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Assessment of left ventricular systolic synchrony by peak strain dispersion in patients with systemic lupus erythematosus

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Abstract. – OBJECTIVE: The aim of the study was to investigate the clinical value of the peak strain dispersion (PSD) in evaluating left ventricular (LV) systolic synchrony in patients with systemic lupus erythematosus (SLE).

PATIENTS AND METHODS: 58 SLE patients without cardiovascular diseases and 60 healthy subjects were enrolled in the study. Both groups were examined by transthoracic two-dimensional echocardiography. Traditional parameters were measured by conventional echocardiography. Two-dimensional speckle tracking imaging (2D-STI) was used to analyze the PSD and LV global longitudinal strain (LVGLS). Related ultrasound and blood test results were analyzed and compared.

RESULTS: The PSD was significantly higher in SLE patients than in controls ($p<0.05$). The LVGLS was significantly lower in SLE patients than in controls ($p<0.05$). The PSD was negatively correlated with the LVGLS.

CONCLUSIONS: LV systolic synchrony is impaired in patients with SLE disease. The PSD can be used as a new reliable index to evaluate LV systolic synchrony.

Key Words:

Echocardiography, Peak strain dispersion, Synchrony, Systemic lupus erythematosus, Left ventricular function, Speckle tracking imaging.

Introduction

Systemic lupus (SLE) is a chronic autoimmune inflammatory disease which may affect many organs[1,2]. SLE patients may have cardiac complications[3], and cardiac involvement is one of the main causes of death. Cardiovascular events in SLE patients include pulmonary artery hypertension, pericarditis, myocarditis, valvular heart disease, endocarditis etc.[4-6]. It is difficult to make early diagnosis with general imaging and ECG, because patients with early cardiac involvement have no obvious clinical symptoms. Two-dimensional speckle tracking imaging (2D-STI) is an effective method for the assessment of left ventricular (LV) function[7-10]. 2D-STI could detect myocardial strain impairment in rheumatoid arthritis

(RA) patients, even if conventional two-dimensional and Doppler echocardiography showed no decrease of systolic function. Several studies[11,12] have successfully evaluated LV global longitudinal strain (LVGLS) in SLE patients by 2D-STI, although the LV myocardial synchrony could not be reflected by LVGLS. Peak strain dispersion (PSD) is the standard deviation of the peak time of longitudinal strain in each segment of left ventricle, which could accurately reflect the coordination of heart movement and has been utilized in the assessment of LV synchrony in several diseases[13-15]. The purpose of this study was to assess the myocardial function and LV systolic synchrony in SLE patients, and to explore the clinical value of the PSD in the assessment of LV systolic synchrony in SLE patients.

Patients and Methods

Patient Selection

58 SLE patients with normal left ventricular ejection fraction (LVEF) were selected in the First Affiliated Hospital of Wannan Medical College between March 2020 and May 2021. The SLE group included 8 males and 50 females with a mean age of 45.24±6.08 years, and the incident age ranged between 35-56 years. 60 age- and sex-matched healthy subjects were selected as control group. The control group included 10 males and 50 females with a mean age of 44.67±5.54 years, and the incident age ranged between 36-55 years. The exclusion criteria for this study were: cardiac

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involvement, including valve diseases, congenital heart diseases, cardiomyopathy, coronary heart diseases, heart failure, and pericardial effusion; extracardiac diseases that could lead to cardiac dysfunction, such as hypertension, renal insufficiency, and diabetes; inability to cooperate during examinations; poor ultrasound transmission; and lack of satisfactory ultrasound images. We excluded three patients with valve diseases, two with pericardial effusion, six with coronary heart diseases, and two with poor-quality images.

Ethics

The study protocol was approved by the ethics committee and institutional review board of the First Affiliated Hospital of Wannan Medical College [(2019) Ethics research No. 87], and written informed consent was obtained from each participant included in the study and his/her family members. All photographs in which a patient or another person is identifiable have been published with written permission from that person. All participants have consented to and placed no restrictions on the publication of their photographs. All methods were performed in accordance with relevant guidelines and regulations.

Echocardiography

Transthoracic two-dimensional echocardiography was performed in all participants using a Philips EPIQ 7C ultrasonic system equipped with an S5-1 probe with a frequency of 3.5 to 5.0 MHz. We obtained the LV end-diastolic diameter (LVEDD), LV end systolic diameter (LVESD), and LV posterior wall thickness (LVPWT) from the long axis view of left ventricle. We used Simpson's biplane method of disks in the four- and two-chamber views to estimate LVEF, LV end-diastolic volume (LVEDV), and LV end-systolic volume (LVESV). The Devereux formula was applied to calculate the LV mass[16]. Sex, age, height, weight, blood pressure, and heart rate of all the subjects were recorded. BSA was calculated using the following formula: BSA (m^2) = 0.0061 × height (cm) + 0.0128 × weight (kg) − 0.1529. Then we obtained the standardized parameters of LVEDD index (LVEDDI), LVESD index (LVESDI), LVEDV index (LVEDVI), LVESV (LVESVI), and LV mass index (LVMI).

The collected dynamic images were transferred to a QLAB 10.5 workstation for 2D-STI analyses. The endocardium of the LV was tracked point by point in the apical four-chamber, apical three-chamber, and apical two-chamber views. The software automatically provided the PSD and longitudinal strain in each view of the left ventricle, and then the LV global PSD, LVGLS were automatically obtained (Figures 1, 2, 3 and 4).

Thirty data sets were randomly selected to test the repeatability of PSD measurement within and among observers. The intraobserver consistency test was analyzed by the same operator at least one week apart with 2D-STI software, and another experienced operator analyzed the data of 30 patients without knowing the results of the former. The two sets of results were then compared to test the consistency between the observers.

Statistical Analysis

Continuous outcome variables were expressed as mean ± standard deviation (SD). For the quantitative data with normal distribution and ho-

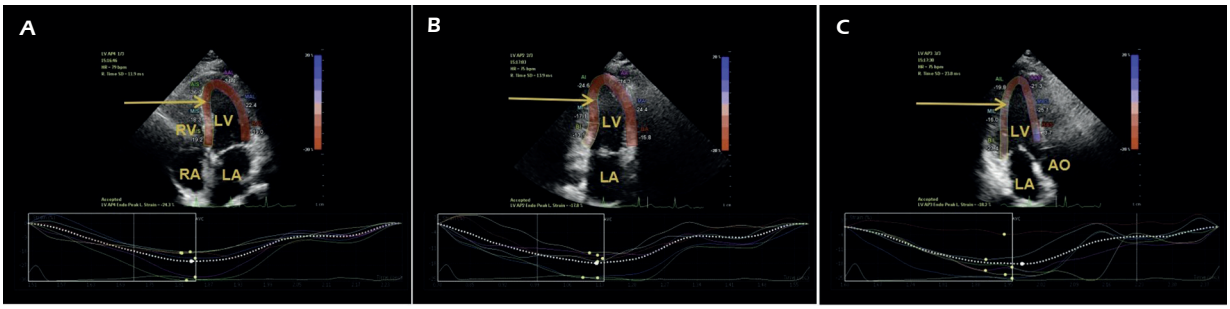

Figure 1. 2D-STI parameters of left ventricle in control group. **A,** The software automatically generated the endocardial border trace (*arrow*) and offered 2D-STI parameters of left ventricle from apical four-chamber view in control group. **B,** The software automatically generated the endocardial border trace (*arrow*) and offered 2D-STI parameters of left ventricle from apical two-chamber view in control group. **C,** The software automatically generated the endocardial border trace (I) and offered 2D-STI parameters of left ventricle from apical three-chamber view in control group.
Abbreviations: LV: Left ventricle; LA: Left atrium; RV: Right ventricle; RA: Right atrium; AO: Aorta.

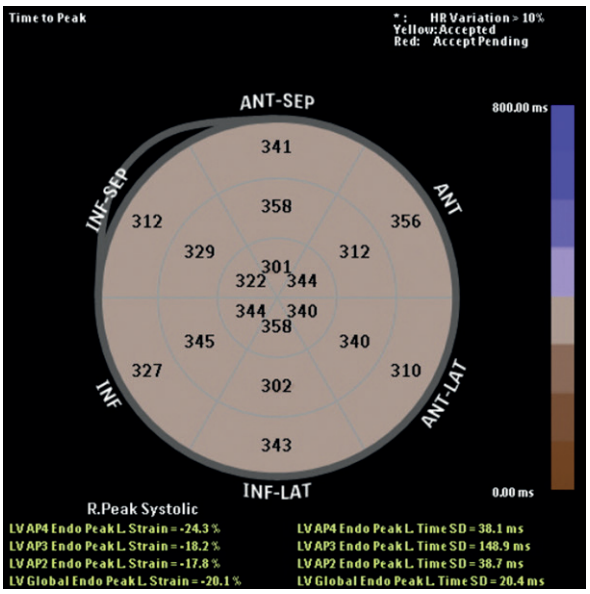

Figure 2. Bulls eye in control group. The aCMQ software automatically calculated LVGLS (-20.1%) and LV global PSD (20.4ms) and provided a color-coding 17 segment bulls eye in control group. Abbreviations: PSD: Peak strain dispersion; LVGLS: Left ventricular global longitudinal strain.

mogeneous variance, the independent samples t-test was used for comparison between groups. Chi-square test was used for the analysis of categorical variables. Pearson's correlation analysis was applied to show the correlation between two sets of data. Bland-Altman scatter plot was performed to show the intraobserver and interobserver variability. SPSS 21.0 software (IBM Corp., Armonk, NY, USA) was used for statistical analysis. A p-value <0.05 was considered significant.

Results

There were no significant differences in general data between the groups (all $p>0.05$) (Table I).

The LVEDDI, LVESDI, LVEDVI, LVESVI, LVMI, and LVPWT in SLE group were significantly higher than those in control group (all $p<0.05$). Control group and SLE group showed no significant differences in LVEF ($p>0.05$) (Table II).

The PSD was significantly higher in SLE group than in control group ($p<0.05$). The LVGLS was significantly lower in SLE group than in control group ($p<0.05$) (Table III).

In SLE patients, a positive correlation was found between the PSD and SLE disease duration (r=0.81, $p<0.05$), and a positive correlation was found between the PSD and the parameters of LV geometry, including LVPWT and LVMI (r=0.83, 0.68, respectively; both $p<0.05$) (Table IV).

The PSD was negatively correlated with the absolute value of LVGLS in all study subjects (r=-0.96, $p<0.01$) (Figure 5).

Bland-Altman analyses of the PSD obtained by 2D-STI showed that there was a high consistency in interobservers as well as intraobserver (Figure 6).

Discussion

Strain echocardiography has provided help in the evaluation of cardiac diseases[17]. 2D-STI is a reliable and accurate method for the evaluation of the myocardial movement and deformation function. By tracking the speckle patterns in 2-D plane, 2D-STI could give a better evaluation of global and local myocardial deformation[18,19].

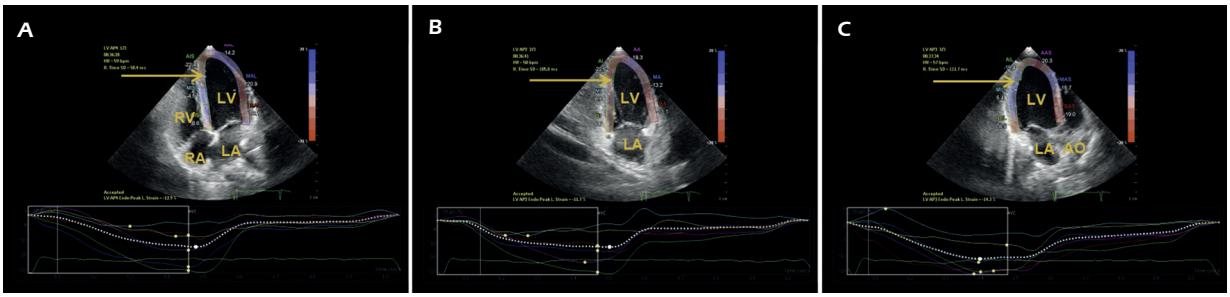

Figure 3. 2D-STI parameters of left ventricle in SLE group. **A,** The software automatically generated the endocardial border trace (*arrow*) and offered 2D-STI parameters of left ventricle from apical four-chamber view in SLE group. **B,** The software automatically generated the endocardial border trace (*arrow*) and offered 2D-STI parameters of left ventricle from apical two-chamber view in SLE group. **C,** The software automatically generated the endocardial border trace (*arrow*) and offered 2D-STI parameters of left ventricle from apical three-chamber view in SLE group.
Abbreviations: LV: Left ventricle; LA: Left atrium; RV: Right ventricle; RA: Right atrium; AO: Aorta.

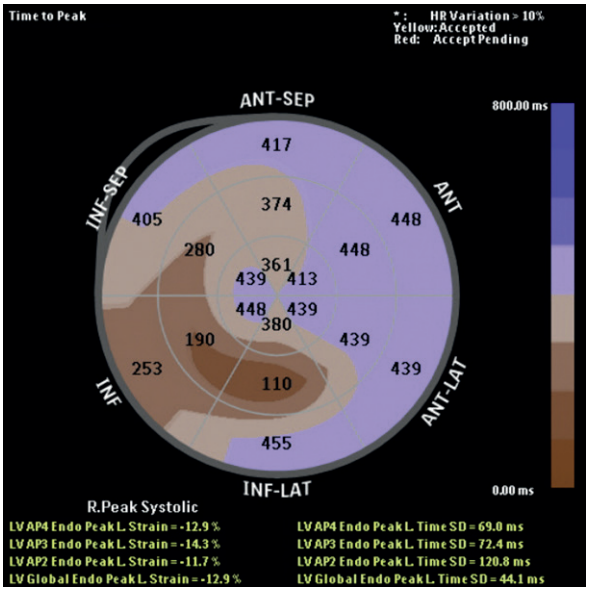

Figure 4. Bulls eye in SLE group. The aCMQ software automatically calculated LVGLS (-12.9%) and LV global PSD (44.1ms) and provided a color-coding 17 segment bulls eye in control group. *Abbreviations:* PSD: Peak strain dispersion; LVGLS: Left ventricular global longitudinal strain.

Tissue doppler imaging (TDI) could be applied in the evaluation of myocardial deformation, despite its defect of angle dependence[20]. Myocardial longitudinal movement ability, which plays an important role in maintaining normal cardiac function, could be reflected by LVGLS.

According to some studies[11,12] LVGLS obtained by 2D-STI has been helpful in the evaluation of LV systolic function in SLE patients, while it has the limitation of ignoring the change of myocardial movement sequence.

PSD is derived from 2D-STI and could overcome the defect of LVGLS, since it reflects the standard deviation of the time to peak strain of the 17 segments. The smaller the PSD, the better the synchrony of myocardial motion. PSD is a reliable tool for accurate evaluation of the myocardial synchrony in the early stage of disease[21,22]. PSD is superior to peak time and strain peak time in the evaluation of left ventricular systolic synchrony. Because of the ability of performing three plane imaging in the same cardiac cycle, PSD has higher accuracy than LV synchrony

Table I. Characteristics of all the subjects.

	Control	SLE group	*p*-value
Age (years)	44.67 ± 5.54	45.24 ± 6.08	0.59
BMI (kg/m^2)	21.03 ±1.51	21.41 ± 1.53	0.18
Systolic pressure (mm/Hg)	115.55 ± 10.81	113.91 ± 12.88	0.46
Diastolic pressure (mm/Hg)	75.22 ± 5.90	74.59 ± 6.02	0.57
Female (%)	83.33	86.21	0.66
HR (bmp)	74.92 ± 6.19	76.26 ± 7.69	0.30

Data are presented as mean ± standard deviation unless otherwise indicated.

Table II. Conventional echocardiographic analysis.

	Control	SLE group	*p*-value
LVEDDI (mm/m^2)	22.74 ± 1.16	24.54 ± 1.50*	< 0.001
LVESDI (mm/m^2)	13.46 ± 1.46	14.69 ± 1.28*	< 0.001
LVEDVI (ml/m^2)	42.89 ± 1.69	46.31 ± 2.60*	< 0.001
LVESVI (ml/m^2)	15.01 ± 1.33	16.55 ± 2.34*	< 0.001
LVPWT (mm)	8.18 ± 0.91	10.15 ± 1.35*	< 0.001
LVMI (g/m^2)	81.07 ± 11.20	102.95 ± 14.97*	< 0.001
LVEF (%)	64.95 ± 3.26	64 ± 3.97	0.25

Data are presented as mean ± standard deviation. *Represents compared with control group, $p < 0.05$.

Table III. 2D-STI parameters.

	Control	SLE group	*p*-value
PSD (ms)	23.12 ± 1.44	38.22 ± 5.42*	< 0.001
LVGLS (%)	-23.44 ± 2.10	-15.49 ± 2.27*	< 0.001

Data are presented as mean ± standard deviation. *Represents compared with control group, $p < 0.05$.

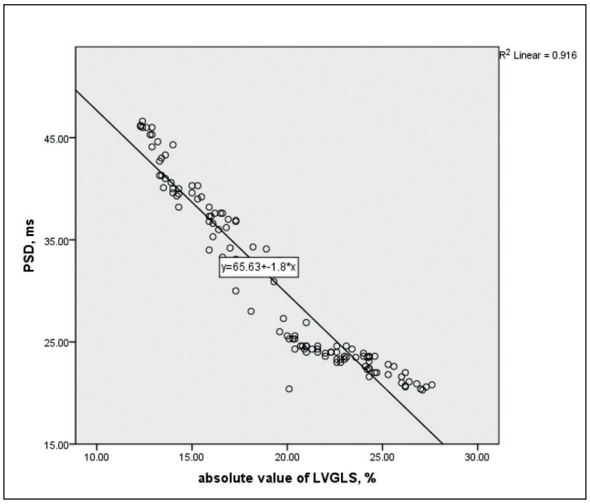

Figure 5. Linear correlation between PSD and absolute value of LVGLS.
Abbreviations: PSD: Peak strain dispersion; LVGLS: Left ventricular global longitudinal strain.

parameters estimated by 2D-STI. An increased PSD in patients with normal LVGLS has been showed by one study[23]. Because of the higher time and spatial resolution, 2D-STI technology is more advantageous in assessing PSD than real-time three-dimensional echocardiography (RT-3DE). In our study, we assessed the PSD using the 2D-STI, and remarkable differences between controls and SLE patients have been revealed.

Our results showed that the LV geometry changed in patients with SLE. Persistent inflammation and hormone therapies may lead to the development of vascular stiffness and LV hypertrophy.

To the best of our knowledge, this is the first evaluation of the correlation between PSD and LV geometry parameters and LVGLS in SLE patients. Our findings revealed impaired LVGLS in SLE patients, which is consistent with previous studies[11,12]. The increased PSD has also been detected by us, which is in accordance with the phenomenon found by Li et al[24]. Our study also demonstrated that the SLE duration and LV geometry parameters were significantly related to the PSD in SLE patients. Because of the deposition of immune complexes, the coronary artery disease and myocardial impairment may appear in SLE patients. Myocardial damage first involved the inner longitudinal myocardium, and thus lead to the impairment of myocardial longitudinal movement. Various factors, such as the deposition of immune complex, the damage of vascular endothelium, and the use of hormone drugs may be involved in LV remodeling in SLE patients and may lead to the impairment of LV synchrony. With the prolongation of the SLE duration, the persistent inflammation and hormone therapies, which have immunosuppressive effects, may lead to more advanced coronary artery diseases and the aggravation of LV remodeling. Then, the rhythm of myocardial electrical activity was further impaired. Further decrease of LVGLS and increase of PSD appeared because of the pathogenesis mentioned above. The good reproducibility of PSD, as measured by 2D-STI in SLE patients, has also been revealed by our study.

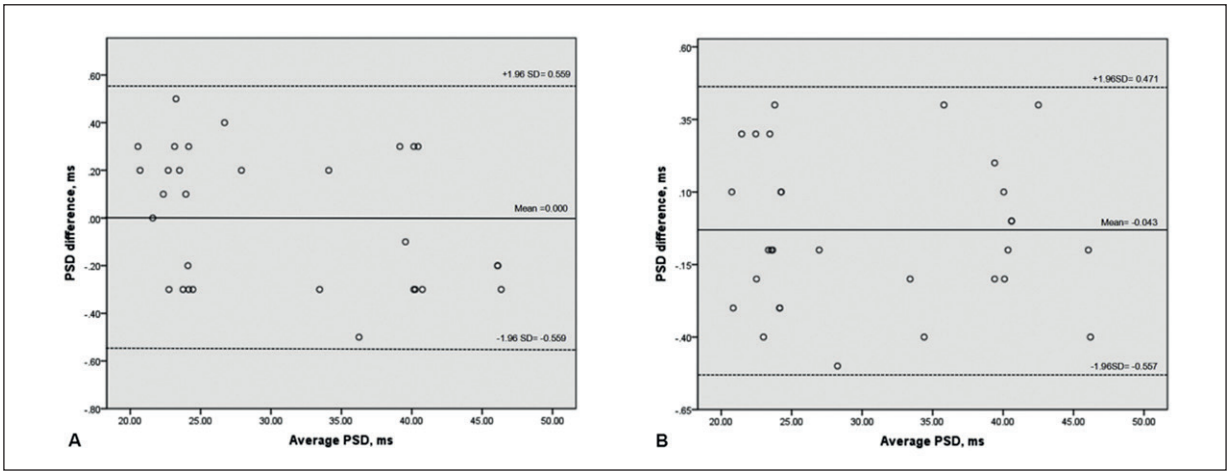

Figure 6. Bland-Altman analyses. **A,** Bland-Altman analysis of PSD obtained by 2D-STI showed that there was a high consistency in interobservers. **B,** Bland-Altman analysis of PSD obtained by 2D-STI showed that there was a high consistency in intraobserver.
Abbreviations: PSD: peak strain dispersion; 2D-STI: Two dimensional speckle tracking imaging.

The major limitation of the presented study is a single center experience with a small number of patients. Further multicenter studies of larger samples of SLE patients are needed to confirm our findings. In addition, the findings of the study could not be applied to patients with histories of cardiac involvements, who were therefore excluded from our study. Finally, this study lacked follow-up data, thereby we need to follow up the patients in a future study.

Conclusions

In SLE patients with no clinical cardiovascular disease and preserved LVEF, the LV systolic synchrony is abnormal. The use of the PSD allows an early, accurate, and quantitative evaluation of LV systolic synchrony in patients with SLE, facilitating early clinical interventions.

Conflict of Interest

The Authors declare that they have no conflict of interests.

Statement

All patients involved in this study gave their informed consent. Institutional review board's approval of our hospital was obtained for this study. Informed consent was obtained from all participants included in the study and the photographs in which a patient or another person is identifiable have been published with written permission from that person. The patients have agreed to the publication of the photographs. They have no restrictions on the publication of photographs.

Authors' Contribution

Xiang ji performed the research, wrote the main manuscript text, and prepared figures and tables. Both the authors reviewed the manuscript. Xia Zhang designed the study and carried out additional analyses.

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Compliance with Ethical Standards

The study protocol was approved by the ethics committee of the First Affiliated Hospital of Wannan Medical College, and informed consent was obtained from each patient's family.

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