The QRS Complex
Normal Activation of the Ventricles

Giuseppe Bagliani, MD[a,b,*], Roberto De Ponti, MD, FHRS[c], Carola Gianni, MD, PhD[d], Luigi Padeletti, MD[e,f]

KEYWORDS

• QRS complex • Ventricular conduction system • Bundle branch block • Ashman phenomenon

KEY POINTS

- The ventricular conduction comprises the right and left bundle branches and the Purkinje network.
- The ventricular conduction system is responsible for the synchronized and almost simultaneous activation of both ventricles.
- The QRS complex is determined by the electrical currents originating from ventricular depolarization.
- Any change in the normal ventricular activation sequence determines a delay that produces a wide QRS on the surface electrocardiogram, usually secondary to delay or block in one of the 2 branches.
- The Ashman phenomenon is a kind of functional aberrant conduction that occurs after a long-short cycle.

INTRODUCTION

The currents generated by ventricular depolarization (when transmitted to the body surface) generate the QRS complex, a sequence of high-amplitude waves visible on the 12-lead electrocardiogram (ECG). The well-ordered sequence of the QRS waves is caused by the synchronized electrical activation of the myocardium driven by the ventricular conduction system. The primary function of the ventricular conduction system is to synchronize the segmental activation of the ventricles, optimizing energy demand. In a normal heart, the ventricular contraction starts at the apex of the heart and moves with a twisting motion to the side walls, reaching the base of the heart, ensuring that blood is directed toward the outflow tracts of the 2 ventricles using the least amount of energy.

THE VENTRICULAR CONDUCTION SYSTEM

The ventricular conduction system starts below the His bundle, where it bifurcates into the 2 bundle branches (right and left) that taper out to the subendocardial Purkinje network, which in turn activates the ventricular myocardium. Although the bundle of His divides into 2 branches, it is normal to consider the ventricular conduction as a trifascicular system, because the left bundle branch subdivides into 2 fascicles (anterior and posterior), which are anatomically distinct and activate the left ventricle simultaneously from 2 areas, optimizing the ventricular contraction. In contrast,

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[a] Arrhythmology Unit, Cardiology Department, Foligno General Hospital, Via Massimo Arcamone, 06034 Foligno (PG), Italy; [b] Cardiovascular Diseases Department, University of Perugia, Piazza Menghini 1, 06129 Perugia, Italy; [c] Cardiology Department, University of Insubria, Via Ravasi, 2, 21100 Varese, Italy; [d] Texas Cardiac Arrhythmia Institute, St. David's Medical Center, 3000 N IH 35, Ste 700, Austin, TX 78705, USA; [e] Heart and Vessels Department, University of Florence, Largo Brambilla, 3, 50134 Florence, Italy; [f] IRCCS Multimedica, Cardiology Department, Via Milanese, 300, 20099 Sesto San Giovanni, Italy
* Corresponding author. Cardiovascular Diseases Department, University of Perugia, Piazza Menghini 1, 06129 Perugia, Italy.
E-mail address: giuseppe.bagliani@tim.it

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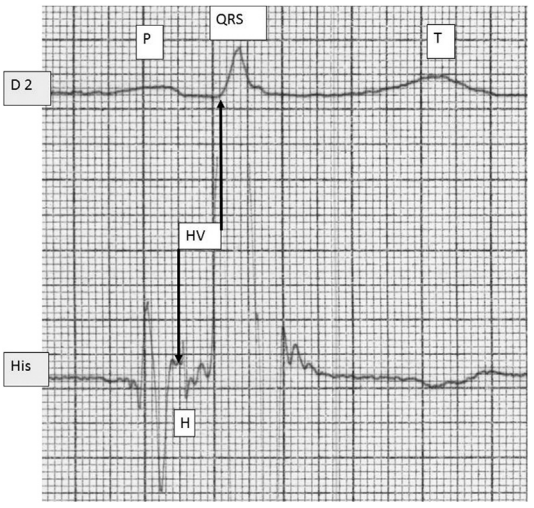

Fig. 1. His potential (H) (*arrow*) and HV interval.

the right bundle branch does not have functionally or anatomically distinguishable pathways and it is considered a single fascicle. The trifascicular system activates the Purkinje network, a subendocardial plexiform layer of dense intramural branches able to finely activate the small corresponding segmental myocardial segments. For this reason, under normal conditions, the myocardium is activated from the endocardium toward the epicardium.

The electrical activation of the ventricular conduction system produces very low amplitude currents that cannot be detected on the surface ECG, and the QRS comprises electrical currents originating from the contractile myocardium. Activation of the ventricular conduction system lies in the terminal portion of the PR interval, and can be detected only by intracardiac recordings: electrodes positioned at the level of the atrioventricular junction can record activation of the His bundle (His potential; Fig. 1), and the interval between the recording of His bundle electrogram and the beginning of the QRS (the so-called HV interval) represents the activation of the ventricular conduction system.

THE NORMAL QRS

The QRS complex represents ventricular depolarization, the electrical activation of the myocardial mass. Normal ventricular depolarization is a rapid process, and the subsequent QRS complex comprises electrical signals of high amplitude and steep slope, with a duration between 80 and 110 milliseconds. The nomenclature of the QRS refers to the sequence of deflections seen in lead I: the Q wave is the first negative wave placed at the beginning of the QRS, the R wave is the first positive deflection, whereas the S wave is the terminal negative deflection. Activation of the various ventricular myocardium segments does not take place simultaneously but according to a precise temporal sequence such as that depolarization starts from the apical portion of the interventricular septum and continues toward the side walls up to the base of the ventricles. This complex process of activation determines 3 successive activation fronts, each represented by a distinct electric vector, contributing to the overall morphology of the QRS complex (Fig. 2):

- The first vector (activation of the apical portion of the interventricular septum) is directed from left to right, has a duration of less than

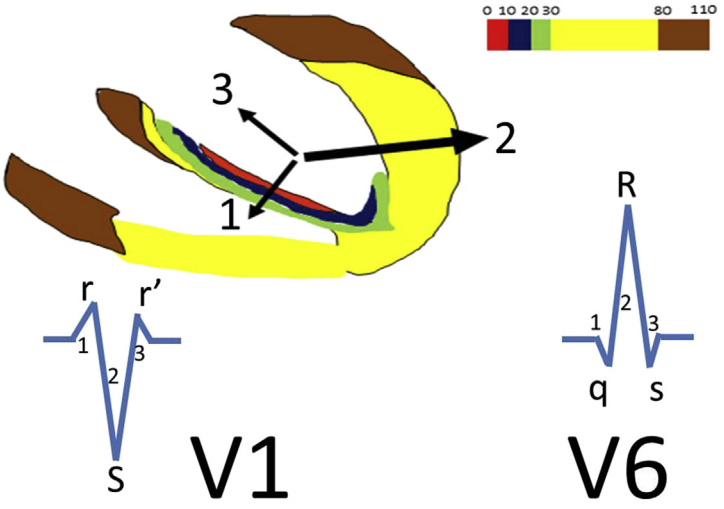

Fig. 2. Vectorial determinants of the QRS complex.