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Evaluation of R-wave offset in the left chest leads for estimating the left ventricular activation delay: An evaluation based on coronary sinus electrograms and the 12-lead electrocardiogram

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Abstract

Background: The QRS duration does not always reflect the left ventricular (LV) activation delay in patients with ventricular conduction disturbances. The R-wave offset in left chest leads may more closely reflect the LV activation delay than the QRS offset.

Methods: We evaluated 138 cases with left bundle branch block (LBBB, $n = 11$), right BBB (RBBB, $n = 38$), non-specific intraventricular conduction disturbance ($n = 11$), narrow QRS (<120 ms, $n = 56$) and right ventricular pacing ($n = 22$). Cases with right axis deviation (120 to 270 degrees) were excluded. The intervals from the QRS onset to the V-waves in coronary sinus bipolar electrograms (QCS) were measured, and the longest interval was defined as the QCSmax. In the 12-lead electrocardiogram, the interval from the QRS onset to the R-wave offset (QR) was measured and then averaged in leads I–aVL, II–III–aVF, V1–V2, V3–V4 and V5–V6.

Results: Significant correlations ($p < 0.05$) were found between QCSmax and QR in I–aVL ($r = 0.83$), II–III–aVF ($r = 0.51$) and V5–V6 ($r = 0.86$) in cases with a normal axis (0 to 90 degrees, $n = 64$); and I–aVL ($r = 0.90$), II–III–aVF ($r = 0.31$) and V5–V6 ($r = 0.69$) in cases with left axis deviation (−45 to −89 degrees, $n = 52$). Overall, the QRS duration was also correlated with QCSmax ($r = 0.72$, $p < 0.001$); however, this correlation was weaker than the correlation between QCSmax and QR in I–aVL ($r = 0.89$, $p < 0.001$) due to disparities in RBBB ($p < 0.001$).

Conclusions: The interval from the QRS onset to R-wave offset in the left chest leads reflects the degree of LV activation delay regardless of differences in QRS duration and morphology.

Keywords: 12-Lead ECG; Bundle branch block; Conduction disturbance; QRS duration

Introduction

Criteria for defining left bundle branch block (LBBB) that include a wide QRS duration and the presence of mid-QRS notching/slurring allow for a clear distinction between true LBBB and an LBBB-like pattern, which may not be associated with actual impaired conduction in the left bundle [1]. A large activation delay between the interventricular septum and left ventricular (LV) free wall is observed in patients who satisfy the criteria for true LBBB [2]. On the other hand, QRS waveforms in patients with right bundle branch block (RBBB) or non-specific intraventricular conduction disturbances (IVCD) are highly variable and their QRS duration does not necessarily reflect the degree of left ventricular (LV) activation delay. Therefore, it may be useful if the LV activation delay can be estimated from the 12-lead electrocardiogram (ECG). In this study, we evaluated coronary sinus (CS) electrograms and the 12-lead ECG to test the hypothesis that the interval from QRS onset to R-wave offset in left chest leads may reflect the degree of LV activation delay regardless of differences in QRS duration and morphology.

Methods

Subjects

Subjects included 123 arrhythmia patients who had CS bipolar electrograms recorded in an electrophysiological study (EPS). We evaluated 138 CS electrograms in these patients. Fifteen patients had evaluations during both their

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Table 1
Patient characteristics.

Patients (n = 123)	
Age (years)	67 ± 12
Male/Female (*n*)	97/26
Structural heart disease (*n*)	15 (12%)
DCM 5, OMI 4, VHD 4, HCM 2	
LV EF (%)	61 ± 11
LV diastolic diameter (mm)	49 ± 8
LA diameter (mm)	38 ± 7
QRS morphology (total 138 cases) and QRS duration	
LBBB (*n* = 11)	155 ± 23 ms
RBBB (*n* = 38)	140 ± 13 ms
IVCD (*n* = 11)	132 ± 9 ms
RV pacing (*n* = 22)	159 ± 19 ms
Narrow QRS (*n* = 56)	94 ± 10 ms

DCM: non-ischemic dilated cardiomyopathy, OMI: old myocardial infarction, VHD: valvular heart disease, HCM: hypertrophic cardiomyopathy, LV: left ventricle, EF ejection fraction, LA: left atrium, LBBB: left bundle branch block, RBBB: right bundle branch block, IVCD: non-specific intraventricular conduction disturbance, RV: right ventricle.

intrinsic beats and right ventricular (RV) paced beats. The patients' characteristics are shown in Table 1. Patients who had suffered from myocardial infarction within 6 months before the EPS were excluded. We also excluded cases with right axis deviation (RAD) (120 to 270 degrees) and cases in which it was difficult to determine the latest V-wave in the CS electrogram due to low voltage or failure to place the CS electrode at a deep enough position in the CS. The study protocol was approved by the institutional ethics committee and written informed consent was obtained from each of the patients.

Twelve-lead electrocardiogram

In the 12-lead ECG, the interval from the QRS onset to the R-wave offset in each lead (QR) and the QRS duration were measured automatically (Cardiofax V, Nihon Kohden, Tokyo, Japan). The QRS onset was determined as the earliest deflection of the QRS complex in 12 leads. The R-wave offset was defined as the intersection between the descending limb of the R-wave and baseline (Fig. 1). In cases with an R′-wave, QR was determined as the interval from the QRS onset to R′-wave offset. The QR was averaged in lead sets that included I–aVL, II–III–aVF, V1–V2, V3–V4 and V5–V6. The QRS morphology was classified as LBBB, RBBB, IVCD, narrow QRS (QRS duration <120 ms) or RV paced rhythm (RVP) according to previously determined morphological criteria [3]. The QRS axis was defined as normal (0 to 90 degrees) or left axis deviation (LAD) (−45 to −89 degrees).

Coronary sinus electrograms

A 5 F 10-pole catheter with a 4- or 5-mm interval between electrodes (Inquiry, Steerable Diagnostic Catheter, St. Jude Medical, Minnetonka, MN, USA) was positioned in the CS via the right jugular vein. The interval from the QRS onset to the major positive peak of the V-wave in each CS electrogram (QCS) was measured using the cursor on a computer screen (EP Work Mate, St. Jude Medical, Saint Paul, MN, USA). QCSmax was defined as the longest QCS interval found (Fig. 1). The location of the QCSmax was determined in the left anterior oblique (LAO) view (Fig. 2) [4–6].

Statistics

The data are presented as the mean ± SD. Categorical parameters were compared using a chi-square analysis. The

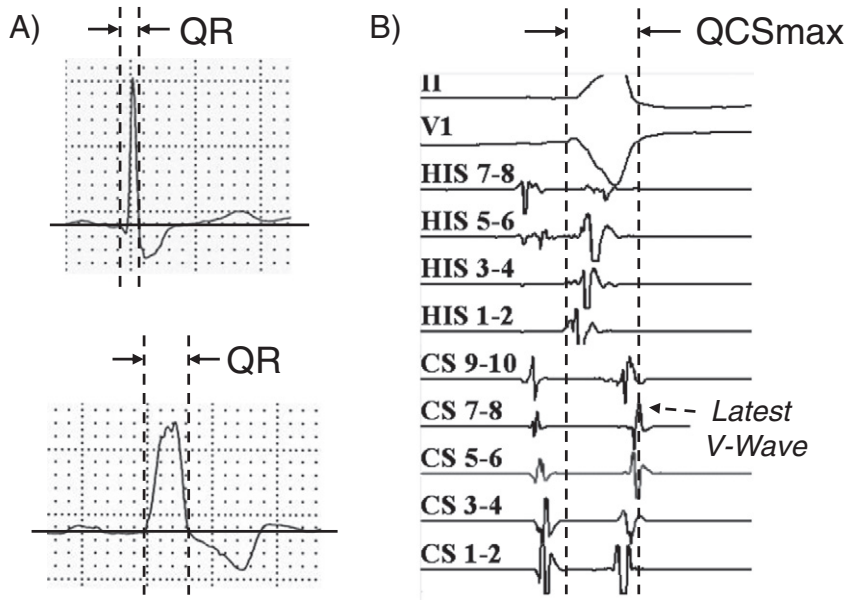

Fig. 1. (A) Measurements of the interval from the QRS onset to R-wave offset (QR). The R-wave offset was determined as the intersection between the descending limb of the R-wave and baseline. (B) Evaluation of the V-wave in the coronary sinus (CS) bipolar electrograms. A 5 F 10-pole electrode with an interval of 4 or 5 mm between electrodes was positioned in the CS. The electrodes are numbered from #1 (distal) to #10 (proximal). The waveform of CS 1–2 is a bipolar electrogram recorded between the #1 and #2 electrodes. The interval from the QRS onset to the major positive peak of the V-wave in each CS electrogram (QCS) was measured. QCSmax was defined as the longest QCS interval found.