Speckle tracking imaging combined with myocardial comprehensive index to evaluate left ventricular function changes in patients with systemic lupus erythematosus

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March 29, 2021

Abstract

Objective: To evaluate early changes in left ventricular systolic function in patients with systemic lupus erythematosus (SLE) using three-dimensional speckle tracking imaging (3D-STI). Methods: Thirty SLE patients and 30 healthy people (control group) were selected, the patients were further divided into subgroups according to their Safety of Estrogens in Lupus Erythematosus National Assessment version of the SLE Disease Activity Index (SELENA-SLEDAI) score: SELENA-SLEDAI [?] 12 (mild-to-moderate group), SELENA-SLEDAI $>$ 12 (severe group). Blood samples were obtained from patients and laboratory investigations were performed. All participants were examined using 3D-STI, the 3D conventional and strain parameters were obtained. The above parameters were compared in the three studied groups. Receiver operating curves (ROC) were prepared for above parameters and analyzed to identify correlations among LVEF, GLS, GCS, LVtw, Tor, MCI and hs-TropT. Results: Compared with the control group, the absolute values of LVEDV, LVEF, GLS, GCS, LVtw, Tor and MCI decreased, LV EDmass, LV ESmass and PSD increased in the mild-to-moderate and the severe groups (P2 $<$ 0.05, P3 $<$ 0.05). There was statistically significant difference in terms of strain parameters between the mild-to-moderate group and the severe group (P1 $<$ 0.05). The highest area under the ROC for MCI was 0.909, the highest sensitivity for MCI was 90.00%, and the highest specificity for Tor was 86.67%. Correlation analysis showed that there was a good correlation between the MCI and hs-TropT (r = - 0.677). Conclusion: 3D-STI technology may help detect early changes in left ventricular systolic function in patients with SLE

1 Introduction

Systemic lupus erythematosus (SLE) is a diffuse connective tissue disease that is characterized by an inflammatory immune response. The mortality rate of SLE is increasing year by year owing to its propensity to induce severe cardiovascular damage [1, 2]. Echocardiography is widely used in the detection of cardiac structure and function because of its unique advantages such as its dynamic and non-invasive nature; however, it cannot detect changes in cardiac function in the early stage of disease progression[3]. As a new technique that is superior to conventional two-dimensional echocardiography, three-dimensional speckle tracking imaging (3D-STI) can be used to evaluate left ventricular systolic function in the early stage of disease progression[4]. The purpose of this study was to use 3D-STI to detect the effect of SLE on left ventricular systolic function, to explore its application value, and to provide an objective diagnostic basis for clinical use.

Materials and Methods

2.1 Study Population

This study enrolled 30 SLE patients (SLE group) treated from September 2019 to July 2020. The patients were further divided into subgroups according to their SELENA-SLEDAI score: SELENA-SLEDAI [?] 12

(mild-to-moderate group), SELENA-SLEDAI > 12 (severe group). All patients met the diagnostic criteria of SLE established by the American Rheumatology Association (ACR) in 1997. Blood samples were obtained from all patients and laboratory investigations were performed: complete blood count, fasting glucose, low-density lipoproteins (LDL), anti-double stranded DNA (anti-dsDNA), complement component C3 (C3), complement component C4 (C4) and high sensitivity-TropT (hs-TropT). At the same time, 30 healthy people were selected as a control group. All participants were examined using 3D-STI to obtain relevant parameters. The inclusion and exclusion criteria are as follows: inclusion criteria: (1) accorded with the SLE classification standard of the ACR; (2) left ventricular ejection fraction (LVEF) > 55% in the SLE group, and age, sex body mass index et al were matched to the control group; (3) no cardiovascular risk factors and no history of heart disease or other autoimmune diseases; (4) patients in the SLE group were treated regularly and their condition was relatively stable. Exclusion criteria: (1) coexisting hypertension, coronary heart disease, diabetes mellitus, hyperlipidemia, valvular disease, pericardial disease, atrial fibrillation, congenital heart disease, or kidney disease; (2) other autoimmune diseases. All participants were informed of the aim of the study and agreed to participate. The participants signed an informed consent form before the examination, and approval was obtained from the Medical Ethics Committee.

Echocardiography

All participants underwent an echocardiographic examination. The images were collected by ultrasound diagnostic doctors with more than 10 years of experience. The participant was instructed to take the left recumbent position and the electrocardiograph was manually connected. Color Doppler ultrasonography (GE Vivid E9, probe: 4V, frequency: 1.5–4.0 MHz) was used, and the on-machine 3D-STI analysis software was used for post-processing. After the patient was instructed to hold their breath to display a two-dimensional image (clear apical four-chambers), the 4D mode was selected, and three consecutive and stable complete cardiac cycles were collected quickly and without interruption. The frame rate was then adjusted to 40% of the participant's maximal heart rate, and the image was stored. In the 4D auto LVQ mode, the software automatically tracked the boundaries of the left ventricular wall (endocardium and epicardium) during the complete cardiac cycle. The following 3D routine parameters were obtained: left ventricular end-diastolic volume (LVEDV), left ventricular end systolic volume (LVESV), left ventricular ejection fraction (LVEF), spherical index (SPI), left ventricular end diastolic mass (LV EDmass), and left ventricular end systolic mass (LV ESmass). Besides, the following 3D strain parameters were obtained simultaneously: global longitudinal strain (GLS), global circumferential strain (GCS), left ventricular twist angle (LVtw), torsion (Tor), and peak strain dispersion (PSD), myocardial comprehensive index (MCI = GLS × LVtw).

Statistical Analysis

SPSS 22.0 software was used for statistical analysis, and measurement data were expressed by $? \pm s$. Single factor analysis of variance (*ANOVA*) was used for inter-group comparison and the *LSD-t*method was used for pairwise comparison. Receiver operating characteristic (*ROC*) curve analysis was used to evaluate the diagnostic efficacy of the 3D-STI parameters on left ventricular systolic function in patients with SLE, the best cut-off point was determined, F and P values were calculated simultaneously. The correlation between 3D-STI parameters and hs-TropT was analyzed using Pearson's correlation analysis. Intra-group correlation coefficients (*ICC*) were calculated to assess repeatability between and within observers. The difference was statistically significant ($P < 0.05$).

Results

3.1 Baseline characteristics and laboratory results

Baseline characteristics of the study population are given in Table 1: compared with the mild-to-moderate group, the SELENA-SLEDAI was significantly higher in the severe group ($P < 0.05$). Laboratory results of the SLE patients are given in Table 2: compared with the mild-to-moderate group, the anti-dsDNA, C3, C4 and hs-TropT were significantly higher in the severe group ($P < 0.05$).

Table1: baseline characteristics of the study population

	mild-to-moderate group (n = 16)	severe group (n = 14)	control group (n = 30)	test	P
sex(f/m)	13/3	12/2	26/4	$\chi^2 = 0.247$	0.884
age(years)	42.38 ± 8.81	45.07 ± 7.93	46.30 ± 7.30	$F = 1.301$	0.280
BMI (kg/m^2)	24.88 ± 3.00	24.80 ± 3.18	25.04 ± 2.65	$F = 0.039$	0.961
HR (bpm)	75.56 ± 6.69	73.50 ± 11.37	72.63 ± 6.99	$F = 0.669$	0.511
SBP (mmHg)	111.06 ± 6.14	111.07 ± 6.32	112.30 ± 5.85	$F = 0.313$	0.732
DBP (mmHg)	72.13 ± 5.85	71.93 ± 5.33	71.87 ± 5.13	$F = 0.012$	0.988
Disease duration (months)	137.25 ± 69.16	153.93 ± 63.26	-	$t = 0.69$	0.499
SELENA-SLEDAI	5.75 ± 2.62	20.93 ± 7.77	-	$t = 7.37$	<0.001*

Note: BMI: body mass index; HR: heart rate; SBP: systolic blood pressure; DBP: diastolic blood pressure

*: $P < 0.05$

Table2: laboratory results of the SLE patients

	mild-to-moderate group (n = 16)	severe group (n = 14)	t	P
Hb (g/L)	115.69 ± 15.79	113.00 ± 12.06	0.518	0.609
Plt (10^9 /L)	247.69 ± 64.93	218.00 ± 66.90	1.232	0.228
glucose (mmol/L)	5.19 ± 0.65	5.30 ± 0.57	0.470	0.642
LDL (mmol/L)	6.25 ± 0.51	6.32 ± 0.48	0.389	0.700
anti-dsDNA (UI/l)	41.39 ± 18.47	820.61 ± 326.36	0.956	<0.001*
C3 (mg/L)	0.88 ± 0.33	0.63 ± 0.22	2.427	0.022*
C4 (mg/L)	0.24 ± 0.08	0.10 ± 0.05	5.371	<0.001*
hs-TropT (ng/L)	17.82 ± 8.45	24.03 ± 7.05	2.362	0.039*

Note: Hb: hemoglobin; PLT: platelets; LDL: low-density lipoprotein cholesterol; C3: complement component C3; C4: complement component C4; hs-TropT: high-sensitivity TropT

*: $P < 0.05$

3.2 Comparison of 3D conventional parameters

There was no statistically significant difference in terms of LVESV and SPI in the three studied groups (P = 0.151, 0.708, respectively). Meanwhile, LVEDV and LVEF was statistically significantly lower in the mild-to-moderate and the severe groups compared to the control group ($P_2 < 0.05$, $P_3 < 0.05$); LV EDmass and LV ESmass was statistically significantly higher in the mild-to-moderate and the severe groups compared to the control group ($P_2 < 0.05$, $P_3 < 0.05$). However, there was no statistically significant difference in terms of LVEDV, LVEF, LV EDmass and LV ESmass between the mild-to-moderate group and the severe group (P_1 = 0.999, 0.380, 0.144, 0.321, respectively). (Table 3)

Table3: Comparison of 3D Conventional Parameters

	mild-to-moderate group (n = 16)	severe group (n = 14)	control group (n = 30)	*P*
LVEDV (ml)	78.48 ± 18.64	78.48 ± 9.51	105.76 ± 10.66	<0.001*
Significance between groups:	Significance between groups:	Significance between groups:	Significance between groups:	Significance between groups:
$P_1 = 0.999$, $P_2 < 0.001^*$, $P_3 < 0.001^*$	$P_1 = 0.999$, $P_2 < 0.001^*$, $P_3 < 0.001^*$	$P_1 = 0.999$, $P_2 < 0.001^*$, $P_3 < 0.001^*$	$P_1 = 0.999$, $P_2 < 0.001^*$, $P_3 < 0.001^*$	$P_1 = 0.999$, $P_2 < 0.001^*$, $P_3 < 0.001^*$
LVESV (ml)	30.75 ± 3.01	28.49 ± 4.24	31.11 ± 4.67	0.151
LVEF (%)	60.19 ± 3.80	59.00 ± 3.74	62.80 ± 3.57	0.004*
Significance between groups:	Significance between groups:	Significance between groups:	Significance between groups:	Significance between groups:
$P_1 = 0.380$, $P_2 = 0.025^*$, $P_3 = 0.002^*$	$P_1 = 0.380$, $P_2 = 0.025^*$, $P_3 = 0.002^*$	$P_1 = 0.380$, $P_2 = 0.025^*$, $P_3 = 0.002^*$	$P_1 = 0.380$, $P_2 = 0.025^*$, $P_3 = 0.002^*$	$P_1 = 0.380$, $P_2 = 0.025^*$, $P_3 = 0.002^*$
SPI (%)	0.41 ± 0.04	0.40 ± 0.04	0.41 ± 0.05	0.708
LV EDmass (g)	136.66 ± 8.73	140.64 ± 5.75	123.00 ± 7.21	<0.001*
Significance between groups:	Significance between groups:	Significance between groups:	Significance between groups:	Significance between groups:
$P_1 = 0.144$, $P_2 < 0.001^*$, $P_3 < 0.001^*$	$P_1 = 0.144$, $P_2 < 0.001^*$, $P_3 < 0.001^*$	$P_1 = 0.144$, $P_2 < 0.001^*$, $P_3 < 0.001^*$	$P_1 = 0.144$, $P_2 < 0.001^*$, $P_3 < 0.001^*$	$P_1 = 0.144$, $P_2 < 0.001^*$, $P_3 < 0.001^*$
LV ESmass (g)	140.51 ± 6.03	142.52 ± 4.30	128.27 ± 5.65	<0.001*
Significance between groups:	Significance between groups:	Significance between groups:	Significance between groups:	Significance between groups:
$P_1 = 0.321$, $P_2 < 0.001^*$, $P_3 < 0.001^*$	$P_1 = 0.321$, $P_2 < 0.001^*$, $P_3 < 0.001^*$	$P_1 = 0.321$, $P_2 < 0.001^*$, $P_3 < 0.001^*$	$P_1 = 0.321$, $P_2 < 0.001^*$, $P_3 < 0.001^*$	$P_1 = 0.321$, $P_2 < 0.001^*$, $P_3 < 0.001^*$

Note: P_1 : compares between mild-to-moderate group and severe group; P_2 : compares between mild-to-moderate group and control group; P_3 : compares between severe group and control group; *: $P < 0.05$

LVEDV: left ventricular end-diastolic volume; LVESV: left ventricular end systolic volume; LVEF: left ventricular ejection fraction; SPI: spherical index; LV EDmass: left ventricular end diastolic mass; LV ESmass: left ventricular end systolic mass

3.3 Comparison of 3D strain parameters

There was a statistically significantly decrease in GLS, GCS, LVtw, Tor and MCI in the mild-to-moderate and severe groups compared to the control group ($P_2 < 0.05$,$P_3 < 0.05$). There was a statistically significantly increase in PSD in the mild-to-moderate and severe groups compared to the control group ($P_2 < 0.05$, $P_3 < 0.05$). There was statistically significant difference in terms of 3D strain parameters between the mild-to-moderate group and the severe group ($P_1 < 0.05$). (Table 4, Figure 1-4)

Table4: Comparison of 3D Strain Parameters

	mild-to-moderate group (n = 16)	severe group (n = 14)	control group (n = 30)	*P*
GLS (%)	18.50 ± 1.97	16.57 ± 2.38	20.43 ± 2.36	<0.001*

	mild-to-moderate group (n = 16)	severe group (n = 14)	control group (n = 30)	*P*
Significance between groups: $P_1 = 0.024^*$, $P_2 = 0.008^*$, $P_3 < 0.001^*$	Significance between groups: $P_1 = 0.024^*$, $P_2 = 0.008^*$, $P_3 < 0.001^*$	Significance between groups: $P_1 = 0.024^*$, $P_2 = 0.008^*$, $P_3 < 0.001^*$	Significance between groups: $P_1 = 0.024^*$, $P_2 = 0.008^*$, $P_3 < 0.001^*$	Significance between groups: $P_1 = 0.024^*$, $P_2 = 0.008^*$, $P_3 < 0.001^*$
GCS (%)	20.56 ± 2.06	17.29 ± 2.89	22.17 ± 2.55	$<0.001^*$
Significance between groups: $P_1 = 0.001^*$, $P_2 = 0.044^*$, $P_3 < 0.001^*$	Significance between groups: $P_1 = 0.001^*$, $P_2 = 0.044^*$, $P_3 < 0.001^*$	Significance between groups: $P_1 = 0.001^*$, $P_2 = 0.044^*$, $P_3 < 0.001^*$	Significance between groups: $P_1 = 0.001^*$, $P_2 = 0.044^*$, $P_3 < 0.001^*$	Significance between groups: $P_1 = 0.001^*$, $P_2 = 0.044^*$, $P_3 < 0.001^*$
LVtw (°)	11.36 ± 2.21	9.59 ± 2.27	13.76 ± 1.82	$<0.001^*$
Significance between groups: $P_1 = 0.021^*$, $P_2 < 0.001^*$, $P_3 < 0.001^*$	Significance between groups: $P_1 = 0.021^*$, $P_2 < 0.001^*$, $P_3 < 0.001^*$	Significance between groups: $P_1 = 0.021^*$, $P_2 < 0.001^*$, $P_3 < 0.001^*$	Significance between groups: $P_1 = 0.021^*$, $P_2 < 0.001^*$, $P_3 < 0.001^*$	Significance between groups: $P_1 = 0.021^*$, $P_2 < 0.001^*$, $P_3 < 0.001^*$
Tor (°/cm)	1.48 ± 0.25	1.15 ± 0.29	1.83 ± 0.24	$<0.001^*$
Significance between groups: $P_1 = 0.001^*$, $P_2 < 0.001^*$, $P_3 < 0.001^*$	Significance between groups: $P_1 = 0.001^*$, $P_2 < 0.001^*$, $P_3 < 0.001^*$	Significance between groups: $P_1 = 0.001^*$, $P_2 < 0.001^*$, $P_3 < 0.001^*$	Significance between groups: $P_1 = 0.001^*$, $P_2 < 0.001^*$, $P_3 < 0.001^*$	Significance between groups: $P_1 = 0.001^*$, $P_2 < 0.001^*$, $P_3 < 0.001^*$
PSD (ms)	33.71 ± 4.70	41.80 ± 4.06	23.60 ± 5.77	$<0.001^*$
Significance between groups: $P_1 < 0.001^*$, $P_2 < 0.001^*$, $P_3 < 0.001^*$	Significance between groups: $P_1 < 0.001^*$, $P_2 < 0.001^*$, $P_3 < 0.001^*$	Significance between groups: $P_1 < 0.001^*$, $P_2 < 0.001^*$, $P_3 < 0.001^*$	Significance between groups: $P_1 < 0.001^*$, $P_2 < 0.001^*$, $P_3 < 0.001^*$	Significance between groups: $P_1 < 0.001^*$, $P_2 < 0.001^*$, $P_3 < 0.001^*$
MCI (% × °)	209.08 ± 41.96	158.16 ± 39.15	281.15 ± 50.47	$<0.001^*$
Significance between groups: $P_1 = 0.004^*$, $P_2 < 0.001^*$, $P_3 < 0.001^*$	Significance between groups: $P_1 = 0.004^*$, $P_2 < 0.001^*$, $P_3 < 0.001^*$	Significance between groups: $P_1 = 0.004^*$, $P_2 < 0.001^*$, $P_3 < 0.001^*$	Significance between groups: $P_1 = 0.004^*$, $P_2 < 0.001^*$, $P_3 < 0.001^*$	Significance between groups: $P_1 = 0.004^*$, $P_2 < 0.001^*$, $P_3 < 0.001^*$

Note: P_1 : compares between mild-to-moderate group and severe group; P_2 : compares between mild-to-moderate group and control group; P_3 : compares between severe group and control group; *: $P < 0.05$

GLS: global longitudinal strain; GCS: global circumferential strain; LVtw: left ventricular twist angle; Tor: torsion; PSD: peak strain dispersion; MCI: myocardial comprehensive index

Figure 1: Comparison of 3D-STI Strain Parameters GLS in the three studied groups. A: mild-to-moderate group; B: severe group; C: control group

Figure 2: Comparison of 3D-STI Strain Parameters GCS in the three studied groups. A: mild-to-moderate group; B: severe group; C: control group

Figure3: Comparison of 3D-STI Strain Parameters LVtw in the three studied groups. A: mild-to-moderate

group; B: severe group; C: control group

Figure4: Comparison of 3D-STI Strain Parameters Tor in the three studied groups. A: mild-to-moderate group; B: severe group; C: control group

3.4 Diagnostic efficiency of 3D strain parameters

The areas under the curve (AUC) of LVtw, Tor, and MCI were all > 0.8 ($P< 0.05$), the sensitivity and specificity were all $> 60\%$, and the Youden indices were all > 0.5. Among them, the AUC of the MCI was the highest (0.909), the sensitivity of MCI was the highest (90.00%), and the specificity of Tor was the highest (86.67%) (Table 5, Figure 5).

Table 5. ROC Curve of 3D-STI Parameters in the Diagnosis of Cardiac Function in Patients with SLE

Parameters	Threshold (%)	AUC	Sensitivity (%)	Specificity (%)	Youden index
LVEF (%)	60.0	0.720	53.33	80.00	0.33
GLS (%)	18	0.818	66.67	80.00	0.47
GCS (%)	21	0.789	80.00	63.33	0.43
LVtw (°)	12.9	0.874	83.33	80.00	0.63
Tor (°/cm)	1.6	0.898	86.67	86.67*	0.73
MCI (%×°)	237.8	0.909*	90.00*	80.00	0.70

Note: *: $P < 0.05$

Figure 5: ROC Curve of 3D-STI Parameters in the Diagnosis of Cardiac Function in Patients with SLE

3.5 Correlation analysis between the 3D strain parameters and hs-TropT

All parameters were negatively correlated with hs-TropT ($P< 0.01$), and the absolute values were as follows: MCI > Tor > LVtW > GLS > GCS > LVEF (Table 6).

Table 6: Correlation between 3D-STI Parameters and hs-TropT

	LVEF	GLS (%)	GCS (%)	LVtw (°)	Tor (°/cm)	MCI
r	-0.338	-0.415	-0.365	-0.523	-0.578	-0.677
P	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

3.6 Repeatability test of 3D strain parameters

The intra-observer and inter-observer parameters showed that the intra-group repeatability test intraclass correlation coefficient (ICC) of the left ventricular Tor and MCI were 0.868 and 0.899, respectively, and the inter-group repeatability test $ICCs$ were 0.878 and 0.894, respectively; this indicated that the reliability and repeatability of the above parameters were relatively high (Figure 6).

Figure 6: 3D strain Parameters: Left ventricular Tor and MCI repeatability test (Bland–Altman diagram)

Discussion

As an autoimmune disease with the ability to impart chronic damage to multiple organs, SLE is characterized by remission and deterioration. Moreover, cardiovascular damage is an important cause of death and is becoming increasingly serious [5]. However, heart damage is often hidden in the early stage and can be easily ignored; if it can be detected earlier, prevention will be of great significance to the prognosis of the disease [6]. At the point when heart damage in SLE can be detected by two-dimensional ultrasound, the myocardium is seriously damaged, and the possibility of recovery is low. The 3D-STI technique eliminates

the plane limitation of two-dimensional ultrasound and allows for comprehensive analysis of left ventricular wall motion such that the actual situation of the left ventricle is accurately reflected [7].

Compared with the control group, this study showed that LVEF and LVEDV in the mild-to-moderate and the severe groups decreased significantly, LV EDmass, and LV ESmass increased significantly. There was no statistically significant difference in terms of LVESV in the three studied groups. Moreover, although SPI reflected left ventricular geometry, there was no significant difference in the three studied groups, indicating that the early left ventricular systolic function may be locally impaired in SLE; however, the decline in function is not obvious, and the overall function is still within the normal range [8]. At the same time, there was a statistically significantly decrease in GLS, GCS and LVtw in the mild-to-moderate and severe groups compared to the control group, indicating that the left ventricular systolic function is damaged in the early stage. This may be due to fact that SLE can lead to the deposition of immune complexes in the cardiovascular system or inflammatory changes after complement activation that result in the degeneration of collagen fibers in the myocardial interstitium. Ultimately, this leads to damage to myocardial systolic function, which is consistent with the findings of Huang et al[9].

The results also showed that the sensitivity, specificity, and AUC of Tor were higher than those of GLS and GCS, indicating that LVtw may be a better index to reflect the changes in left ventricular systolic function than the three-dimensional strain GLS and GCS, whereas GLS is more sensitive in the three-dimensional strain[10]. This may be due to the high sensitivity of subendocardial myocardium to ischemia, so coronary artery lesions, endocarditis and myocardial metabolic disorders occur in patients with SLE. These lesions are the first to cause longitudinal myocardial injury, which lead to a decrease in systolic motor function along the long axis of the myocardium. Therefore, we conclude that the overall longitudinal strain of the left ventricle should be more sensitive to changes in ventricular systolic function than the circumference. Left ventricular torsion is also affected by the degree of myocardial contraction, the arrangement of endomyocardial muscle fibers, and the contraction balance. This is because the outer myocardial torque is larger and the contraction torque is greater. The left ventricular torsion direction is consistent with the outer myocardial rotation direction. SLE leads to a decrease in left ventricular myocardial elastic deformation ability, torsion abnormality, and amplitude, thus reflecting a decrease in left ventricular systolic function more accurately [11].

However, during collection, we found that the lack of clear anatomical reference in the apical part of the left ventricle led to differences in the location of LVtw in different patients, resulting in measurement errors. Therefore, the left ventricular Tor, which avoids this error, can be introduced as another index to evaluate left ventricular systolic function [12]. It was found that there was a statistically significantly decrease in Tor in the mild-to-moderate and severe groups compared to the control group, indicating that Tor can be used as an effective index to reflect the myocardial damage caused by SLE in the early stage. The ROC curve also showed that the sensitivity, specificity, and AUC of Tor were higher than those of LVtw, indicating that left ventricular Tor may reflect changes in left ventricular systolic function better than LVtw, with higher repeatability. At the same time, we found that myocardial deformation in the three-dimensional space is caused by myocardial strain and torsional motion. Thus, the new parameter MCI, which is composed of GLS and LVtw, may be used to evaluate left ventricular systolic function more comprehensively. The results showed that there was a statistically significantly decrease in MCI in the mild-to-moderate and severe groups compared to the control group, and the repeatability was high. The ROC curve showed the highest area and sensitivity under the left ventricular MCI curve, which was consistent with the results of Mornos et al, indicating that no single form of exercise can fully reflect the movement of the left ventricular myocardium [13]. At the same time, correlation analysis showed that there was a good correlation between MCI and hs-TropT [14]. Therefore, MCI can be used as a new sensitive index for the early detection of SLE heart injury and provide a basis for clinical intervention, timely adjustment, or change of drugs to avoid aggravation of myocardial damage, resulting in irreversible myocardial injury.

PSD is the standard deviation of the peak time of the longitudinal strain in 17 segments of the left ventricle. There was a statistically significantly increase in PSD in the mild-to-moderate and severe groups compared

to the control group, indicating that the dispersion of myocardial mechanical motion is increased, that is, myocardial systolic synchronization is worse [15]. It has been suggested that the deposition of SLE-associated immune complexes in the cardiovascular system may lead to degeneration of cardiomyocytes and myocardial sympathetic nerves, which directly leads to the damage of the normal function of cardiomyocytes and the dysfunction of nerve fibers in the myocardial layer; this, in turn, has a serious impact on myocardial synchronous movement.

Limitations

The limitations of this study are as follows: (1) the image must be clear and of high quality; (2) the inspection operation and image post-processing greatly depend on the accuracy of human operation; (3) the sample size is small; (4) there are individual differences.

Conclusion

SLE can cause left ventricular systolic function damage in the early stage, and 3D-STI can be used to monitor myocardial subclinical injury at the early stage. The new parameters, including MCI and Tor, are particularly relevant as they can provide an objective imaging basis for early clinical diagnosis of left ventricular myocardial involvement and guide prognosis in patients with SLE.

Conflict of interest disclosure statement

The authors declare that they have no conflict of interest.

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