Noninvasive 3D imaging of electrophysiological activity in the heart

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A novel system for imaging electrical activity in the heart can aid in diagnosis, therapy, and development of new treatment strategies.

Abnormal cardiac electrical activity is the cause and manifestation of many forms of heart disease. The primary noninvasive diagnostic technique for detecting electrical dysfunction remains the electrocardiogram (ECG), which offers limited sensitivity and specificity. To obtain high-resolution data, an electrophysiological study (EPS) can be performed, in which a catheter with electrodes is introduced into the chambers of the heart. But this is invasive, time-consuming, and can be non-diagnostic.

A more recent solution is electrocardiographic imaging (ECGI), a noninvasive modality that provides high resolution three-dimensional images of cardiac electrical activity. ECGI uses multi-site potential measurements and the patient’s heart-torso geometry, derived from computer tomography (CT) images, to provide high-resolution maps. Surface potentials are recorded while the patient is fitted with a multi-electrode vest connected to a multi-channel mapping system. A chest CT scan is used to obtain heart and body surface geometry (Figure 1). Patented computer algorithms generate ECGI images in various useful formats.

Over 30 human studies to date have applied ECGI. A technical report published in Nature Medicine introduced the methodology for clinical use. In another study, ECGI was validated through comparison with recordings of cardiac potentials obtained by placing electrodes in direct contact with the heart during open-heart surgery. These results further substantiated ECGI’s ability to image cardiac electrical activity with high resolution and accuracy. Figure 2 shows close correspondence between electrograms (potential variation at each point on the heart) imaged by ECGI (black) and those directly measured during surgery (red).

ECGI is also able to localize cardiac events, such as the origination of an abnormal heartbeat, with high resolution. Figure 3 shows an ECGI potential map (spatial display of potentials at a particular instant in time) where the abnormal origina-
Figure 2. Validation with direct heart mapping. Directly mapped electrocardiogram measurements (red) compared to ECGI (black). The outline of the heart identifies electrogram locations. RV: right ventricle. LV: left ventricle. AV: atrioventricular.

Figure 3. The ECGI imaging during pacing. Shown is the heart potential map during pacing. The translucent view (left) shows the pacing lead. The opaque view (right) indicates the potential minimum at the pacing site (dark blue, with asterisk). LAD: left anterior descending coronary artery.

Figure 4. A comparison of catheter mapping and ECGI during focal ventricular tachycardia. The left panel shows a map obtained by electroanatomical catheter mapping using the CARTO® system. The right panel shows a noninvasive image obtained by ECGI. White arrows in both panels indicate the origination of the aberrant beat.

tion simulated by pacing is imaged accurately (blue, asterisk) and corresponds nicely to the location of the tip of the pacing wire/lead.

Recently, ECGI was used in a patient to assist the diagnosis and management of ventricular tachycardia. Noninvasive ECGI isochrones (depicting activation sequence) corresponded well with images obtained through invasive electrophysiological study (Figure 4). ECGI also provides insights into the electrical processes in the hearts of patients undergoing cardiac resynchronization therapy for heart failure. It has also been used to characterize normal human cardiac activity.

ECGI may become an essential tool for diagnosing abnormal cardiac electrical activity. It can be used in conjunction with other techniques, such as the electrophysiological study, to make diagnosis more efficient. ECGI could also become a screening tool for early identification and prophylactic treatment of patients at risk for heart disease. This technique can be used to image electrical abnormalities of the heart during arrhythmia, infarction, heart failure and conduction disorders. ECGI is a versatile platform technology that clinicians and researchers could use to gain insights into the underlying mechanisms of these diseases, to increase the efficacy of current therapy, and to promote development of new treatment strategies.

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Dr. Ramanathan has been involved in development of electrocardiographic imaging for the past 10 years. A former research assistant to Yoram Rudy, the chief inventor of ECGI technology, she is currently with CardioInsight Technologies, a company she co-founded to commercialize ECGI.

References


