Clinical Application Value of Echocardiography in Evaluating Left Ventricular Local Myocardial Function and Left Ventricular-Arterial Coupling of Male Patients with Metabolic Syndrome

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Abstract: Objective: To apply echocardiography technique to evaluate left ventricular local myocardial function and ventricular - arterial coupling of male patients with metabolic syndrome (MetS). Methods: 80 male patients with MetS were classified into MetSN group (EF≥ 50%) (50 cases) and MetSA group (EF<50%) (30 cases). 50 healthy men with the matched age were chosen as the control group. Relevant indicators were measured and calculated, including left ventricular ejection fraction (EF), left ventricular Tei index, left ventricular contraction end elasticity (Ees), effective arterial elasticity (Ea), ventricular-vascular coupling index (VVI), left ventricular myocardium global longitudinal strain (GLS) and strain rate (GLSR), left ventricular myocardium radial strain (RS) and strain rate (RSR). The results were compared and analyzed. Results: (1) compared with control group, Tei index of MetSA group increased, higher than that of MetSN group. Tei index of MetSN group was higher than that of control group ($p<0.05$). (2) Longitudinal peak strain, strain rate and radial peak strain, strain rate of MetSA group were lower than those of control group and MetSN group. Longitudinal peak strain and strain rate of MetSN group were lower than those of control group ($p<0.05$). (3) Compared with control group, Ea of MetSN group and MetSA group increased ($p<0.05$). Ea had no significant difference in the MetSN and MetSA groups ($p>0.05$). Ees of MetSN group increased, and Ees of MetSA group declined ($p<0.05$). VVI of MetSA group increased, higher than that of MetSN group ($p>0.05$). Significant difference of VVI was not observed in the control and MetSN groups ($p>0.05$). (4) Simple linear regression analysis showed that, VVI of MetSA group presented negative correlation with longitudinal peak strain and positive correlation with Tei index ($p<0.05$). Conclusions: For MetSA group, Ea increased; Ees decreased obviously, and decompensation which causes ventricular-arterial decoupling happened; and this state of suboptimal coupling is deteriorated with the decrease of left ventricular function. For MetSN group, Tei and Ees increased, indicating that left ventricular diastolic function of the patients in the group reduces, while compensation of left ventricular systolic function increases. Besides, radial myocardial strain of left ventricle plays certain role in maintaining ventricular-arterial coupling.

Keywords: echocardiography; metabolic syndrome; Tei index; speckle tracking; myocardial strain; cardio-vascular coupling

Metabolic syndrome (MetS) is a clinical syndrome which integrates multiple metabolic disorders such as hypertension, abnormal glucose metabolism, dyslipidemia and abdominal obesity. Its pathogenesis is still unclear. At present, it is believed that MetS is the result of interactions among multiple genes and multiple environments, and has a close relation with heredity and immunity. Cardiovascular disease (CVD) is a major clinical outcome of MetS. At the beginning of 20th century, the death rate caused by CVD in the world did not exceed 10%. At the beginning of 21st century, this proportion rose to nearly a half in the developed countries, and reached 25% in the developing countries. By the end of 2020, CVD will have become the first cause of death. In other words, at least one patient will die of CVD among every 3 dead patients [1]. CVD seriously affects people's living quality. For the patients with MetS, the risk of suffering CVD and death is obviously higher than that of healthy people and the people with single hazard. Thus, cardiovascular damage evaluation, prevention and treatment for the patients with MetS have become one of important research topics in the world. This study aims to explore the application value of echocardiography technique in clinically evaluating left ventricular function and ventricular-arterial coupling of patients with MetS.

1. Data and Method

1.1. Object of Study

80 male patients who diagnosed with MetS in the hospital from March 2016 to June 2017 were chosen, including 50 cases in MetSN group (EF≥50%) and 30 cases in MetSA group (EF<50%). After excluding the

patients with metabolic disease and CVD through medical history inquiry, physical examination, blood biochemical analysis, ultrasonic and electrocardiographic examination, 50 healthy men with the matched age were chosen as the control group. The tentative uniform definition of MetS is based on the joint declaration published by six authoritative academic institutions in 2009, including epidemic and prevention policy group of International Diabetes Federation (IDF), American Heart Association (AHA), National Heart Lung and Blood Institute (NHLBI) [2].

1.2. Instruments and Methods

PhilipsIE33 echocardiography instrument, S5-1 cardiac probe and QLAB workstation were used. The subjects took left lateral position and were connected with ECG. Firstly, conventional cardiac ultrasonography was conducted. Then, 2D speckle tracking imaging technology was used to gain various parameters.

1.3. Image Analysis and Processing

(1) Measurement of general parameters: height, weight, body surface area. Left brachial arterial blood pressure was measured three times under the calm condition. The average values of systolic blood pressure (SBP) and diastolic blood pressure (DBP) were taken to calculate ESP (left ventricular end systolic pressure) = 0.9 × SBP [3].

(2) Conventional cardiac parameters: biplane Simpson method was used to measure left ventricular end-diastolic volume (LVEDV), left ventricular end-systolic volume (LVESV), and ejection fraction (EF), and stroke volume (SV) was calculated. Under the mode of tissue Doppler imaging (TDI), dynamic spectrum of mitral annulus was gained. Dynamic spectrum of mitral annulus was utilized to measure isovolumetric contraction time (ICT), ejection time (ET) and isovolumic relaxation time (IRI). Tei index (= (ICT+IRT)/ET) was calculated (it reflects the whole function of left ventricle) [4]. Meanwhile, (Ea) = ESP/SV [3,5], (Ees)=ESP/ESV [5-7] and (VVI)=Ea/Ees [5,8] were figured out.

(3) Analysis of technical parameters of 2D speckle tracking imaging: the dynamic images of apical four-chamber, two-chamber and three-chamber in three cardiac cycles as well as mitral valve level of short axial section of left ventricle, papillary muscle level and apex cordis were collected and imported into CMQ plug-in offline analysis in QLAB9.0 workstation to gain longitudinal peak strain, strain rate, radial peak strain and strain rate of left ventricle. For all measured values, the average value in the three cardiac cycles was taken.

1.4. Statistical Analysis

SPSS16.0 statistical analysis software was applied. The measurement data were expressed with ($\bar{x}$ ±s). Univariate analysis of variance was used for comparison of multiple samples in random groups. Simple linear regression was adopted to analyze the change relations of VVI with strain, strain rate and Tei index. $p<0.05$ means there is statistical significance.

2. Results

2.1. Comparison of General Information

Age comparison difference had no statistical significance ($p>0.05$). The body surface area of both MetSN group and MetSA group was greater than that of control group ($p<0.05$). The inter-group difference had no statistical significance ($p>0.05$), as shown in Table 1.

Table 1. Comparison of general information between MetS group and control group ($\bar{x} \pm s$).

Group	No.	Age (year)	Body surface area (m^2)
MetSN group	50	59.14 ± 4.28	1.80 ± 0.20 *
MetSA group	30	58.24 ± 5.49	1.81 ± 0.43 *
Control group	50	56.78 ± 5.21	1.75 ± 0.06

Note: Compared with control group, * $p<0.05$.

2.2. Comparison of Left Ventricular Function

Compared with control group, Tei index of MetSA group increased, higher than that of MetSN group. Tei index of MetSN group was higher than that of control group ($p<0.05$), as shown in Table 2.

Table 2. Comparison of left ventricular function between MetS group and control group ($\bar{x} \pm s$).

Group	No.	EF	Tei
MetSN group	50	0.70 ± 0.02	0.57 ± 0.11 *
MetSA group	30	0.37 ± 0.07 $^{*,\#}$	0.97 ± 0.23 $^{*,\#}$
Control group	50	0.66 ± 0.04	0.36 ± 0.06

Note: compared with control group, *$p<0.05$; compared with MetSN group, $^{\#}$ $p<0.05$.

2.3. Comparison of Strain and Strain Rate

Longitudinal peak strain, radial peak strain, and corresponding strain rate of MetSA group were lower than those of control group and MetSN group. Longitudinal peak strain and strain rate of MetSN group were lower than those of control group ($p<0.05$), as shown in Table 3.

Table 3. Comparison of left ventricular function between MetS group and control group ($\bar{x} \pm s$).

Group	No.	Peak in systole (%)		Peak strain rate in systole (S^{-1})	
		Longitudinal	Radial	Longitudinal	Radial
MetSN group	50	-18.56 ± 2.17*	42.67 ± 12.05	-1.12 ± 0.34*	2.61 ± 0.28
MetSA group	30	-12.17 ± 3.05 $^{*,\#}$	15.14 ± 9.85 $^{*,\#}$	-0.62 ± 0.21 $^{*,\#}$	1.2 ± 0.02 $^{*,\#}$
Control group	50	-21.36 ± 1.89	43.33 ± 11.81	-1.32 ± 0.32	2.67 ± 0.54

Note: compared with control group, * $p<0.05$; compared with MetSN group, $^{\#}$ $p<0.05$.

2.4. Comparison of Left Ventricular-Arterial Coupling

Compared with control group, Ea of MetSN group and MetSA group increased ($p<0.05$). Ea had no statistical significance between MetSN group and MetSA group (p>0.05). Ees of MetSN group increased, and Ees of MetSA group declined (p<0.05). VVI of MetSA group increased, higher than that of MetSN group (p<0.05). VVI difference between control group and MetSN grouphad no statistical significance (p>0.05), as shown in Table 4.

Table 4. Comparison of cardio-vascular coupling parameters between MetS group and control group ($\bar{x} \pm s$).

Group	No.	Ea (mmHg/ml)	Ees (mmHg/ml)	VVI (Ea/Ees)
MetSN group	50	1.96 ± 0.44 *	4.62 ± 1.37 *	0.44 ± 0.37
MetSA group	30	1.89 ± 0.24 *	1.07 ± 0.56 *,#	1.90 ± 0.45 *,#
Control group	50	1.50 ± 0.17	3.89 ± 0.72	0.42 ± 0.53

Note: compared with control group, * p<0.05; compared with MetSN group, # p<0.05.

2.5. Simple Linear Regression Analysis of Tei Index and VVI

GLS and Tei were used as the independent variables, and VVI was used as the dependent variable. Simple linear regression showed that VVI in MetSA group presented negative correlation with GLS and positive correlation with Tei index (p<0.05), as shown in Tables 5 and 6.

Table 5. Simple linear regression of VVI in MetA group.

	b	*t*	*p*
Tei	3.335	8.049	0.000

R^2 = 0.601, r = 0.775.

Table 6. Simple linear regression of VVI in MetA group.

	b	*t*	*p*
GLS	-0.191	16.6	0.000

R^2 = 0.974, r = 0.948.

3. Discussion

MetS is a risk factor of various CVD diseases, and can damage multiple cytokines and the balance of vasoactive substance, thus leading to the occurrence of type-2 diabetes mellitus and MetS and causing reconstruction of ventricular muscle and blood vessels. Further, cardiovascular event is caused [10]. In the early stage of ventricular reconstruction, the disorder has happened to myocardium energy generation and supply. The content of collagen I in extracellular matrix and the ratio of collagen I and collagen III increases so that myocardium stiffness rises, diastole function declines and filling volume reduces. The experiments have proven that systolic and diastolic properties of hypertrophic myocardium of unit weight reduce. But for the whole heart, the gross of myocardial contractile protein increases, which can enhance total contraction capacity of myocardium and increase cardiac output and ejection speed [11]. The defect of such compensation is that oxygen consumption of hypertrophic myocardium increases and blood supply of coronary artery cannot be met. In addition, each component of MetS can promote the formation of atherosclerosis of coronary artery, which can aggravate myocardial ischemia and finally result in cardiac failure.

Strain rate imaging (SRI) technology is a method to evaluate local myocardial functions, which develops based on DTI technology and aims to study features of myocardial tissues. With high temporal and spatial resolution, SRI can reflect myocardial systolic and diastolic motions of local ventricular wall and identify slight differences of myocardium shape changes in different stages in time and space distribution. Meanwhile, ventricle and arterial system as a whole interact and coordinate with each other, so it is a closely coupled system, i.e. ventricular-arterial coupling. Sunagawa adopted cardiac catheterization the first time to gain Ees and Ea parameters with the same unit through pressure volume loop (PV), and indicated that the matching degree of left ventricular elasticity and arterial elasticity could reflect cardio-vascular coupling state [8]. Ea is effective arterial elasticity. The larger Ea value, the higher arterial system stiffness [3,5]. Ees is left ventricular contraction end elasticity. The larger Ees value, the higher myocardial contractility [5-7], Ea/Ees is cardio-vascular coupling index VVI, which reflects the interaction between left ventricle and arterial system [5,8]. The normal range of VVI is 0.3-1.3 [9]. Under the quiescent condition, VVI is between 0.6 and 1.2, which is considered as the optimal interaction state between arterial system and ventricle [5].

4. Conclusion

Based on the research results, although effective arterial elasticity of MetSN group and MetSA group increased, their clinical prognosis differed obviously, i.e. left ventricular-arterial coupling for the former, and left ventricular-arterial decoupling for the latter. Ees may play a more pivotal role in the coupling state. The overall function of left ventricle of MetSN patients declined, and Ees increased, indicating that diastolic dysfunction had happened in the early stage of the disease, which is consistent with the previous studies [12]. The contraction function was still in the compensatory state, but the longitudinal strain and strain rate of its left ventricular myocardium lowered, promoting that radial strain may play a role in maintaining normal cardiac function and keeping left ventricular-arterial coupling in this stage. The decrease in the longitudinal strain of left ventricular myocardium was earlier than radial strain. This may be because in the early stage of the disease, longitudinal muscle fibers of left ventricle become more sensitive to myocardial interstitial fibrosis and microcirculation disturbance due to the dissection, which may easily lead to insufficient blood supply and affect contraction function [13]. Thus, the longitudinal strain of left ventricular myocardium can more sensitively reflect the impairment of myocardial contraction function than ejection fraction in the early stage of the disease. In the middle and advanced stage, obvious disorders happened to systolic and diastolic functions of MetSA group. Ees lowered significantly. Besides, longitudinal stain and radial strain of left ventricular myocardium as well as strain rate reduced. Ventricular-arterial coupling was lost, and worsened with the reduction of cardiac function. Therefore, in the early stage of MetS, lowering left ventricular afterload and preventing cardiovascular reconstruction play a crucial role for the disease outcome. The application of echocardiography technique can evaluate local myocardial function of left ventricle and left ventricular - arterial coupling state of MetS patients in a noninvasive, sensitive and accurate way.

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