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Original Research Article

Electromechanical delay in right bundle branch block: suggestive predictor of right ventricular systolic function

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ABSTRACT

Background: RV dysfunction is a powerful predictor of prognosis in cardiopulmonary diseases. Recognition of RV dysfunction is clinically important, because impairment of RV systolic function is independently associated with adverse outcomes. ECG may serve as a simple tool for detection of underlying RV dysfunction in patients with RBBB.
Methods: Patients with complete RBBB (n=225) who underwent ECG and echocardiography were screened from May 2017 to Jan 2019. Demographic, comorbidity data, ECGs and echocardiography were obtained. QRS and R' duration was measured. RV dysfunction was defined by RV FAC<35%, TAPSE<17 and RV TEI Index>0.54.
Results: As compared to normal RV function, patients with RV dysfunction showed reduced TAPSE and RV FAC and increased RV systolic pressure, RV dimension and RV myocardial performance index (all p<0.05). The R′ duration was significantly associated with RV FAC (r=-0.615, p<0.001), RV systolic pressure (r=0.138, p=0.008), RV dimension (r=0.189, p<0.001) and RV Myocardial Performance Index (r=0.190, p<0.001). On ROC curve analysis, V1R′ duration>100 ms was associated with RV dysfunction with 40% sensitivity and 90% specificity (AUC: 0.883; p<0.001). Lead V1 QRS duration>137 ms and the ratio of R′:QRS duration was also useful for predicting RV dysfunction (all p<0.001).
Conclusions: In patient with RBBB, the electromechanical delay has a correlation with RV systolic dysfunction. R′ prolongation in lead V1 can be a useful marker to determine the presence of underlying RV dysfunction as a non-expensive tool.

Keywords: Electromechanical delay, Right bundle branch block, Right ventricular systolic function, TAPSE

INTRODUCTION

Right ventricular (RV) dysfunction is a powerful predictor of prognosis in cardiopulmonary diseases. Recognition of RV dysfunction is clinically important, because impairment of RV systolic function is independently associated with adverse outcomes. Elevated RV pressure and/or volume may affect electrical properties of right bundle branch, which results in conduction delay or block, manifesting as increased QRS duratio.[1] Right bundle branch is a part of the myocardial conduction system relaying impulses from the HIS bundle to the RV myocardium via Purkinje network. This rapidly conducting pathway consists of fibres traversing the sub-endocardium. Right bundle branch block (RBBB) is a common electrocardiographic (ECG) which can be seen incidentally in normal individuals.[1,2] The common causes of RBBB include hypertension, cor-pulmonale, coronary artery disease, congestive heart failure, degenerative conduction system disease and structural heart disease.[3,4]

Previously thought to be innocuous, RBBB has been lately associated with increased mortality in cardiovascular disorders. Recent 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.[3] In the presence of RBBB, there occurs a delayed onset of depolarization of the RV leading

to a prolongation of total RV activation further culminating in a late opening of the pulmonic valve. This leads to a delayed ejection of the RV which can have an impact RV function.[5] CMR is now considered to be the gold standard for RV function evaluation with a recent study having shown the correlation of RBBB with RV function.[6] A recent study highlighted that there was an inverse relation of QRS width with RV function appreciated on CMR.[6] However, CMR is a costly investigation which is also not available everywhere and is a time consuming procedure hence, not feasible in emergency situation in sick patients. Echocardiography based RV function evaluation have been performed by various parameters such as TAPSE (tricuspid annulus plane systolic excursion), RVFAC (right ventricular fraction area change), TDI based RVMPI (right ventricular myocardial performance index) in different clinical trials. RV function prediction improves with addition of these parameters in comparison to single parameter used alone.[7] ECG which being an inexpensive investigation with a widespread availability makes it easier to correlate parameters such as QRS duration,R' duration in RBBB with RV Function. There have been a few studies on the relationship between RV electromechanical dyssynchrony induced by RBBB and RV systolic function.[3] As there is worsening of RV electromechanical coupling, there is a delayed conduction across the RV myocardium and this reflected as R0 (the later portion of the QRS complex) prolongation on surface ECG. This study envisages to determine the association between R0 duration in lead V1 and echocardiographic RV functional parameters in patients with RBBB.

METHODS

Study design

This cross-sectional, observational study included 225 consecutive patients aged 18 years and above with complete RBBB who underwent electrocardiogram (ECG) and Echocardiography in the Department of Cardiology, SMS Medical College and associated hospitals. Complete RBBB was defined based on the presence of all of these criterion: (I) QRS duration>120 msec; (II) rsr', rsR' or rSR' pattern in V1 or V2; (III) Duration of S wave>duration of R wave or greater than 40 msec in leads I and V6. Exclusion criteria 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.[8]

Demographic and comorbidity data were obtained from the medical record. Classic cardiovascular risk factors were considered in this study, in addition to the epidemiologic variables of age and sex. ECGs recorded closest to the time of the 2D echocardiogram were carefully reviewed for all patients. All ECG measurements were performed using EP Calipers software (EP Studios Inc, Poland). The software provides an electronic caliper tool that is accurate to 4 ms. Specific measurements included QRS duration, R′ wave duration and amplitude and R′: QRS duration ratio in lead V1. Amplitude measurements were defined as maximum deviation from the isoelectric line. ECG features of RBBB were compared between patients with echocardiographic impression of RV systolic dysfunction (group 1) and those with normal RV systolic function (group 2). This study was approved by the Institutional review board and a written informed consent were obtained from all patients prior to inclusion in the study.

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). Two-dimensional and Doppler analyses were conducted according to the recommendations of the American Society of Echocardiography (ASE).[9] The maximal tricuspid regurgitation velocity (TR Vmax; in m/s) was obtained from continuous-wave Doppler of the TR signal. The Doppler-derived pulmonary artery systolic pressure (PASP; in mm Hg) was calculated from the maximal TR Vmax using the simplified Bernoulli formula as follows: PASP=4 × (TR Vmax) + right atrial (RA) pressure (RA pressure was determined according to diameter and collapse of inferior vena cava, as recommended by ASE guidelines).[2] 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. 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. 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 24.0 for Windows (SPSS Inc., Chicago, IL, USA). Data are presented as mean+standard deviation for continuous variables and percentage (%) if the data are categorical. 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 tested using the Kolmogorov–Smirnov test. Relationships between variables were examined with Pearson correlation coefficients. A two-

tailed p value<0.05 was considered to be statistically significant.

RESULTS

A total of 225 patients with RBBB (male/female: 140/85 and age: 65.4+12.2 years) were enrolled in the study. Clinical features of the subjects have been summarized in Table 1. RV dysfunction was seen in 66/225 (29.4%) with RBBB. Patients presenting with RV dysfunction [Group 1] (n=66) were more likely to be male and had more prolonged QRS duration (144.2+17.3 ms vs. 130.6+12.8 ms, p<0.001), predominantly due to R`: QRS duration (142.5+12.6 ms vs. 103.7+12.0 ms, p<0.001) as compared to patients with normal RV function [group 2] (n=159). No statistically significant difference could be found in terms of cardiovascular risk factors such as hypertension, diabetes, dyslipidemia, or current smoking status in between the two groups. In addition, there were no differences in conditions leading to RV dysfunction, except presence of pulmonary hypertension. A comparison of echocardiography parameters between patients with RBBB according to RV failure is shown in Table 2.

Table 1: Baseline demographic data and clinical characteristics of the cohort.

Characteristics	Patients without RV dysfunction (n=159)	Patients with RV dysfunction (n=66)	P value
Age (years)	65.2±14.2	66.4±14.5	0.61
Gender			
Male (N, %)	96 (60.3)	42 (63.6)	0.46
Female (N%)	63 (39.7)	24 (36.4)	0.58
Body mass index (kg/m^2)	22.6±3.5	22.4±3.3	0.61
Systolic blood pressure (mmHg)	126.7±16.4	128.8±15.4	0.55
Diastolic blood pressure (mmHg)	80.7±49.0	78.9±12.3	0.79
Cardiovascular risk factors			
Current smoking (N, %)	42 (26.4)	16 (24.2)	0.22
Hypertension (N, %)	76 (47.8)	28 (42.4)	0.61
Diabetes mellitus (N, %)	51 (32.0)	20(30.3)	0.98
Dyslipidemia (N, %)	72 (45.2)	28 (42.4)	0.72
Conditions leading to RV dysfunction			
Coronary artery disease (N, %)	35 (22)	15 (23)	0.12
COPD (N, %)	32 (20.1)	16 (24.2)	0.98
Pulmonary embolism (N, %)	12 (7.5)	6 (9.1)	0.85
Atrial fibrillation (N, %)	19 (12)	7 (10.6)	0.77
Valvular heart disease (N, %)	14 (9)	8 (12.1)	0.60
Pulmonary hypertension (N, %)	50 (32)	32 (48.4)	0.006
Heart rate (bpm)	74.9±18.2	86.7±17	0.89
QRS duration (ms)	130.6±12.8 ms	144.2±17.3 ms	<0.001
R` duration (ms)	84.8±13.0 ms	102.9±12.0 ms	<0.001
R`/QRS duration	0.63±0.07 ms	0.72±0.05 ms	<0.001

Table 2: Comparison of echocardiography parameters between patients with RBBB according to RV dysfunction.

Characteristics	Patients without RV dysfunction (n=159)	Patients with RV dysfunction (n=66)	P value
TAPSE (mm)	18.2±1.6	12.4 2±8	<0.001
RV systolic pressure (mmHg)	28.9±7.9	35.2±17.1	0.001
RV dimension (mm)	3.30±0.24	3.73±0. 61	<0.001
RV free wall thickness (mm)	0.31±0.04	0.35±1.2	0.029
RV myocardial performance index	0.38±0.27	0.56±0.29	<0.001
RV fractional area change (%)	40.4±5.1	26.9±6.6	<0.001
LV end-diastolic volume (ml)	46.7±6.1	47.1±4.3	0.06
LV end-systolic volume (ml)	29.8±5.9	31.8±6.92	0.029
LV ejection fraction (%)	64.5±6.1	62.1±5.4	0.021
LA volume index (ml/m^2)	20.1±12.8	23.3±12.5	0.055
E velocity (cm/s)	70.9±25.2	76.8±36.1	0.114
A velocity (cm/s)	80.2±24.4	80.6±22.1	0.61

Continued.

Characteristics	Patients without RV dysfunction (n=159)	Patients with RV dysfunction (n=66)	P value
E/Ea	11.6±5.3	13.7±7.9	0.012
LV ejection time (ms)	277.0±40.5	266.7±33.9	0.082
RV ejection time (ms)	280.4±46.7	271.2±38.6	0.028
Tricuspid regurgitation			
None (N, %)	87 (54.7%)	27 (42%)	
Grade 1 (mild) (N, %)	56 (35.3%)	29 (44%)	
Grade 2 (moderate) (N, %)	13 (8.17%)	7 (10.6%)	
Grade 3 (severe) (N, %)	3 (1.83%)	3 (4.4%)	

Table 3: Correlation between RV functional parameters and R` wave duration in patients with RBBB.

Characteristics	Correlation coefficient	P value
TAPSE (mm)	-0.59	<0.001
RV systolic pressure (mmHg)	0.138	0.008
RV dimension (mm)	0.289	<0.001
RV myocardial performance index	0.390	<0.001
RV fractional area change (%)	- 0.615	<0.001

As compared to patients with normal RV function (group 2), patients with RV dysfunction (group 1) showed significantly reduced TAPSE and RV FAC and increased RV systolic pressure, RV dimension and RV myocardial performance index (all p<0.05, Table 3).

In addition, patients with RV dysfunction (group 1) showed significantly increased LV end-systolic volume and reduced LVEF. RV ejection time was significantly reduced in patients with RV dysfunction with comparable LVEF. The R` duration was significantly associated with RV FAC (r=-0.615, p<0.001), RV systolic pressure (r=0.138, p=0.008), RV dimension (r=0.189, p<0.001) and RV myocardial performance index (r 0.190, p<0.001). On ROC curve analysis, V1 R` duration >93 ms was associated with RV dysfunction with 90% sensitivity and 87% specificity (AUC: 0.883; p<0.001). In addition, lead V1 QRS duration >137 ms and the ratio of R`:QRS duration was also useful for predicting RV dysfunction (all p<0.001).

DISCUSSION

The most important finding from this study was that in patients with RBBB, the presence of a prolonged R`wave duration in lead V1 was significantly associated with various RV functional parameters assessed by echocardiography. This prolongation of the R` wave duration simply reflected the RV electromechanical delay. Classical teaching has been that presence of LBBB on electrocardiogram is not benign and it does reflect underlying cardiovascular dysfunction. RBBB can often been seen in asymptomatic subjects with no demonstrable long-term cardiac morbidity or mortality. This concept however achieved a bit of setback when a recent study showed that RBBB served as a negative prognostic indicator in various cardiovascular diseases such as heart failure, ischemic heart disease and in patients with chronic obstructive pulmonary disease.[10] It is now fairly well established that there are two forms of RBBB: one is interruption of the main right branch of the bundle of His, termed proximal block, and the other is the disturbance of the terminal ramifications of the right bundle, termed distal block.[10-12] Brooks et al and Dancy et al speculated on the basis of the time analysis of right-sided systolic events using echophonocardiography that the proximal block is relatively isolated and benign, but the distal block is associated with diffuse myocardial disease which was likely to be more widespread and progressive.[13,14]

RBBB results in delayed ejection of the RV and this leads to an electromechanical dyssynchrony which has an adverse impact on RV systolic function similar to that seen in LBBB. There has been recently a renewed interest in assessment of RV function. The two major causes of RV dysfunction are RV volume overload and an elevated RV afterload which are usually caused due to TR, pulmonary arterial hypertension, myocardial infarction, LV dysfunction and COPD. Clinically, the recognition of RV dysfunction is important as impairment of RV systolic function has been independently associated with adverse outcomes.[3]

Assessment of RV function is an issue as the anatomy is complex and also impact of the loading and pressure conditions. MRI is usually the gold standard for evaluation of RV anatomy and its function6. However, 2D echocardiography subserves its function and is an indispensable and cost-effective imaging tool for assessment of RV systolic function. In patients with RBBB and RV dysfunction, there occurs a stress on the right bundle branch and Purkinje network which leads to a myocardial conduction delay and is evident as prominent QRS and R0 wave duration prolongation on ECG. In patients with RBBB, the predominant conduction delay would be expected to be reflected in the R′ wave which

largely represents slow conduction across the diseased RV. In a study conducted among 34 patients with RV dysfunction, Adams and colleagues showed an association between TAPSE and V1 R0 wave duration.[15] Since TAPSE is volume dependent, it is not suitable for assessment of RV functions in RV pressure overload conditions such as COPD or CHD. Our study showed that there was a significant association between prolonged R0 wave duration in lead V1 and FAC, TAPSE, and RV myocardial performance index all of which are markers of either pressure and/or volume overload in RV. Park et al had studied the RBBB cohort using TAPSE and FAC for RV function evaluation.

This study proved the association of QRS and R' duration with RV dysfunction. The sensitivity and specificity of R' duration >93 ms to predict RV dysfunction were 90% and 87% respectively.[16] Devrapalli et al had evaluated RV dysfunction by CMR, which is gold standard for RV function evaluation in patients of RBBB. They correlated R' duration with RV dysfunction and showed that R' duration had predicted RV dysfunction. The presence of R' duration>100ms predict RV dysfunction with 93% specificity and 41% sensitivity, which is similar to our study where R'>100 ms.[6]

One of the major limitations of this study is that is a single centre study having a small sample size. In addition, the was a lot of heterogeneity in the clinical conditions associated with RV dysfunction which increases the chances of bias. Another important limitation of this study is the difficulty in estimation of RV parameters with echocardiography.

An additional study limitation is that echocardiographic RV function assessment is difficult. Several parameters may be used in RV function assessment, but complex RV geometry creates problems for consistent imaging and reproducibility among patients. The investigators therefore elected to use TAPSE and Tei index as an index of RV systolic function as it is an objective measurement with low interobserver variability that can be easily performed offline. Furthermore, these parameters have been shown to correlate with several more complex methods of RV function assessment such as radionuclide imaging, biplane Simpson ejection fraction and RV fractional area shortening. The results of this study must therefore be interpreted with new echocardiographic modalities such as strain imaging and cardiac MRI which may be better to define RV function.

CONCLUSION

The findings from this study showed that in patients with RBBB, the electromechanical delay has a correlation with RV systolic dysfunction with and without PH. ECG features such as R0 prolongation in lead V1 can be a useful marker to determine the presence of underlying RV dysfunction. Further large scale studies are needed to further elucidate this concept.

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