# The Role of Electrocardiography Today

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## 1. Introduction

The electrocardiography is an old technique born more than one hundred years ago. Augustus Waller published the first human electrocardiographic recording in 1887. In subsequent years, the technique was developed mainly by Einthoven: he invented the string galvanometer, proposed the limb leads and the terminology of the electrocardiographic waves (P, Q, R, S, T).

During the past century the ECG became an indispensable tool for diagnosis and management of patients with varying heart diseases. As pointed out by Fisch [1] the main merit of ECG is to be a non-invasive technique, simple, easily available, reproducible, inexpensive.

Despite the widespread clinical use of electrocardiography, in the last decades the ECG has lost some of its diagnostic importance with the emerging and growing clinical use of newer sophisticated imaging techniques. In fact, anatomic and functional information on several heart conditions (e.g., hypertrophy, location and extension of myocardial infarction, and so on) that in the past were obtained, with various degree of accuracy, almost exclusively by means of electrocardiographic techniques, today can be more precisely and directly obtained by other techniques such as echocardiography, nuclear imaging, magnetic resonance, multislice computed tomography. Nevertheless, still today the ECG provides useful diagnostic and prognostic information in every type of heart disease. It maintains a unique, primary role not only in the field of arrhythmias and conduction disturbances, in which no other technique can provide relevant insights, but also in other clinical settings such as in the ischemic heart disease, particularly during the acute phase.

For the sake of brevity, this presentation will be confined to focus only few most important contributions given by the electrocardiographic technique in the daily cardiology practice and the newer development of ECG imaging.

## 2. Acute Coronary Syndrome

In this field the ECG is essential for classification of acute myocardial infarction on the basis of the presence or absence of ST elevation (the term STEMI is today commonly used by cardiologists) [2] and hence for the treatment. In patients presenting with symptoms of acute myocardial ischemia a rapid decision-making is mandatory. In this situation the ECG provides essential information on the extent and severity of myocardial ischemia. Moreover the continuous ECG monitoring provides “in real time” the evolution of the ischemic/necrotic process. All these data are important for the choice of treatment and specifically for indicating the need of coronary reperfusion procedures.

## 3. Cardiac Arrhythmias and Conduction Disturbances

In supraventricular arrhythmias the ECG often allows the correct identification of different types of tachyarrhythmias (atrial tachycardias, flutter, fibrillation) and their arrhythmogenic substrate (e.g.: ectopic focus, A-V nodal re-entry, accessory AV pathway).

In ventricular tachycardias the ability of the ECG to identify the site of origin of the arrhythmias can be poor in presence of extensive myocardial damage (myocardial infarction, scar), but the localization is easier in idiopathic VT (for instance, aortic or pulmonary root).

In genetic arrhythmias, specifically long and short QT syndromes, Brugada syndrome, catecholaminergic polymorphic VT, right ventricular arrhythmogenic cardiomyopathy, the 12- lead ECG plays a paramount diagnostic and prognostic role.

In conduction disturbances the ECG has obviously a primary role in the diagnosis of the various types of AV and intraventricular blocks, indicating the need of different device implantation. Moreover, today it has become also essential in specific situations, such as in ventricular dysfunction/heart failure for selecting patients who can benefit from cardiac resynchronization therapy (biventricular pacing) and for the optimization of the LV lead position [3].

## 4. Electrocardiografic Markers of Arrhythmias Vulnerability

In addition to the use of ECG for the diagnosis of specific arrhythmias and conduction disturbances, the ECG has gained an important role in the identification of subjects prone to malignant ventricular arrhythmias and sudden cardiac death (SCD), which is still an unsolved problem. In fact, different indices of vulnerability to arrhythmias have been studied, but no marker has proved sufficiently sensitive in predicting high risk. Various methods of analysis of short or long periods of electrocardiographic recordings have been proposed in order to detect information not deducible by the traditional analysis of the standard 12-lead ECG, specifically, signal averaging ECG (ventricular late potentials), T wave alternans, RR/QT relation variations, heart rate variability, heart rate turbulence and others.

Many investigations have focused on the key role of ventricular repolarization abnormalities in the genesis of cardiac arrhythmias. Schematically, vulnerability to arrhythmias can arise from two conditions of repolarization process. 1) Dynamic (beat to beat) variation of repolarization sequence. This condition can be detected exceptionally by visual inspection of routine ECG (for instance in cases of long QT syndrome), because the beat to beat variations of the ST-T waves are usually very subtle (in the order of microvolts) and sophisticated computerized analyses of multiple beats of an ECG tracing have to be used (analysis of T wave alternans,). The prognostic significance of micro T wave alternans was demonstrated by several studies, mainly in patients with ischemic heart disease, and heart failure [4]. 2) State of heterogeneity of repolarization, i.e. a greater than normal dispersion of recovery times. This condition can be detected by analyzing even a single beat, using the 12-lead ECG or body surface potential maps.

Various methods for quantification of repolarization heterogeneity from the standard 12-lead ECG have been proposed: a) QT dispersion: the measurement of 12-lead QT interval dispersion was widely used as an index of repolarization heterogeneity mainly because of its semplicity, but it has several methodological and theoretical limitations, which can explain the controversial results reported in the literature [5]; b) principal component analysis: PCA has been originally applied on body surface potential maps (BSPM) and subsequently also on the 12-lead ECG waveforms. The method defines several independent components, which contain all the information of the T waves of the ECGs recorded; an increased PCA ratio in the 12-lead ECG was reported to be an independent predictor of cardiovascular mortality [6]; c) T wave morphology descriptors: a set of variables has been proposed [7,8], which measure the spatial and temporal variations of T wave morphology, the difference of the mean wavefront direction between ventricular depolarization and repolarization, the non-dipolar component (total cosine R-to-T, spatial QRS-T angle, T wave residuum).

## 5. ECG-Imaging

Beyond the traditional clinical use of 12-lead ECG, it is worth mentioning a new modality of electrocardiology which has been developed and applied in humans in the last decade, called ECG-imaging (ECG-I) [9]. The ECG-I, based on mathematical studies and experimental investigations in animal models started in the seventies of the last century and aimed at the solution of the so called “inverse problem of electrocardiography”, requires 2 sets of data: the electrocardiographic potentials over the entire thoracic surface (BSPM usually from 250 electrodes) and the geometries of the heart and torso surface obtained by a computed tomography (CT). The recorded torso potential and CT-derived geometric information provide the input data for the ECG-I algorithm, which reconstructs on the heart surface electrograms, potential distributions, activation sequences (isochrones) and repolarization patterns. The ECG-I gives also the possibility to identify, with sufficient degree of accuracy, transmural reentry and intramural focal arrhythmias, and to define ischemic or necrotic areas within the myocardium.

Recently improvements to the inverse solution method were made by van Oosterom and coworkers [10].The required computation time and the quality of the results obtained should facilitate the applications of this inverse procedure in a clinical setting.

The ECG-I has been successfully applied in humans in different situations including the normal heart, hearts with conduction disorders, ventricular pre-excitation, focal activation initiated by right or left ventricular pacing, ventricular tachycardias, focal atrial tachycardia, flutter and atrial fibrillation [11,12]. Recently, the ECG-I was used by other research groups in elctrophysiology laboratory to identify in each patient the different mechanisms initiating and maintaining AF (localization of active sources, rotors, re-entry circuits). These findings were validate by endocardial recordings and catheter ablation results [13, 14].

## 6. Conclusion

The ECG, in its second century of life, is still quite “vital”. In fact, the continuing research in the field of electrocardiology has provided new knowledge that gives the possibility, in clinical setting, to gain from the analysis of the 12-lead ECG more information than in the past for the diagnosis and prognosis of various heart diseases.

Moreover the tremendous advance in technology allows to merge electrical information from ECG with anatomic, functional and metabolic information provided by other imaging modalities. This results in new clinical applications enabling an accurate localization of arrhythmias mechanisms, with respect to cardiac anatomy, useful for catheter ablation guidance.

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