General Introduction, Classification, and Electrocardiographic Diagnosis of Cardiac Arrhythmias

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KEYWORDS

• Cardiac electrophysiology • Normal heart rhythm • Electrocardiogram
• Cardiac arrhythmias diagnosis • Laddergram

KEY POINTS

- The electrocardiogram remains the primary instrument for detecting the electrical currents of the heart, both during normal and abnormal cardiac rhythm.
- Different mechanisms are at base of cardiac arrhythmias: impaired conduction, enhanced automaticity, or reentry.
- Electrocardiographic classifications concern the tendency to reduction or increase of the heart rate; well-defined sites of origin are the atria the atrioventricular junction and the ventricles.
- Particular forms of activation detectable both at atrial and ventricular levels are constituted by fibrillation and flutter.
- A rational method of analysis is the construction of the laddergram, a useful tool to make a rational diagnosis and to validate diagnostic hypotheses.

THE NORMAL CARDIAC RHYTHM

The complex apparatus of electrical activation of the heart is based on the presence of specific cardiac structures having the function of generating, conducting, and distributing the electrical signal to the contractile myocardium (**Fig. 1**). The function of generating the electric impulse is deputed to specific ionic channels located in particular cells whose activity is particularly pronounced in the sinus node (primary pacemaker); other cardiac structures, the secondary pacemakers, in "emergency" conditions can show pacemaker activity. The ability to create spontaneous depolarizations decreases as one moves away from the sinus node, and is lowest at the ventricular level.[1–3] The primary pacemaker receives important neurovegetative inputs, which regulate the frequency of depolarization, adapting it to the metabolic needs of the organism. The sinus impulse then spreads to the heart through the conduction system; the internodal tracts connect the sinus node to the atrioventricular node that constitutes the physiologic decelerator essential for optimum adjustment of the electromechanical delay between the atrial and ventricular conduction. Passed the atrioventricular node, the structures of the conduction system show high unidirectional conductive capabilities: the His bundle splits in the right and left branches, the latter with the division in 2

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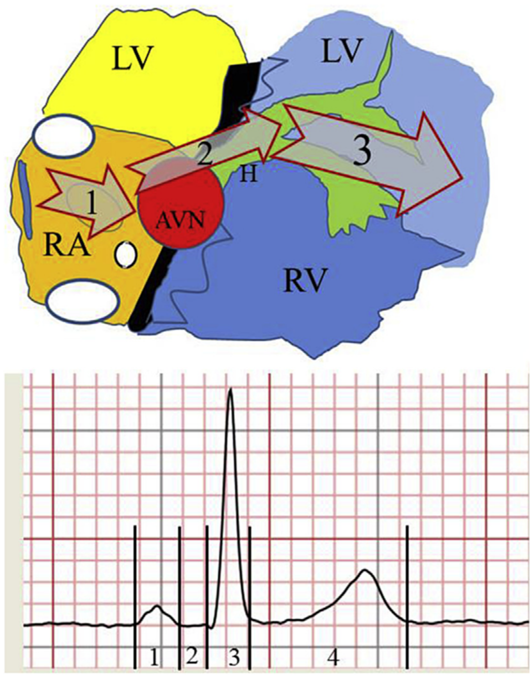

Fig. 1. The conduction system and the normal activation of the heart. 1 = P wave (atrial activation; 2 = PQ tract (junctional conduction); 1 + 2 = PQ interval; 3 = QRS complex (ventricular activation); 4 = ventricular polarization; 3 + 4 = QT interval. AVN, atrioventricular node; AVN + His, atrioventricular junction; His, His, bundle; LA, left atrium, LV, left ventricle; RA, right atrium; RV, right ventricle.

fascicles (anterior and posterior); this trifascicular activation of the Purkinje system optimizes the contraction of the ventricles.

THE ELECTROCARDIOGRAPH AS A TOOL FOR DETECTION OF THE ELECTRICITY OF THE HEART: "CONDUCTION" AND "CONTRACTION" CURRENTS

In the heart, there are essentially 2 types of structures producing electrical currents: the conduction system and the contracting myocardium (atrial and ventricular).The cardiac conduction system, with sophisticated structures that depart from the upper part of the right atrium and arrive to the ventricles, produces currents of very low intensity, infinitesimally smaller than the ordinary atrial and ventricular myocardium.

The electrocardiogram (ECG) begins from the historical observations of the ability to detect the electrical currents transmitted from the heart to the body surface.[4,5] This is a process of conduction through which the currents are dispersed in a considerable manner, because it is possible to record from the body surface only about 1% of the currents produced at the level of the heart. The conventional ECG is therefore a very weak system for the study of the currents of the heart; this difficulty that seems to be inherent to the method, remains unchanged in time, and does not seem to be overtaken by the various technological advancements, including digital acquisition.[6]

The surface ECG is, therefore, characterized by a series of methodologic difficulties that we can synthetically summarize in dispersion of electrical charges to the body surface, fusion of the currents produced by various structures, and morphology of the signals.

Dispersion of Electrical Charges to the Body Surface

The standard ECG is able to record only the electrical activity of the big myocardial masses, that is, the atria and the ventricles. Thus, the cardiac conduction system is absolutely not recordable from the body surface.

Fusion of the Currents Produced by Various Structures

The diffusion of electric charges of different structures leads to the merging of their currents with consequent formation of signals of summation of the original electrical phenomena: depolarization of the various parts of the atria will give the P wave, the "trifascicular" depolarization of the ventricles will generate the QRS, the repolarization of the ventricles will produce the QT. If the fusion phenomenon of the various currents produced by the heart is not problematic in the course of normal cardiac activation (because the signals themselves are clearly discernible from one another), during an arrhythmia, electrical events from different cardiac chambers change their temporal sequence, and overlap each other; this phenomenon represents a true interpretative difficulty in the diagnosis of cardiac arrhythmias (Fig. 2).

Morphology of the Signals

The slope of the recorded signals is an expression of the amount of current in the unit of time, and therefore will be low for the atria (rounded morphology with low amplitude) and high for the ventricles (the QRS components; Fig. 3). Considering the repolarization signals, they move in the opposite direction the same amount of electrical charges of the depolarization, but in a much longer time. This causes the almost complete disappearance of the signals of atrial repolarization and the formation of rounded shape signals of ventricular