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# A larger vectorcardiographic QRS area is associated with left bundle branch block and good prognosis in patients with cardiac resynchronization therapy☆

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ABSTRACT

*Background:* The association between the vectorcardiographic QRS area, bundle branch pattern and clinical long-term prognosis in patients who have undergone cardiac resynchronization therapy (CRT) has been unclear.
*Methods:* We enrolled 50 consecutive patients who underwent CRT. Vectorcardiograms were constructed from preprocedural digital 12-lead electrocardiograms using the inverse Dower method. The vectorcardiographic QRS area was defined as the root of the sum of the square in the integral between the ventricular deflection curve and the baseline from QRS beginning to end in leads X, Y, and Z. The primary endpoints were total mortality and admission due to heart failure.
*Results:* The vectorcardiographic QRS area in left bundle branch block (N = 13), right bundle branch block (N = 13), interventricular conduction delay (N = 11) and pacemaker rhythm (N = 13) were 218 ± 99, 97 ± 44, 90 ± 40, and 131 ± 58 μVs, respectively (ANOVA p < 0.001). During the mean follow-up period of 28 (2–86) months, 13 primary endpoints occurred. We divided patients into two groups: a large QRS area group (QRS area ≥114 μVs, N = 25) and a small QRS area group (QRS area <114 μVs, N = 25) by the median. The large QRS area group had a significantly lower rate of the primary endpoint compared with that of the small QRS area group (log rank 4.35, p = 0.037). The Cox regression analysis revealed that a QRS area <114 μVs was a significant predictor of the primary endpoint (HR 3.98, 95% CI 1.01–15.63, p = 0.048).
*Conclusions:* A larger preprocedural vectorcardiographic QRS area was associated with left bundle branch block and good prognosis in patients who underwent CRT.



## Introduction

Cardiac resynchronization therapy (CRT) is useful to improve cardiac function due to its improvement of left ventricular dyssynchrony in heart failure patients [1–3]. However, 30% of patients do not respond to CRT [3]. Left ventricular dyssynchrony is evaluated by echocardiography, but it is difficult to accurately predict CRT non-responders from the degree of left ventricular dyssynchrony evaluated by echocardiography [4]. The prolongation of QRS duration is associated with the degree of dyssynchrony, and no proven benefit has been demonstrated with narrow QRS duration [5,6]. Therefore, in the current guidelines for CRT implantation, a wide QRS on the 12-lead electrocardiogram (ECG) is one of the main criteria for performing the procedure [7].

The improvement of cardiac function of CRT was mainly due to an improvement of left ventricular dyssynchrony. Thus, patients with left bundle branch block (LBBB) responded well to CRT, even among patients with narrow QRS duration, while many patients without LBBB fail to respond to CRT [8–10]. Recently, increases in the vectorcardiographic (VCG)-QRS area have been identified with left ventricular conduction delay, LBBB [11], and associated with response to CRT [12].

However, the association between the QRS area, other ventricular conduction disturbances, the mortality and prognosis of heart failure remains unclear. The aim of this study was to evaluate the association between the QRS area, bundle branch block pattern and clinical long-term prognosis in Japanese patients who underwent CRT.

## Methods

We enrolled 50 consecutive patients who underwent CRT. All patients had medically refractory heart failure, and all had appropriate

☆ The authors declare that there are no conflicts of interest related to this study.

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indications for CRT in accordance with the guidelines of the Japanese Circulation Society [13].

We conducted a preprocedural 12-lead ECG before CRT implantation (Fukuda Denshi Co., Tokyo, Japan). We extracted the dominant QRS wave (8 leads: I, II, and V1 to V6), and calculated III, aVR, aVL, and aVF. Then the start and end point of the minimum change of amplitude at the start and end of QRS (Fukuda Denshi, TG version) were determined automatically, and finally VCGs were converted using the inverse Dower method (Fig. 1) [14]. In the coronal plane, by using the X and Y leads, and in the axial plane, by using the X and Z leads, each electrogram was plotted at 2 ms intervals from the start to the end of QRS (Fig. 1). The QRS area on VCG was defined as the root of the sum of the square in the integral between the ventricular deflection curve and the baseline from QRS beginning to end in leads X,Y, and Z according to past reports [11,12] (Fig. 1).

Right bundle branch block (RBBB), LBBB, and intraventricular conduction delay (IVCD) were defined according to criteria approved by the World Health Organization [15].

The primary endpoints were total mortality and admission due to heart failure. The determination that a primary endpoint had occurred was made after review of the patient's medical records by cardiologists.

The institutional review board of the Jichi Medical University School of Medicine approved this study. Informed consent for the study was obtained from all of the subjects.

*Statistical analysis*

Data are shown as the mean ± SD or as a percentage. Comparisons between groups were performed using the chi-square test of independence for categorical variables and unpaired *t*-test for continuous variables. The differences in QRS area and QRS duration were assessed by Tukey analysis. Receiver-operating characteristic curve analysis was performed to assess the cutoff values that predicted the primary endpoints. The optimal cutoff threshold of the QRS area was determined by the Youden index, which is represented as the maximum sensitivity plus specificity minus 1. We divided the 50 patients into a large QRS area group (QRS area ≥114 μVs, N = 25) and a small QRS area group (QRS area <114 μVs, N = 25) by a cut-off level based on the median in this study. Cumulative incidences of the primary endpoint were plotted as Kaplan-Meier curves, and the differences were assessed by the log-rank test. The hazard ratio (HR) and 95% CI of incidences of primary endpoint in the two groups according to QRS area were calculated using Cox regression analyses after adjustments for age, gender, hypertension, diabetes, dyslipidemia,

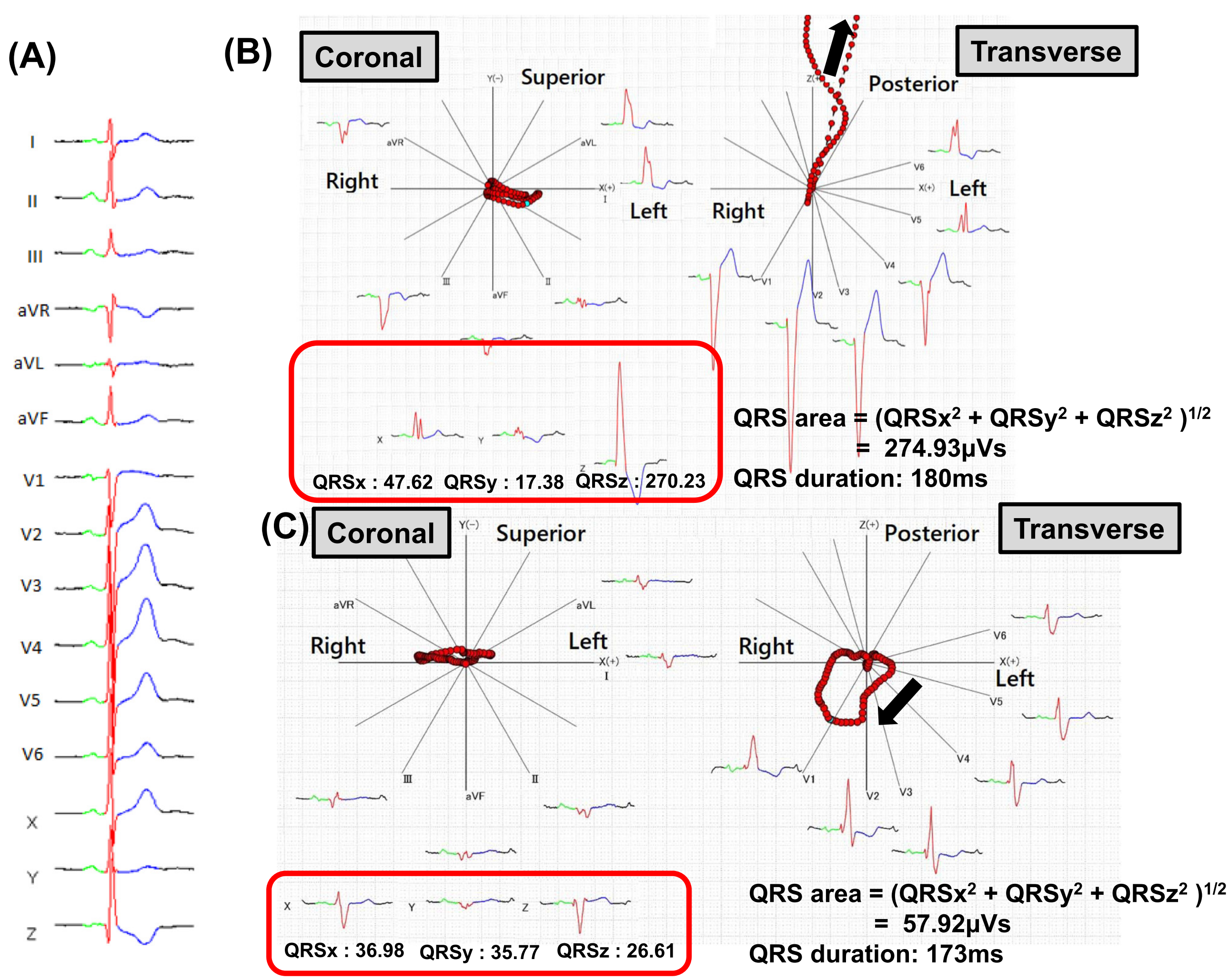


**Fig. 1.** An analysis of vectorcardiography. (A) The start and end of the QRS. Red lines represent the QRS portion in the individual electrograms. (B) A case with left bundle branch block, (C) a case with right bundle branch block. The red line in each electrocardiogram shows the QRS portion in each lead. Red dots represent the individual electrograms, which were plotted every 2 ms from the start of QRS to the end of QRS using X and Y leads in the coronal plane and X and Z leads in the transverse plane. Black arrow in each electrocardiogram shows the direction of ventricular excitation. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)