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Assessment of left ventricular systolic synchrony and cardiac function in patients with ischemic heart disease by echocardiography

H.-P. QU, P.-S. DONG, Y.-J. SONG, H.-M. WANG

Department of Cardiology, First Affiliated Hospital of Henan University of Science and Technology, Luoyang, Henan, China

Abstract. – OBJECTIVE: To investigate the correlation between left ventricular systolic synchrony and cardiac function in patients with ischemic heart diseases of different degrees by echocardiography.

PATIENTS AND METHODS: 84 cases of patients with ischemic heart diseases were consecutively selected including 28 cases of asymptomatic heart failure, 40 cases of mild to moderate heart failure, and 16 cases of severe and refractory heart failure. Interventricular synchrony was evaluated by echocardiography, and the result was expressed by interventricular mechanical delay (IVMD). The ventricular systolic synchrony was evaluated by the standard deviation of systole t_{max} (Ts-SD), cardiac function indexes included left ventricular ejection fraction (LVEF), left ventricular end diastolic diameter (LVEDd), and BNP and QRS wave duration.

RESULTS: IVMD, Ts-SD and QRS wave duration increased gradually following the exacerbation of heart failure; differences were statistically significant ($p < 0.05$). The ratio of the QRS wave duration that was equal to or greater than 120 ms among three groups showed no statistical difference ($p = 0.593$). In patients with QRS wave durations equal to or greater than 120 ms compared to patients with durations less than 120 ms, the levels of IVDM, Ts-SD, LVEDd, and serum BNP were increased ($p < 0.05$) while levels of LVEF were decreased ($p < 0.05$). There were no significant linear correlations among values of IVMD, Ts-SD with LVEF, LVEDd, BNP and QRS wave duration ($p > 0.05$).

CONCLUSIONS: Left ventricular systole synchrony was different in patients with different degrees of ischemic heart diseases, and a comprehensive assessment of the combination of ventricular systole synchrony with cardiac function is needed.

Key Words:

Echocardiography, Ischemic heart disease, Ventricular systolic synchrony, Cardiac function.

Abbreviations

BNP: brain natriuretic peptide; CRT: cardiac resynchronization therapy; CTA: computed tomography angiography; DSA: digital subtraction angiography; ECG: Echocardiogram; LVEDd: left ventricular end diastolic diameter; LVEF: left ventricular ejection fraction; IVMD: interventricular mechanical delay; NYHA: New York Heart Function; TDI: tissue Doppler imaging; Ts-SD: standard deviation of systole t_{max}.

Introduction

Acute and chronic heart failure caused by various heart diseases is often the outcome of patients with heart disease, and it is also the main cause of disability and death[1]. Approximately 30-56% of patients with heart failure die[2]. A research[3] confirmed that the development of heart failure is a continuous and irreversible process. Risk factors associated with heart disease start the process of heart failure, which causes myocardial remodeling to occur even though there is no new myocardial damage in the silent heart failure period. The process of heart failure is also a process in which the ability of the heart to pump blood declines, and the harmony of mechanical diastole and systole is disordered[4]. The disordered systolic synchronicity between inter-ventricular and left ventricular is the core part of the progression to heart failure. A variety of drugs, including diuretics, positive inotropic drugs, calcium channel blockers, and mechanotherapy such as cardiac resynchronization therapy (CRT), aim to improve systolic myocardial synchronization in order to improve cardiac function, relieve clinical symptoms, and improve prognosis of survival[5-7].

Corresponding Author: Pingshuan Dong, MD; e-mail: yqdfo849153@163.com

The theory and foundation of CRT are to restore normal cardiac conduction sequence and realize the ventricular systolic synchrony maximally. It is better suited for patients with conduction block (QRS duration is equal to or greater than 120 ms), left ventricular ejection fraction (LVEF) less than or equal to 35%, not restricted in heart function, and no improvement of clinical symptoms despite optimal medical therapy[8,9]. The actual response rate is about 60-85%[10], and the response rate can be further improved when echocardiography is used to optimize pacing and sensing parameters[11,12]. The advantages include easy repetition, no trauma, easy operation, high accuracy, and popularity in clinical use[13]. Simple continuous ECG and gated nuclide myocardial imaging and other techniques can also be adopted, and it can be confirmed that the sensitivity and accuracy of echocardiography are better[14]. We further evaluated the correlation of left ventricular systolic synchronicity and cardiac function in patients with ischemic heart disease of different degrees by ultrasonic cardiogram, to provide a reference for reasonable selection of clinical treatment and prognosis assessment.

Patients and Methods

Patients

84 cases of patients that were diagnosed with ischemic heart disease for the first time at our hospital from January 2014 to January 2016 were consecutively selected. Examinations were performed, including routine electrocardiogram, dynamic electrocardiogram, and echocardiography or radionuclide myocardial imaging, myocardial magnetic resonance, heart coronary, computed tomography angiography (CTA) and digital subtraction angiography (DSA), etc. Definite myocardial ischemia and coronary artery stenosis were also presented. Patients with congenital heart disease, primary cardiomyopathy, heart valve disease, myocarditis and cardiac surgery, severe hypertension and diabetes mellitus were excluded. Primary disease of other organs, such as lung, liver, kidney, brain and incomplete clinical data were also excluded. This investigation obtained approval from the Ethics Committee of our hospital and the informed consent rights from patients and their families. Among them, there were 28 cases of patients with asymptomatic heart failure (Group A), 40 cases of patients with mild to moderate heart failure (Group B), and 16 cases of patients with severe and refractory heart failure (Group C). The degree of heart failure was classified according to New York Heart Function (NYHA), LVEF, brain natriuretic peptide (BNP) and the treatment effects. NYHA over grade III, LVEF less than or equal to 30%, and poor or aggravated treatment effects were designated as Group C, the rest were classified as Group B. The baseline data in the three groups were comparable (Table I).

Research Methods

End-diastolic and end-systolic diameters of the left and right ventricle and the left and right atrium, were measured by the standard two-dimensional ultrasound of the ultrasonic cardiogram (vivid7 Type, GE Healthcare, San Francisco, CA, USA), and the LVEF was calculated using a simplified double-plane Simpson method. We connected ECG simultaneous monitoring and the examination of the pulse Doppler ultrasonography. We chose the aortic and pulmonary artery pulse spectrum image and started tissue velocity model. Image acquisitions of the second cavity, the third cavity and the fourth cavity of apex cordis in the tissue Doppler imaging (TDI) mode were obtained, which were continuously recorded in five cardiac cycles; the image analysis was

Table I. Comparison of baseline data in three groups.

Groups	Cases	Male/ female	Age (y)	mSBP (mmHg)	mDBP (mmHg)	FBG (mmol/L)	TC (mmol/L)	LDL (mmol/L)
A Group	28	16/12	56.7 ± 12.3	146.7 ± 12.5	82.6 ± 6.7	5.2 ± 1.3	5.5 ± 1.3	4.7 ± 0.8
B Group	40	27/13	57.2 ± 14.5	148.3 ± 13.5	81.5 ± 5.7	5.3 ± 1.4	5.6 ± 1.5	4.8 ± 0.9
C Group	16	10/6	57.5 ± 13.6	147.9 ± 14.8	82.3 ± 7.5	5.4 ± 1.5	5.7 ± 1.4	4.6 ± 0.7
F (χ^2)		0.762	0.214	0.128	0.247	0.326	0.342	0.252
p		0.683	0.863	0.923	0.822	0.658	0.625	0.757

Note: mSBP, mean systolic blood pressure; mDBP, mean diastolic blood pressure; FBG, fasting blood glucose; TC, total cholesterol; LDL, low density lipoprotein.

saved. Evaluation of interventricular synchrony was expressed by interventricular mechanical delay (IVMD), and the pulse Doppler spectrum was applied to measure the time difference of pre-ejection period (initial time of QRS wave respectively to artery and pulmonary flow spectrum starting time). An IVMD > 40 ms meant that interventricular systole was not synchronized. Left ventricular systolic synchrony was expressed by a standard difference of systolic time to peak (Ts-SD).

The 12 segments analysis method included 6 basal segments and 6 middle segments, which were used to measure the mean value and standard difference of the systolic time to peak of each section; the Ts-SD equal to or more than 33 ms was left ventricular dyssynchrony. The body surface 12-lead electrocardiograms of patients in quiet state were synchronously recorded with 25 mm/s paper speed. At the same time, heart rate and QRS wave duration were recorded. The QRS wave duration was the equipotential line interphase from the first turning point to the end of the QRS, and the longest lead time was taken as the time limit. Cardiac function indexes included LVEF, left ventricular end diastolic diameter (LVEDd), BNP and QRS wave duration. The serum BNP level was detected by radioimmunoassay, and the reagent kit was purchased from Beijing North Research Institute of Biotechnology (Beijing, China), which was carried out strictly according to the instruction manual.

Statistical Analysis

The software SPSS 22.0 (IBM SPSS Statistics for Windows, Armonk, NY, USA) was used for statistical analysis, and the measurement data was presented as mean ± standard deviation. Single factor ANOVA analysis was used for comparison among multiple groups. The LSD test was taken in comparison between any two groups. The independent sample *t*-test was used between the two groups, and the count data was expressed in cases or (%). The χ^2-test was used among groups, and the measurement data was analyzed by Pearson test after normal test. $p < 0.05$ was considered statistically significant.

Results

Comparison of Ventricular Systolic Synchrony and QRS Wave Duration Among the Groups

IVMD, Ts-SD and QRS wave duration increased gradually following the exacerbation of heart failure; differences were statistically significant ($p < 0.05$) (Table II).

Comparisons of QRS Wave Duration and the Indexes of Cardiac Function and Ventricular Systolic Synchrony Among Groups

There were 8 cases (28.57%) in Group A with QRS wave duration equal to or greater than 120 ms, 14 cases (35%) in Group B, and 7 cases (43.75%) in Group C. There were no significant differences in comparisons ($\chi^2 = 1.045$, $p = 0.593$). The levels of IVDM, Ts-SD, LVEDd, and BNP increased, while levels of LVEF decreased in patients who had QRS wave durations equal to or greater than 120 ms, compared to patients with wave durations less than 120 ms. The differences were statistically significant ($p < 0.05$).

Discussion

Correlation Between Indexes of Ventricular Systolic Synchrony and Cardiac Function

IVDM and Ts-SD values with LVEF, LVEDd, BNP and QRS wave time limit were conducted respectively with linear correlation analysis. We

Table II. Comparison of ventricular systolic synchrony and QRS wave duration among the groups.

Groups	IVMD (ms)	Ts-SD (ms)	QRS wave duration (ms)
A Group	42.3 ± 3.4	35.5 ± 2.7	112.4 ± 4.6
B Group	48.7 ± 3.5	42.6 ± 2.8	125.6 ± 4.8
C Group	55.6 ± 3.7	48.9 ± 3.1	128.7 ± 5.3
F	6.527	5.748	6.637
p	0.006	0.012	0.004

Note: IVMD, interventricular mechanical delay; Ts-SD, the standard deviation of the peak of systolic time.

concluded that there were no linear correlations among IVMD and Ts-SD values and LVEF, LVEDd, BNP, and QRS wave duration ($p > 0.05$).

The cardiac resynchronization therapy response prediction factor test (PROSPECT) is the largest prospective and multicenter study of cardiac ultrasound on the prediction of CRT efficacy, which includes 12 ultrasonic parameters. It was concluded that although single echocardiographic parameter cannot assess cardiac synchronization and predict the efficacy of CRT very well when combined with partial parameters such as IVMD and Ts-SD, it can significantly improve the diagnosis of synchronization, regulation of pacemaker parameters and prediction of short term and long term therapeutic value[15,16]. In addition to TDI technology, technologies such as myocardial spot and strain rate imaging, and three-dimensional ultrasound blood flow imaging can further improve the application value of ultrasound in preoperative, intraoperative and postoperative follow-up of CRT[17]. At the same time, it has obvious advantages such as the simplicity of the operation, moderate price, good repetition, and thus, ultrasound is most commonly used in heart failure in clinical use.

In spite of this, there is a relative dearth of further analysis on the relationship between myocardial systolic synchrony and cardiac function in patients with different degrees of ischemic heart disease. According to statistics, about 10-30% of patients with asymptomatic heart failure and 20-40% of patients with mild to moderate heart failure have also significant interventricular or left ventricular systolic dyssynchrony. Early intervention is very important[18,19], which may delay or reverse the ventricular remodeling process, thus reducing the heart failure hospitalization rate and saving the cost of health care. At the same time, it will prolong the survival time of patients with heart failure and improve the survival rate. This work concluded that the QRS duration is equal to or greater than 120 ms in patients with asymptomatic heart failure. Patients with light or moderate heart failure respectively account for 28.57% and 35.00%, and their levels of IVMD, Ts-SD, LVEDd and serum BNP were significantly increased compared to patients with a QRS duration of less than 120 ms; the level of LVEF was reduced. However, the occurrence of QRS wave duration equal to or greater than 120 ms in patients with severe and refractory heart failure is approximately 43.75%; there was no difference compared to the other two groups. The more severe symptoms of heart failure, the worse the clinical effects were, and the higher the mortality rate was[20]. Therefore, early intervention has higher therapeutic value.

Conclusions

IVMD, Ts-SD and QRS wave duration gradually increased accompanied with aggravated heart failure, but there was no linear correlation among values of IVMD and Ts-SD with LVEF, LVEDd, serum BNP and QRS wave duration. This indicated that the process of heart failure was not only closely related to ventricular systolic dyssynchrony, but also related to other involved mechanisms such as the Frank-Starling mechanism of cardiac self-regulation, neuroendocrine regulation mechanism and so on. Early effective use of the Frank-Starling mechanism for the best diuretic, enhanced cardiac muscle contraction and the appropriate extension of diastolic time could significantly improve the heart pump blood function and regulate ventricular remodeling process[21]. Successful application of drugs including class ACEI or class ARB, β-receptor blockers, and aldosterone in patients with stable heart failure confirmed the importance of the neuroendocrine regulation mechanism[22]. Nevertheless, the establishment of the database of ventricular systolic synchrony indexes, and cardiac function indexes of ischemic heart disease such as a range of linear correlation or index, parabola and so on can further analyze the correlation with the others. A comprehensive assessment of systolic synchrony and cardiac function were conducted to guide the drugs and CRT treatment programs of ischemic heart disease to improve clinical efficacy.

Conflict of Interest

The Authors declare that they have no conflict of interests.

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