular fibrillation, which causes some 400,000 cases of sudden death yearly in the United States alone.

The technique, developed by a Washington University in St. Louis scientist, is called Electrocardiographic Imaging (ECGI). It combines computerized tomography (CT) with 250 electrocardiograms recorded

by electrodes placed on a vest across a patient's torso to map the source and pattern of VT in the heart and determine the kind of VT irregularity.

Using a special algorithm, ECGI can generate movies of the distinctive VT excitation waves, radiating like the wake caused by a pebble dropped into a pool, or rotating like a tornado, from recordings of multiple heartbeats.

While a wealth of information can be deduced from ECGI analysis of just one heartbeat, multiple heartbeats up to minutes long are often imaged to reveal even more about the nature of the arrhythmia.

Yoram Rudy, PhD, the Fred Saigh Distinguished Professor of Engineering, professor of biomedical engineering and of medicine and director of the Cardiac Bioelectricity and Arrhythmia Center (CBAC) at WUSTL, developed ECGI, first publishing on the technique in 2004.

Now, publishing in the Aug. 31, 2011, issue of *Science Translational Medicine*, Rudy and his collaborators in the Washington University departments of biomedical engineering and medicine, report the first systematic study of 25 cardiology patients with VT using ECGI to map noninvasively, beat by beat, the mechanisms and processes of VT in humans.

Co-authors WUSTL's Yong Wang, PhD, postdoctoral research associate in radiology who was a PhD student in Rudy's biomedical engineering lab, and Phillip S. Cuculich, MD, assistant professor of medicine at the School of Medicine, contributed equally to the study and are members of CBAC, an interdisciplinary center whose goals are to study heart rhythms and their disorders (cardiac arrhythmias) and to develop new tools for their diagnosis and treatment in the prevention of disabilities and cardiac death.

The other co-authors are Junjie Zhang; Kavit A. Desouza, MD; Ramya Vijayakumar; Jane Chen, MD; Mitchell N. Faddis, MD, PhD; Bruce Lindsay, MD; and Timothy W. Smith, DPhil, MD.

Saves hours of mapping

The heart, among other things, is an electric marvel. The 25 VT patients were scheduled to undergo catheter ablation to correct their electrical defects, but first underwent ECGI imaging.

The imaging correctly found the VT origin and categorized the two VT mechanisms, one called focal, comprising a mass of abnormal cells, the other re-entry, in which excitation waves become circular, forming a closed loop called a re-entry circuit.

In each mechanism, the heart's pacemaking activity is seized from its natural, normal site in the sinus node. Rudy and his collaborators showed that the abnormal excitation patterns of VT often began in scar tissues that were tell-tale signs of previous heart attacks.

The study is a breakthrough in the analysis and treatment of arrhythmias in general — VT specifically — because it is noninvasive, fast and can map electrical activity on the entire heart surface in one heartbeat.

Current noninvasive diagnosis of heart rhythms relies on the conventional ECG, which employs 12 electrodes on the body surface.

The ECG can only provide general information about the global heart electrical activity. To locate the source of VT in the heart, a patient must endure up to several hours of invasive mapping using an electrode-carrying catheter that is inserted into the heart and moved as a roving probe to obtain sequentially electrical recordings from many points.

Once the arrhythmia source has been located, ablation is performed to eliminate this source and stop the arrhythmia.

In the state-of-the-art protocol, ECGI would far more quickly find the source and type of VT, saving hours of mapping.

In the future, it is hoped that experimental techniques such as gamma knife radiosurgery and high-frequency ultrasound, under study for noninvasive ablation of cardiac tissue, might be used with ECGI, paving the way for total noninvasive treatment of VTs.

'Tool that opens the door'

ECGI can locate the source of cardiac excitation in the heart with an accuracy of about 6 millimeters. In contrast, the conventional ECG provides only global information.

As Rudy explains: "The big difference between the two is that the ECG measures the reflection of the heart's electrical activity far away from the heart on the torso surface. In the process, resolution is lost.

"ECGI gets far closer," Rudy says. "Imagine a car coming toward you at night from far away. You see only one light. But as it gets closer and closer, you start to resolve the two headlights and their location in space. It's similar here. With ECG, you're far on the body surface and get only a global view instead of the real local details on the heart surface.

"ECGI is a treasure for basic medical research. It is a tool that opens the door to study the electrical functioning of the heart and arrhythmia mechanisms in people with various (hereditary and non-hereditary) cardiac disorders.

"Clinically, it is promising as a diagnostic tool that could guide therapy

of cardiac arrhythmias, and because it is noninvasive, it could also be used as a follow-up tool to evaluate progression of the disorder and the results of therapy," Rudy says.

"Someday it might help to identify patients at risk of developing VT, so that preventive measures can be taken before sudden death occurs.

"Nobody can imagine medicine today without noninvasive imaging. If you have a suspicious backache, you often get an MRI. Yet nothing like this has existed for cardiac arrhythmias, which, as our population ages, are becoming more and more common.

"There should be many ECGI revelations and applications in the future."

Provided by Washington University in St. Louis