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Original article

Association between right ventricular systolic function and electromechanical delay in patients with right bundle branch block

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ABSTRACT

Background: Elevated right ventricle (RV) pressure and/or volume can place stress on the right bundle branch block (RBBB) and its associated Purkinje network, which can affect its electrical properties, resulting in conduction delay or block. We hypothesized that prolonged R′ wave duration in lead V1 would extend the later portion of the QRS complex and can act as an indicator of reduced RV function in patients with RBBB.

Method: Kosin University Gospel Hospital echocardiography and electrocardiography (ECG) database was reviewed to identify patients with complete RBBB between 2013 and 2015. ECGs recorded closest to the time of the echocardiography were carefully reviewed, and QRS and R′ wave duration were measured. RV systolic dysfunction was defined as an RV fractional area change (FAC) less than 35%, as indicated by echocardiography guidelines.

Results: Compared to patients with normal RV function ($n = 241$), patients with RV dysfunction ($n = 123$) showed prolonged QRS duration (145.3 ± 19.3 ms vs. 132.2 ± 13.4 ms, $p < 0.001$), predominantly due to R′ prolongation (84.8 ± 13.0 ms vs. 102.9 ± 12.0 ms, $p < 0.001$). R′ duration was significantly associated with RV FAC ($r = -0.609$, $p < 0.001$), RV systolic pressure ($r = 0.142$, $p = 0.008$), RV dimension ($r = 0.193$, $p < 0.001$), and RV myocardial performance index ($r = 0.199$, $p < 0.001$). On receiving operator characteristic curve analysis, V1 R′ duration ≥93 ms was associated with RV dysfunction with 90% sensitivity and 87% specificity (area under the curve: 0.883, 95% confidence interval = 0.845–0.914, $p < 0.001$).

Conclusion: Prolonged R′ wave duration in lead V1 is an indicator of RV dysfunction and pressure and/or volume overload in patients with RBBB.

Introduction

The right bundle branch is a rapidly conducting pathway consisting of Purkinje fibers that travel in the sub-endocardium of the right ventricular (RV) septum. Altered hemodynamics of a failing RV can place stress on the right bundle branch and Purkinje network, which can present as a conduction delay or block on electrocardiography (ECG). Right bundle branch block (RBBB) is a common ECG finding in emergency department patients, often noted incidentally and thus without clinical import; conversely, it can be encountered in the early phase of significant cardiovascular dysfunction [1]. Several studies of patients with RBBB have shown that otherwise healthy individuals did not experience increased mortality or morbidity [2,3], and RBBB was not considered to be nocuous. However, contrary to common perception, RBBB in asymptomatic individuals has been associated with increased cardiovascular risk and all-cause mortality [4]. Moreover, studies have shown that the prognosis of patients with acute myocardial infarction and RBBB on admission remains poor compared to patients who do not have bundle branch block [5,6].

Because RBBB leads to delayed onset of depolarization of the regional RV with prolongation of total RV activation [7] it results in a late opening of the pulmonic valve and delayed ejection of the RV, which can impact RV function [8]. However, there are few studies on the relationship between RV electromechanical dyssynchrony induced by RBBB and RV systolic function. With worsening RV electromechanical coupling, conduction across the RV myocardium is

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expected to become delayed and can be detected as R′ (the later portion of the QRS complex) prolongation on surface ECG. A recent study showed that prolonged R′ duration in lead V1 was an indicator of RV dysfunction in patients with RBBB [9]. We aimed to investigate the association between R′ duration in lead V1 and echocardiographic RV functional parameters in patients with RBBB.

Methods

Study design

This cross-sectional, observational, correlative study included 364 consecutive patients with complete RBBB who underwent ECG and echocardiography at Kosin University Gospel Hospital from 2013 to 2015. RBBB was defined as a QRS with a duration ≥120 ms in a majority of beats in any of leads I, II, III, aVL, or aVF, plus R′ > R in leads V1 or V2 [10]. Exclusion criteria for the control group included bifascicular block, reduced left ventricular (LV) ejection fraction (EF < 50%), RV infarction, LBBB, or congenital heart disease. Subjects with a paced rhythm or prior tricuspid valve surgery were also excluded. ECGs and echocardiographies were reviewed independently by two investigators in a blinded fashion. Then, ECG features of RBBB were compared between patients with echocardiographic impression of RV systolic dysfunction and those with normal RV systolic function. Demographic and comorbidity data were obtained from medical records. Classic cardiovascular risk factors were considered in this study, in addition to the epidemiologic variables of age and sex. Hypertension was defined as systolic blood pressure (BP) >140 mmHg or diastolic BP >90 mmHg by repeated BP measurement or previous diagnosis; diabetes mellitus (DM) was defined as fasting plasma glucose level ≥126 mg/dL in 2 consecutive assessments or currently undergoing treatment for DM. The presence of dyslipidemia was assumed if subjects were taking lipid-lowering drugs or had high cholesterol level. This study was approved by the Institutional Review Board of Kosin University College of Medicine.

Electrocardiographic design measuement

ECGs recorded closest to the time of echocardiography were carefully reviewed, and QRS and R′ wave duration were measured. All ECG measurements were performed using MUSE Editor software version 7.1.1 (General Electric Company, Fairfield, CT, USA). This software provides an electronic caliper tool that is accurate to 4 ms. Specific measurements included QRS duration, R′ wave duration, and R′:QRS duration ratio in lead V1. A sample of the ECG measurements performed is illustrated in Fig. 1.

Echocardiographic measurement of RV function

Standard two-dimensional echocardiography was performed on all subjects, lying in the left lateral decubitus position, using a 3.5-MHz transducer (Philips iE33, Philips Medical Systems, Bothell, WA, USA), and the echocardiography examiners were blinded to patient information. Two-dimensional and Doppler analyses were conducted according to the recommendations of the American Society of Echocardiography (ASE) [11]. The maximal tricuspid regurgitation velocity (TR Vmax; in m/s) was obtained from continuous-wave Doppler of the TR signal (Fig. 2A). The Doppler-derived pulmonary artery systolic pressure (PASP; in mmHg) was calculated from the maximal TR Vmax using the simplified Bernoulli formula as follows: PASP = 4 × (TR Vmax)^2 Study + right atrial (RA) pressure (RA pressure was determined according to diameter and collapse of inferior vena cava, as recommended by ASE guidelines). Mean pulmonary arterial pressure (mPAP) was calculated by tracing the TR time–velocity integral plus RA pressure. Pulmonary hypertension (PH) was defined as a mPAP of at least 25 mmHg. RV function was measured using tricuspid annular plane systolic excursion (TAPSE), RV MPI, and RV fractional area change (FAC). TAPSE was acquired by placing an M-mode cursor through the tricuspid annulus on the apical 4-chamber view and measuring the distance of longitudinal motion in peak systole (Fig. 2B). To calculate RV MPI, isovolumetric contraction time (ICT), isovolumetric relaxation time (IRT), and ejection time derived from pulsed wave Doppler imaging data were obtained at the tricuspid inflow and RV outflow, and the RV MPI was defined as the sum of ICT and IRT divided by ejection time. RV FAC was measured by tracing the RV endocardium in both systole and diastole (Fig. 2C). RV systolic dysfunction was defined as RV FAC < 35%, as indicated by echocardiography guidelines.

Statistical analysis

Statistical analyses were performed with the commercially available computer program SPSS 18.0 for Windows (SPSS Inc., Chicago, IL, USA). Data are presented as mean ± standard deviation for continuous variables and percentage (%) if the data are categorical. Data in the text and tables are expressed as mean ± SD. The Mann–Whitney *U* test was used for categorical data, and the Chi-square test was used for continuous variables. The normality of the data was

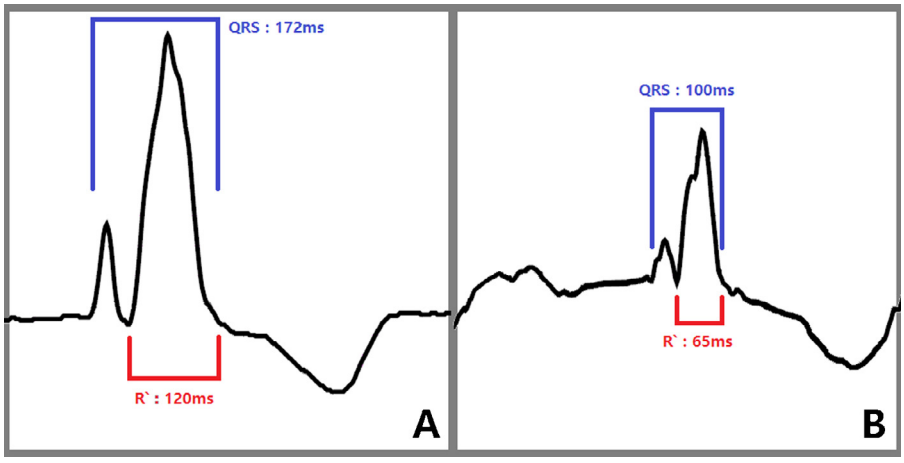

Fig. 1. Representative samples of electrocardiographic measurements from the patient with or without right ventricular (RV) dysfunction. The QRS complex was 172 ms length, R′ duration was 120 ms (patient with RV fractional area change = 12.8%) (A). The QRS complex was 100 ms length, R′ duration was 65 ms (patient with RV fractional area change = 48.8%) (B).

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