Speckle Tracking Imaging Combined With Myocardial Comprehensive Index to Evaluate Left Ventricular Function Changes in Patients With Systemic Lupus Erythematosus

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Original Article

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

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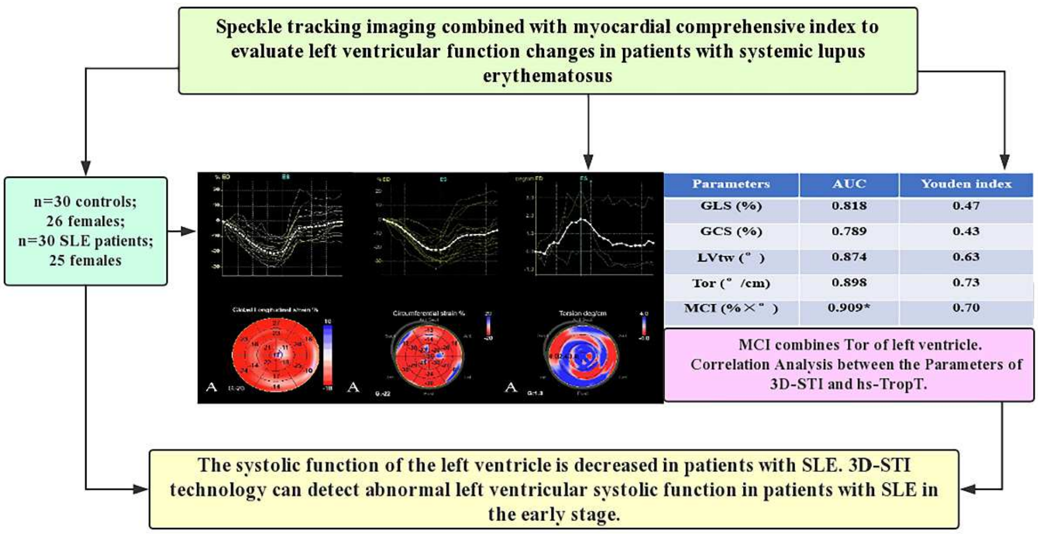
【Abstract】

Objective: To evaluate left ventricular systolic function in patients with systemic lupus erythematosus (SLE) using three-dimensional speckle tracking imaging (3D-STI). **Methods:** Thirty patients with SLE (SLE group) and 30 healthy people (control group) were examined using 3D-STI, and their clinical characteristics were collected. The following conventional 3D 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). The following 3D-STI strain parameters were obtained: global longitudinal strain (GLS), global circumferential strain (GCS), left ventricular twist angle (LVtw), torque (Tor), peak strain dispersion (PSD), and myocardial comprehensive index (MCI). Statistical analysis was used to analyze the differences in the above indicators among the groups and their correlations. **Results:** LVEDV and LVEF decreased; LV EDmass and LV ESmass increased; GLS, GCS, LVtw, Tor, and MCI decreased; and PSD increased in the SLE group compared with the control group (P < 0.05). The receiver operating characteristic curve showed that the area under the curve of the MCI was the highest (0.909), the sensitivity of the MCI was the highest (90.00%), and the specificity of the Tor was the highest (86.67%). Correlation analysis showed that there was a good correlation between the MCI and hs-TropT. **Conclusion:** The systolic function of the left ventricle is decreased in patients with SLE. 3D-STI technology can detect abnormal left ventricular systolic function in patients with SLE in the early stage.

Graphic abstract



【Keywords】 Systemic lupus erythematosus, speckle tracking imaging technique, myocardial index, left ventricle, synchrony

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 stages 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[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.

1 Materials and Methods

1.1 Study Population

From September 2019 to July 2020, 30 SLE patients (SLE group) in the Department of Hematology of the First Affiliated Hospital of Medical College of Shihezi University were randomly selected. The SLE activity index was used to evaluate the condition of the patients, all of whom met the diagnostic criteria established by the American Rheumatology Association (ACR) in 1997. At the same time, 30 healthy people were selected as a control group. All patients 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 of the First Affiliated Hospital of Medical College of Shihezi University.

1.2 Inclusion and Exclusion Criteria

1.2.1 Inclusion Criteria

① Accorded with the SLE classification standard of the ACR

② left ventricular ejection fraction (LVEF) > 50% in the SLE group, and age-, sex-, height-, and weight-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

1.2.2 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

1.3 Instruments and Methods

Clinical characteristics such as age, BMI, and biochemical indices were collected. Color Doppler ultrasonography (GE Vivid E9, probe: 4V, frequency: 1.5–4.0 MHz) was used. Briefly, the patient was instructed to take the left recumbent position, the electrocardiograph was manually connected, and the on-machine 3D-STI analysis software was used. After the patient was instructed to hold their breath to display a two-dimensional image (clear apical four chambers), the 3D mode was selected, and three dynamic and stable cardiac cycles were collected quickly and without interruption. The frame rate was then adjusted (≥ heart rate × 40%), and the image was stored. The following routine 3D parameters were obtained by tracking the boundaries of the left ventricular wall (endocardium and epicardium) during the complete cardiac cycle: 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). 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). The myocardial comprehensive index (MCI) was then calculated.

1.4 Statistical Analysis

SPSS 22.0 software was used for statistical analysis, and measurement data were expressed by $\bar{x} \pm s$. Single factor analysis of variance 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 3D-STI parameters on left ventricular systolic function in patients with SLE and to determine the best cut-off point of some of the parameters. The correlation between 3D-STI parameters and hs-TropT was analyzed using Pearson's correlation analysis. The image data of ten patients were randomly selected and measured repeatedly by two deputy chief ultrasound diagnostic doctors with > 10 years of experience. The reliability analysis was used for the repeatability test among observers. The image data of ten randomly selected patients were measured twice by the deputy chief ultrasound diagnostic physician with > 10 years of experience. The reliability analysis was used for the repeatability test within the observers. The difference was statistically significant ($P < 0.05$).

2 Results

2.1 Baseline Characteristics of the Study Population

Compared with the control group, the systolic blood pressure and the hs-TropT were significantly higher in the SLE group ($P < 0.01$). There was no significant difference between the other general data of the SLE group and the control group ($P > 0.05$) (Table 1).

Table 1. Clinical Characteristics of SLE Patients and Controls

Group	Controls	SLE	*P*
Age(years)	46.30±7.30	43.63±8.38	0.194
Gender(F/M)	26/4	25/5	0.723
Body mass index (kg/m2)	25.04±2.64	24.84±3.03	0.786
Heart rate (bpm)	72.65±7.00	74.60±9.07	0.356
Systolic blood pressure (mmHg)	112.30±5.85	121.90±7.32*	<0.001
Diastolic blood pressure (mmHg)	71.87±5.13	72.03±5.52	0.904
Disease duration (months)	-	145.03±65.87	-
Complement C3 (mg/L)	-	101.73±17.24	-
Complement C4 (mg/L)	-	21.80±6.09	-
High sensitivity-TropT (ng/L)	2.42±1.18	20.40±8.92*	<0.001

2.2 Comparison of 3D Conventional Ultrasonic Parameters

Compared with the control group, LVEF and LVEDV were decreased, and LV EDmass and LV

ESmass were increased in the SLE group ($P < 0.05$) (Table 2).

Table 2. Comparison of 3D Conventional Ultrasonic Parameters

Group	Controls	SLE	*t*	*P*
LVEDV(mL)	105.75±10.65	78.48±14.84*	8.176	<0.001
LVESV(mL)	31.11±4.66	29.69±3.75	1.299	0.199
LVEF(%)	62.80±3.56	59.63±3.75*	3.349	0.001
SPI(%)	0.41±0.05	0.40±0.04	0.835	0.407
LV EDmass(g)	123.00±7.21	138.52±7.64*	8.093	<0.001
LV ESmass(g)	128.27±5.65	141.45±5.31*	9.314	<0.001

Note: Compared with the 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.

2.3 Comparison of 3D-STI strain parameters

Compared with the control group, GLS, GCS, LVtw, Tor, and MCI were decreased, and PSD was increased in the SLE group (Table 3, Figure 1-4).

Table 3. Comparison of the Relative Strain Parameters of 3D-STI ($\bar{x} \pm s$, n = 30)

Group	Controls	SLE	*t*	*P*
GLS(%)	20.43±2.36	17.60±2.34*	4.668	<0.001
GCS(%)	22.16 ±2. 55	19.03±2.95*	4.400	<0.001
LVtw(°)	13.76±1.82	10.54±2.38*	5.888	<0.001
Tor(°/cm)	1.83±0.25	1.32±0.31*	6.970	<0.001
PSD(ms)	23.60±5.77	37.49±5.97*	9.163	<0.001
MCI(%×°)	281.35 ±50.51	185.40±47.43*	7.584	<0.001

Note: *Compared with the control group, $P < 0.05$; GLS: Global longitudinal strain, GCS: Global circumferential strain, LVtw: Left ventricular twist angle, Tor: Torque, PSD: Peak strain dispersion, MCI: Myocardial comprehensive index.

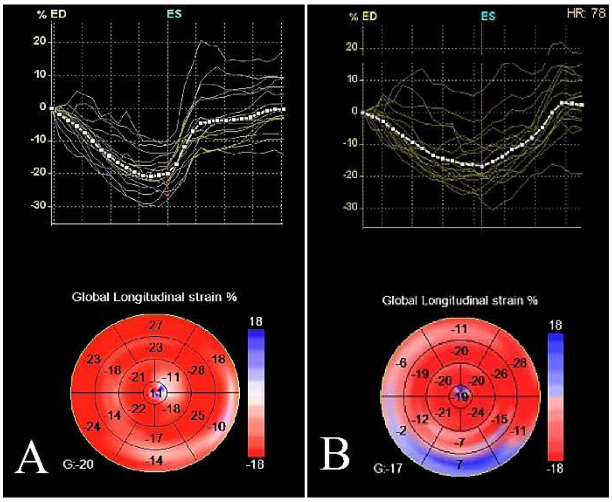


Figure 1. Comparison of 3D-STI Strain Parameters GLS Between the Control Group and the SLE Group. A: Control group; B: SLE group

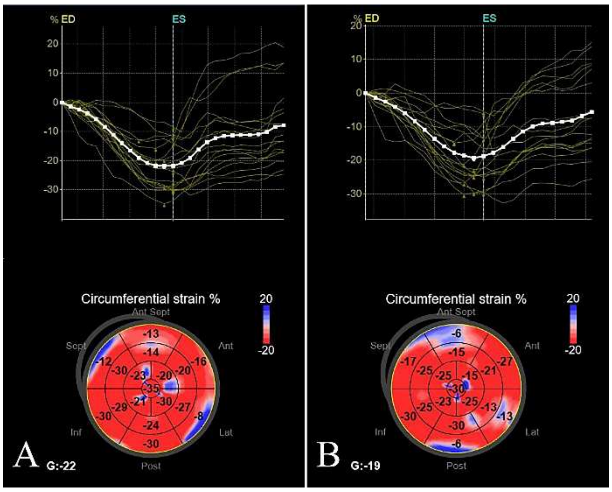


Figure 2. Comparison of 3D-STI Strain Parameters GCS Between the Control Group and the SLE Group. A: Control group; B: SLE group

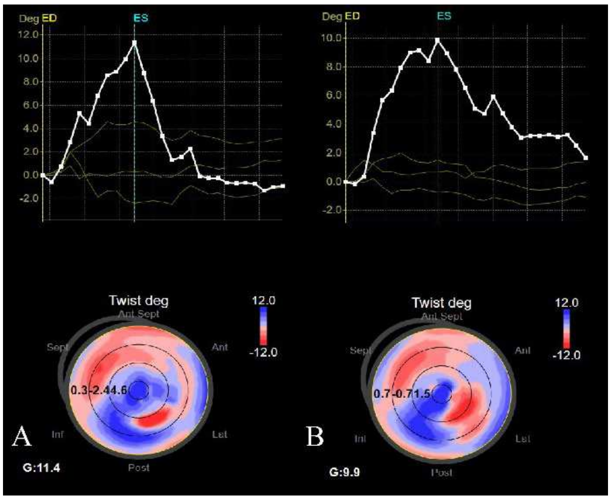


Figure3. Comparison of 3D-STI Strain Parameters LVtw Between the Control Group and the SLE

Group. A: Control group; B: SLE group

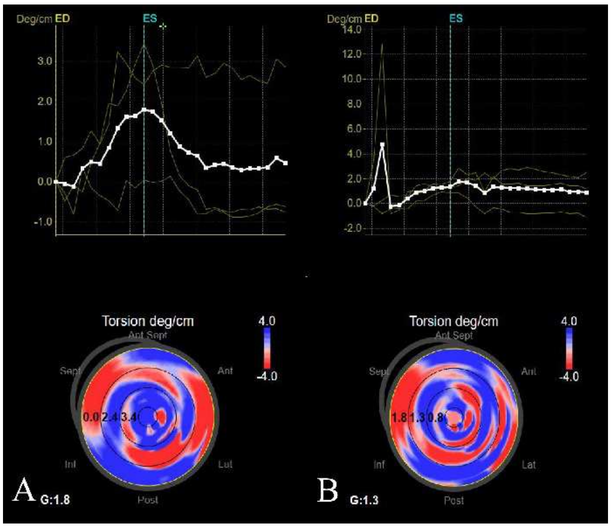


Figure4. Comparison of 3D-STI Strain Parameters Tor Between the Control Group and the SLE Group. A: Control group; B: SLE group

2.4 Diagnostic Efficiency of 3D-STI Parameters

The areas under the curve (AUCs) 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 (0.909) of the MCI was the highest, the sensitivity of MCI was the highest (90.00%), and the specificity of Tor was the highest (86.67%) (Table 4, Figure 5).

Table 4. 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

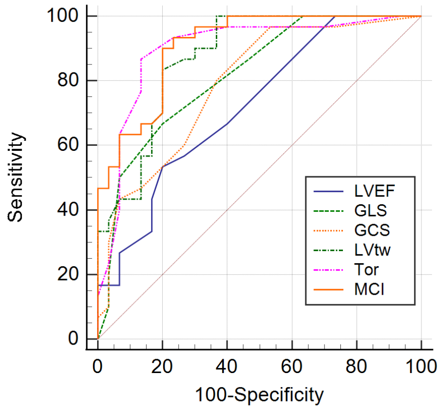


Figure 5. ROC Curve of 3D-STI Parameters in the Diagnosis of Cardiac Function in Patients with SLE

2.5 Correlation Analysis between the Parameters of 3D-STI 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 5).

Table 5. Correlation between 3D-STI and hs-TropT Parameters

	LVEF	GLS (%)	GCS (%)	LVtw (°)	Tor (°/cm)	MCI
r	-0.356	-0.490	-0.423	-0.540	-0.574	-0.636
P	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

2.6 Repeatability Test of 3D-STI-Related 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).

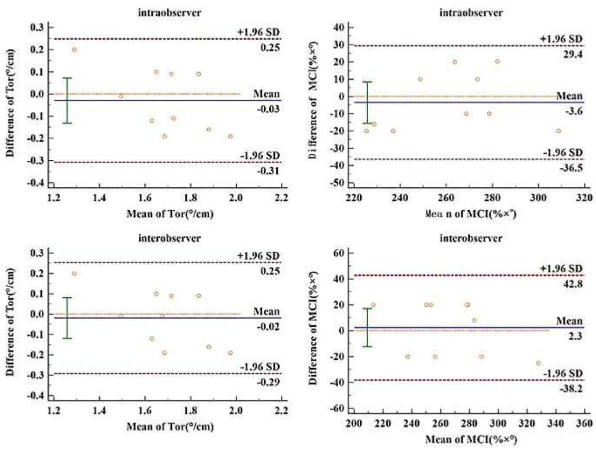


Figure 6. 3D-STI Parameters: Left ventricular Tor and MCI repeatability test (Bland–Altman diagram)

3 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].

This study showed that LVEF in the SLE group decreased significantly, LVEDV, LV EDmass, and LV ESmass increased significantly, and LVESV had no significant change compared with the control group. Moreover, although SPI reflected left ventricular geometry, there was no significant difference, 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, the results showed that the three-dimensional strain parameters of the left ventricle (GLS, GCS, and LVtw) decreased in the SLE group, indicating that the left ventricular systolic function is damaged in the early stage. This may be due to the 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 the left ventricular Tor in the SLE group was lower than that in 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 MCI decreased significantly in the SLE 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. The PSD in the SLE group was higher than that in 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.

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.

4 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.

Compliance with ethical standards

Conflict of Interest: The authors declare that they have no conflict of interest.

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Figures

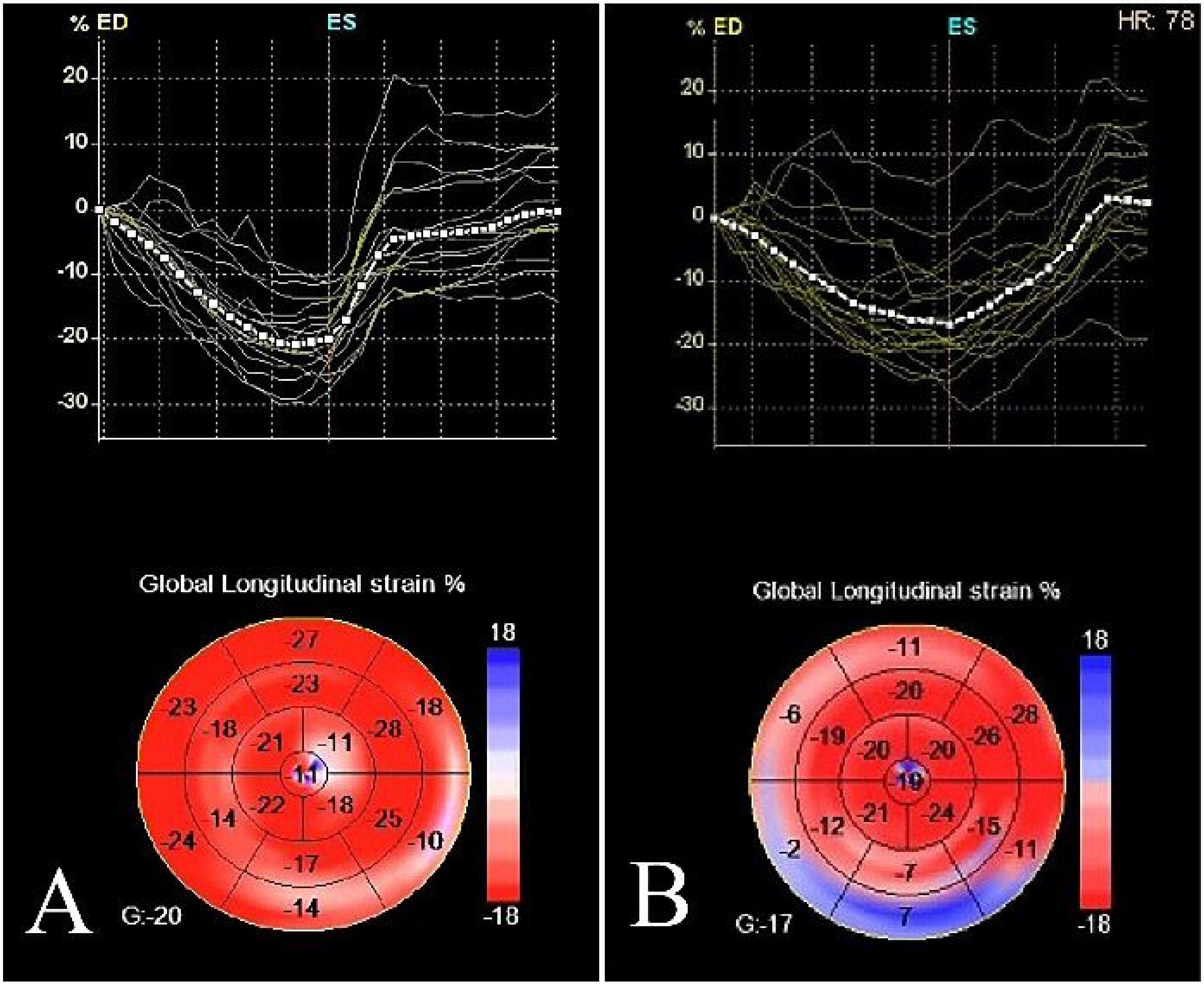

Figure 1

Comparison of 3D-STI Strain Parameters GLS Between the Control Group and the SLE Group. A: Control group; B: SLE group

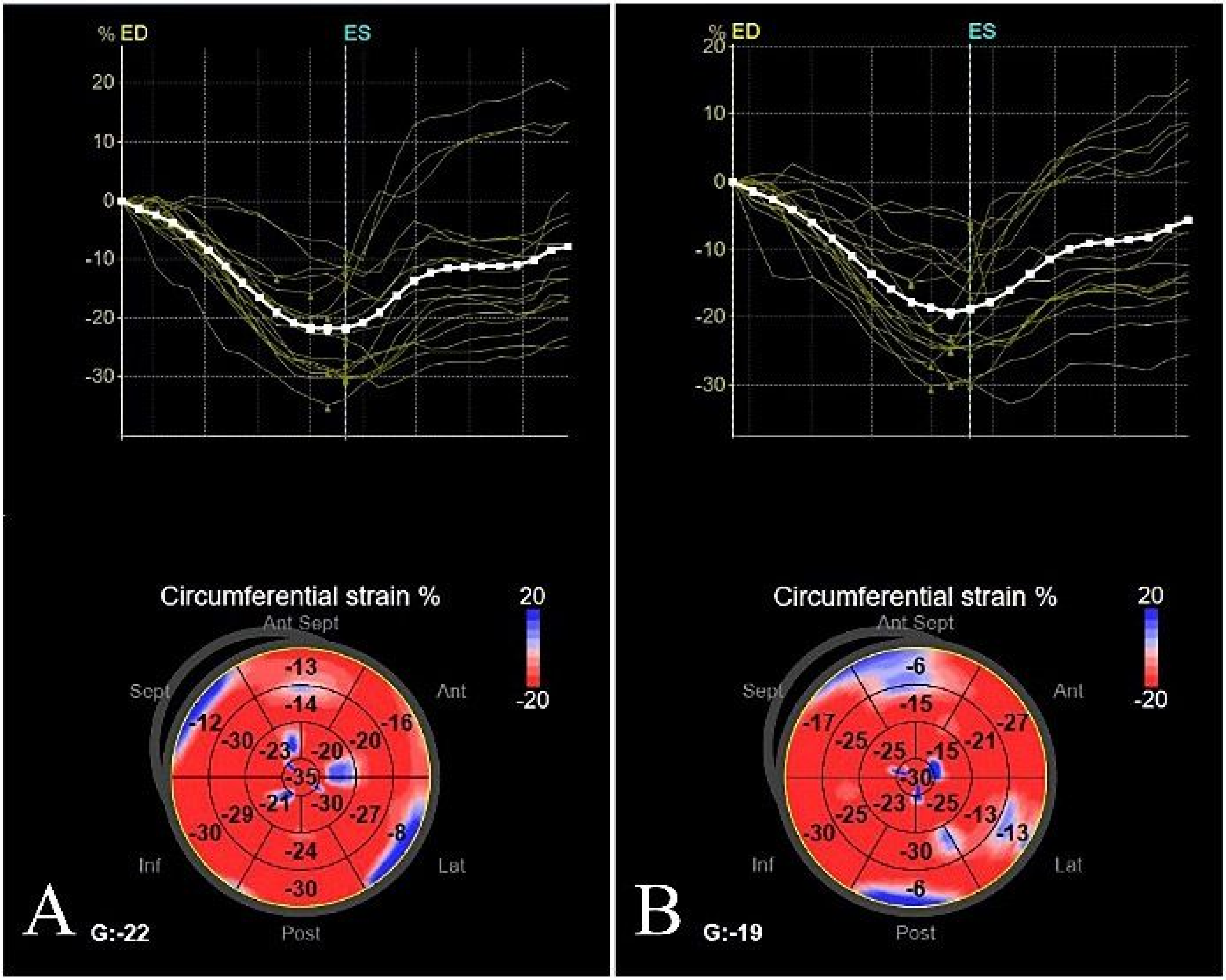

Figure 2

Comparison of 3D-STI Strain Parameters GCS Between the Control Group and the SLE Group. A: Control group; B: SLE group

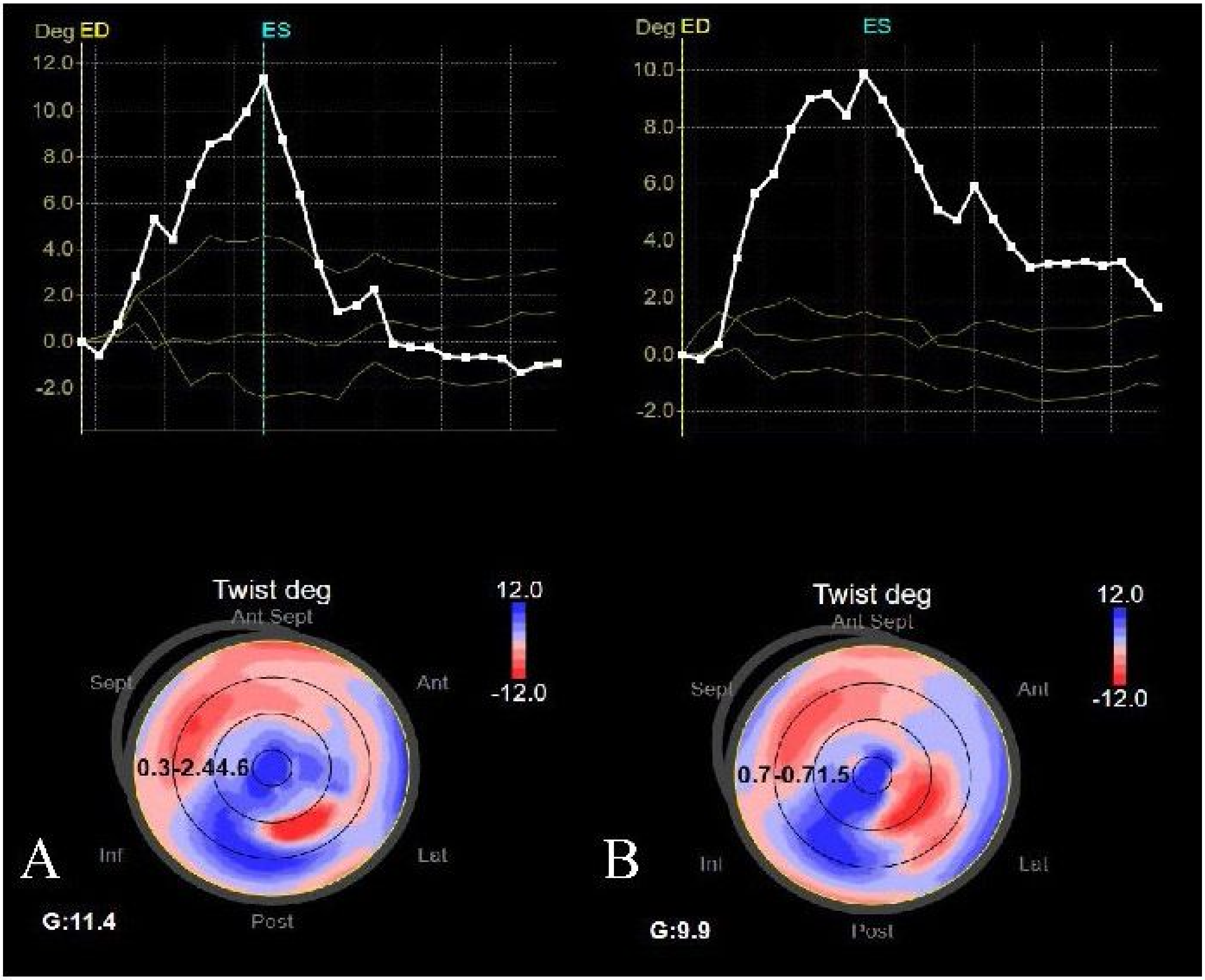

Figure 3

Comparison of 3D-STI Strain Parameters LVtw Between the Control Group and the SLE Group. A: Control group; B: SLE group

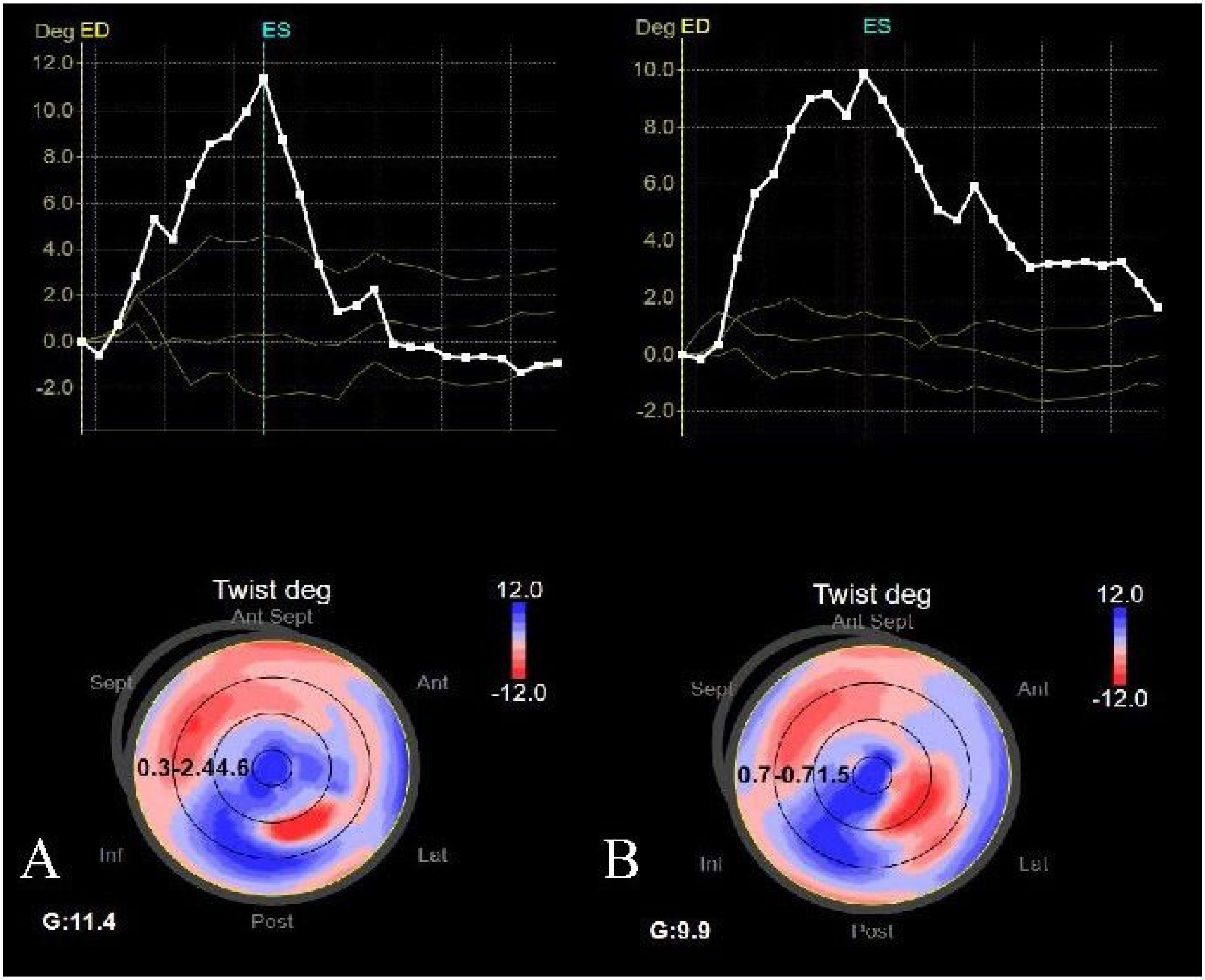

Figure 4

Comparison of 3D-STI Strain Parameters Tor Between the Control Group and the SLE Group. A: Control group; B: SLE group

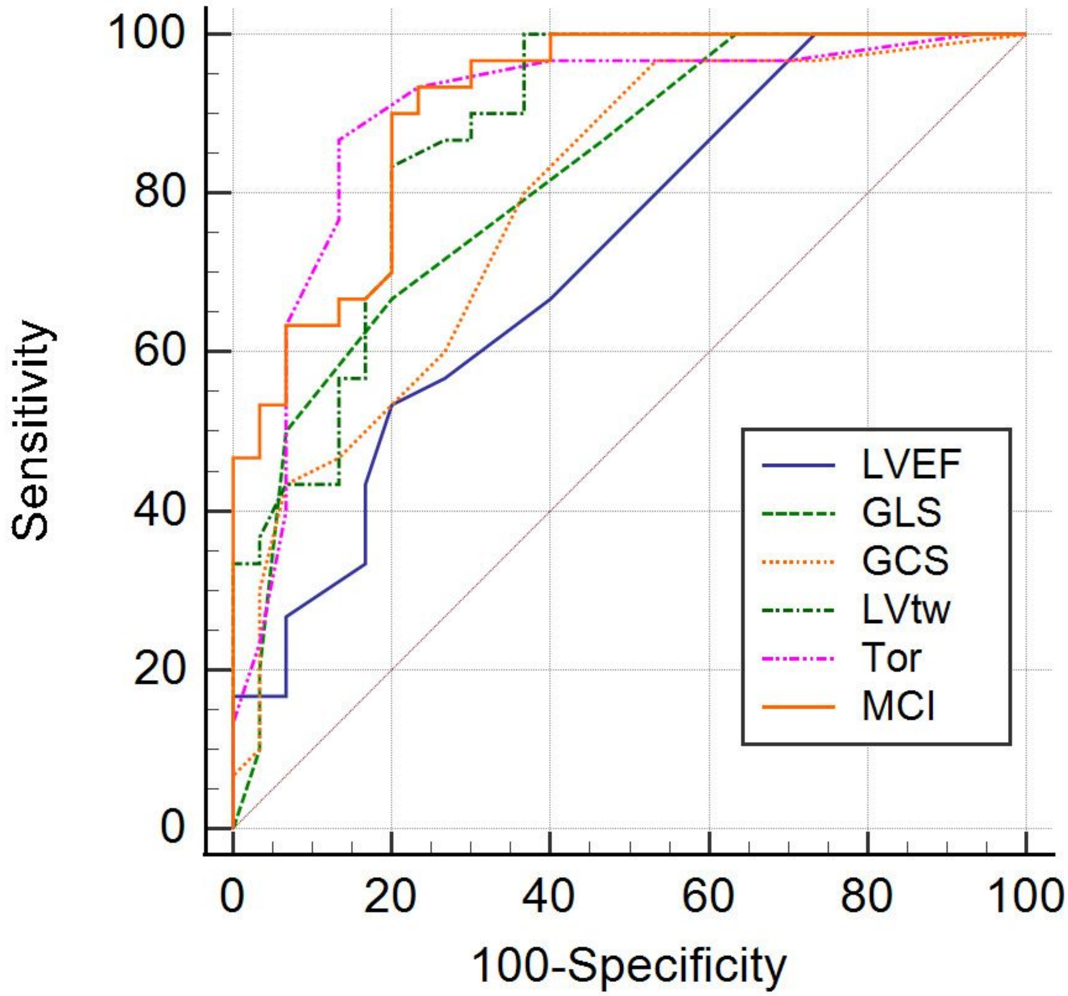

Figure 5

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

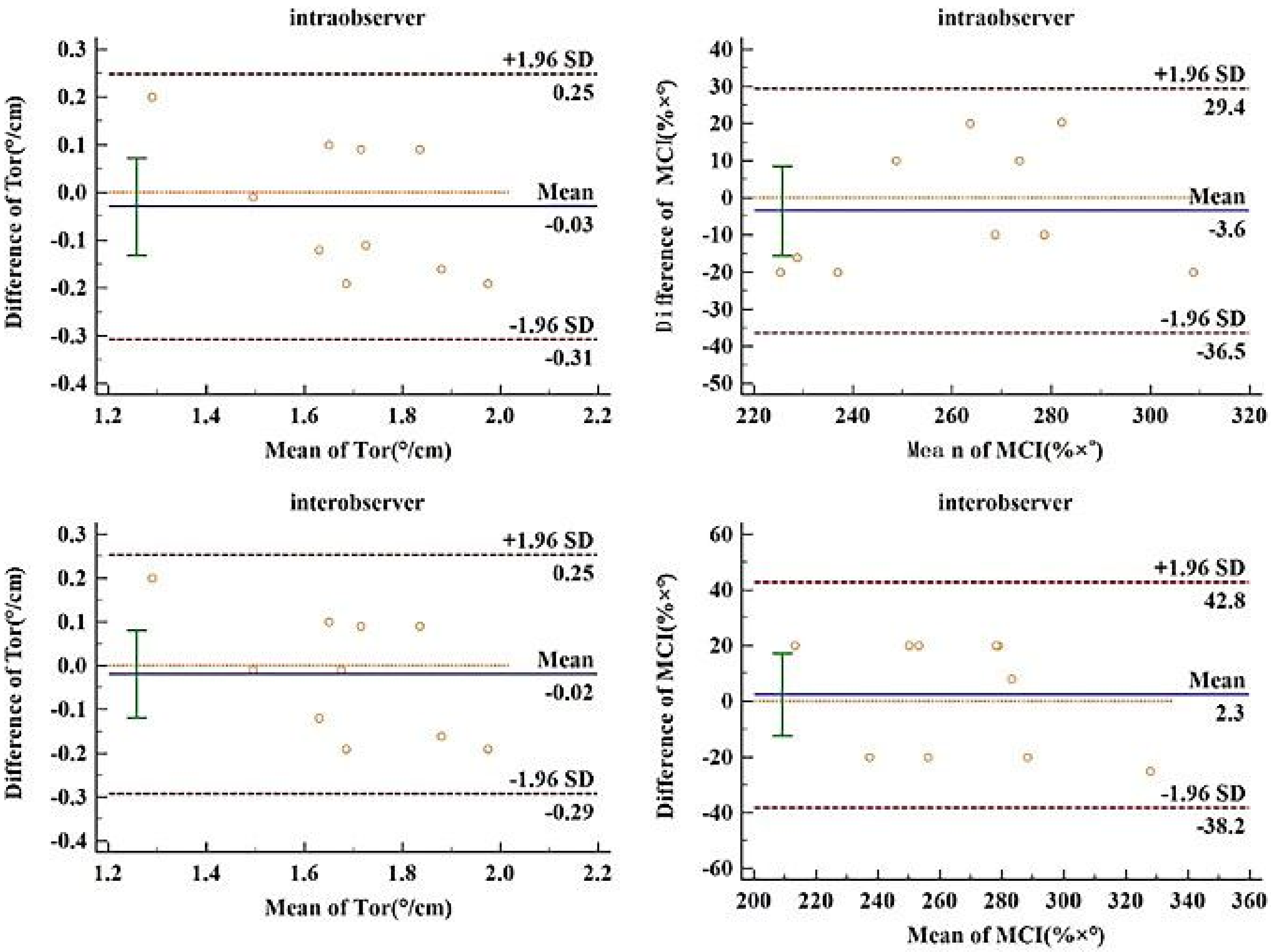

Figure 6

3D-STI Parameters: Left ventricular Tor and MCI repeatability test (Bland–Altman diagram)

Supplementary Files

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