Strain Analysis Using Feature Tracking Cardiac Magnetic Resonance Predict Prognosis of Patients With Ventricular Aneurysm After Myocardial Infarction

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Research Article

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Abstract

Objective We aim to assess the left ventricular strain in patients with ventricular aneurysm(VA) after myocardial infarction(MI) using cardiac magnetic resonance-feature tracking (CMR-FT) and to evaluate its value for long term prognosis of patients.

Methods Sixty-five patients who underwent CMR with VA after MI from January 2018 to December 2019 in Drum Tower Hospital Affiliated Hospital of Nanjing University School of Medicine were selected for the study. They were divided into two groups based on New York Heart Association (NYHA): 25 cases of NYHA I as group A and 40 cases of NYHA II-IV as group B. CMR was performed in both groups to quantify the parameters of overall and segmental left ventricular myocardial strain in patients with aneurysm. 37 of whom underwent a second CMR 3-12 months after cardiac infarction to investigate the effects of aneurysm on patients' left ventricular strain and left ventricular cardiac function.

Results Patients from group B have larger VA basilar transverse diameter and significant more impaired LV Global longitudinal strain(GLS)、Global circumferential strain(GCS)、Global radial strain(GRS) (-12.34±7.31 vs. -7.68±6.11;p=0.0072, -21.31±13.49 vs. -14.93±10.44;p=0.0361, 37.13±27.87 vs. 22.00±20.05;p=0.0135) without change in infarct size. GLS, GCS, GRS were significant indicators of NYHA classification after AMI by multivariate regression analysis.

Conclusions Myocardial strain assessed by CMR-FT may be an independent predictor of NYHA of patients with aneurysm after MI and could be used for identifying high-risk patients with VA.

Background

Ventricular aneurysm(VA) is a common mechanical complication of myocardial infarction(MI) and can be accompanied by ventricular appendage thrombosis, valvular regurgitation, ventricular wall rupture, ventricular tachycardia or sudden cardiac death, with a high mortality rate and a poor clinical prognosis for patients[1]. Therefore, it is important to investigate how to efficiently and accurately detect VA and to investigate their relationship with left ventricular function, in order to provide better guidance for further treatment by surgical treatment or medical drugs.

Cardiac magnetic resonance imaging(CMI) is more accurate than echocardiographic in detecting cardiac anatomy and function, and was recently suggested also to have an important role in pre- and post-surgical evaluation of patients with left VA[2]. CMR cine images is proposed as the most accurate and reproducible method of measuring left ventricular ejection fraction (LVEF) and volumes. LVEF can be used to evaluate the function of heart valve, especially to explore the relationship between the atrioventricular valves to the aneurysmal structure[3]. However, LVEF can not early identify heart failure patients with preserved ejection fraction, nor can it reflect the changes of regional myocardial systolic function. Myocardial strain, defined as the percentage change of myocardial dimension in a specific direction, is an important parameter to assess myocardial performance as it adds independent value to other well-recognized prognosticators[4, 5]. CMR myocardial strain technique can quantitatively evaluate GLS and GCS beyond the LVEF, and has higher sensitivity in the detection of myocardial dysfunction. CMR-FT technique has been validated against the gold standard myocardial tagging and is now considered a preferred CMR solution for strain assessment[6] . However, the role of CMR-FT technique in strain evaluation of left VA is still unknow.

The purpose of this study is to assess strain changes in patients with left VA after MI from January 2018 to December 2019 at Drum Tower Hospital and evaluate clinical value for patient prognosis compared with conventional LVEF.

Materials And Methods

2.1 study population

For the current study, the population includes patients with CMR suggestive of MI with VA from January 2018 to December 2019 in Drum Tower Hospital, Affiliated Hospital of Nanjing University medical school. All patients were confirmed by coronary angiography, electrocardiogram (ECG) and echocardiography. There were 52 men and 13 women with a mean age of 61.8±11.2 (46-84) years; The extent of the patient's VA includes the apical, lateral, anterior and inferior walls of the left ventricle.

Exclusion criteria: (1) the presence of other organic cardiac pathologies such as the following heart valve diseases (severe stenosis or incomplete closure of valves), congenital heart disease (except atrial septal defect with diameter less than 3cm, ventricular septal defect with diameter less than 3mm, patent foramen ovale); (2) pacemaker placement; (3) malignant arrhythmias; (4) chronic obstructive pulmonary disease, severe anaemia, malnutrition, hepatic and renal insufficiency, tumours, autoimmune diseases and thyroid abnormalities; (5) haemodynamic instability; (6) contraindications to MRI: e.g. claustrophobia, contrast allergy, etc.

2.2 Clinical data

Clinical and demographic characteristics of patients were recorded as previous reported[7]. Diabetes mellitus was defined as having a history of diabetes mellitus and currently medical therapy with insulin, oral hypoglycemic drugs. Hypertension was defined as previous use of antihypertensive medications or diagnosed with hypertension. Smoking was defined as currently or previously smoking. During invasive coronary angiography, the culprit vessel was identified and multivessel disease was defined as more than one vessel with >50% luminal stenosis.

2.3 CMR protocol

CMR examinations was performed using an Ingenia CX 3.0T system (Philips Healthcare, Best, The Netherlands). A balanced steady-state free-precession(bSSFP) cine imaging with breath-hold and an ECG gating was acquired using a 32-element phased-array body coil in cardiac vertical and horizontal short-axis and long-axis orientations of left ventricle. The scanning parameters are as follows: time of repetition (TR), 2.9 ms; time of echo (TE), 1.47ms; field of view (FOV), 370 × 320 mm2; matrix, 196 × 202; slice thickness, 8 mm; the number of slices in the left ventricular short axis, 8; slice gap, 3; flip angle (FA), 45°; 30 cardiac phases. Ten minutes after the contrast agent injection (Gadodiamide, 0.1 mmol/kg), T1-weighted segmented phase-sensitive inversion recovery (PSIR) gradient-echo sequence was acquired to detect late gadolinium enhancement (LGE). PSIR sequence preceded by a Look-Locker sequence to determine the optimal inversion time(260~350ms), the scanning parameters are as follows: TR, 6 ms; TE, 3ms; FOV, 300 × 300 mm^2; matrix, 196 × 202; slice thickness, 8 mm; the number of slices in the left ventricular short axis, 8; slice gap, 3; FA, 25°.

2.4 Cardiac function analysis

The CMR images were analyzed on commercially available workstation (IntelliSpace Poral (ISP), Philips Healthcare). The LV epicardial and endocardial contour were delineated semi-automatically based on SA cine images. The left ventricular end-diastolic volume (LVEDV), left ventricular end-systolic volume (LVESV), myocardial mass, LVEF, cardiac out-put (CO), peak ejection rate, first peak filling rate and second peak filling rate were measured using CMR function package within ISP workstation. Spatial enhancement analysis with percentage of the entire LV myocardial mass were performed to visualize and quantify the transmural extent of infraction based on LGE images. The parameters of ventricular aneurysm are obtained based on the largest plane of VA in the cine images.

The infarct size (IS) was calculated as previous decribed[8]. Briefly, the infarcted regions were defined as hyper-enhanced regions with + 5SD signal intensity above the normal remote myocardium. The IS was then expressed as the percentage of left ventricular volume mass. A representative figure shows IS measurement were shown in Figure 1.

The measurement of the parameters of VA is mainly based on cine images. The largest plane showing the largest VA during systole is selected as the measurement slice. The diameter of VA is measured three times: 1) the transverse diameter of the base of AV body (Aneurismal-W, defined as the short diameter of the base section of ventricular wall tumor during the selected plane contraction). The specific measurement method is to measure the basal diameter of VA during contraction of four-chamber, two-chamber or short axial position, and the shortest diameter is taken as its transverse diameter. 2) the height of VA (Aneurismal-H), which is measured by taking the maximum vertical distance from the edge of the tumor to the transverse diameter of the base. 3) the end-diastolic volume (Aneurismal-ED) and end-systolic volume (Aneurismal-SD) of the ventricular wall tumor were automatically recorded by the cardiac function analysis software, combined with the method of manual adjustment, the film sequence of the selected plane was measured, and the endocardial and adventitia boundaries of each systolic and diastolic phase were determined. The report was automatically generated and the end-diastolic volume (Aneurismal-ED) and end-systolic volume (Aneurismal-SD) were recorded.

2.5 Strain analysis

Strain measurements were performed as previous described.[9]Briefly, we use the FT-CMR software method of Medis QStrain Software (Medis Medical Imaging Systems, version 2.0.12.2.) (example of the analysis is in the Supplementary File). All two longitudinal-axis views were used to determine peak GLS. Endocardial contours were manually drawn during end-diastole and end-systole with subsequent automatic tracking during the cardiac cycle. For the assessment of GCS and segmental circumferential strain, the corelab contours for the short-axis images were used. Peak GCS was calculated from 3 short-axis views (basal, mid, and apical). For peak segmental strain, short-axis images were used to define the segments according to the 16-segment model after manual insertion of a reference point (delineated at the anterior insertion of the right ventricle). All studies were loaded into the software and analyzed in a random order by one investigator blinded for randomization outcome under supervision of a CMR cardiologist with > 15 year-experience. The reproducibility of GLS measurements was assessed in 30 CMR scans (15 patients with baseline and follow-up CMR). The intraclass correlation coefficient for interobserver agreement was 0.97 (95% CI 0.89 to 0.99; p<0.005). A representative figure shows strain measurement were shown in Figure 2.

2.6 echocardiography

The heart function of 65 patients was detected by two-dimensional echocardiography, and the LVEF of the patients was measured. The wall movement was detected by tissue Doppler method.

2.7 Statistical analyze method

Data were processed as previous decribed.[10] Continuous variables were expressed as means ± standard deviation (normal distribution) or median with interquartile range (nonnormal distribution). Categorical data were expressed as numbers (n) with percentages (%). Differences between continuous variables were analyzed using Student's t-test (normal distribution) or Mann–Whiney's U test (nonnormal distribution). Categorical variables were compared by the chi-square test. However, univariate regression analysis was used to determine the available variables predicting NYHA in patients with VA after cardiac infarction. Any variable with unadjusted p < 0.1 was included in the multivariate logistic regression analysis. Spearman correlation coefficient was used to test the relationships between continuous variables. Statistical analyses were performed with SaS software.

Results

A total of 65 MI patients with VA were included in this study. After one year follow up, 25 cases of NYHA I as group A and 40 cases of NYHA II-IV as group B

Illustration of infarct size measurement: The endocardium (red line) and epicardium (green line) are outlined separately and the demarcation between the left interventricular septum and the free wall is determined. The software automatically displays the infarcted portion of the myocardium in red and derives the percentage of infarcted myocardium in the left ventricle.

Using CMR-FT Assessment of GLS from the left-ventricular short-axis view (left) and left-ventricular long-axis view (right).

TABLE1: Clinical characteristics of the total population and subgroups

	NYHA I (n=25)	NYHAII-IV(n=40)	P-value
Male, n%	24(96)	28(70)	0.0108
Ages (years)	59±13	63±11	0.1560
BMI	25.23±3.30	25.31±3.28	0.9202
Anterior wall myocardial infarction, n%	18(72)	32(80)	0.4564
Smoking, n%	18(72)	20(50)	0.0799
Hypertension, n%	14(56)	22(55)	0.9371
Diabetes, n%	5(20)	18(45)	0.0403
Culprit vessel			
LAD	23(92)	36(90)	1.0000
RCA	8(32)	18(45)	0.2980
LCX	10(40)	16(40)	1.0000
ACEi/ARB, n%	18(72)	18(45)	0.0331
β-blocker, n%	22(88)	32(80)	0.5087
Diuretics, n%	8(32)	25(62.5)	0.0167
Spironolactone, n%	12(48)	26(65)	0.1760
BNP†	5.03±1.33	5.76±1.28	0.0305
LDL	2.12±0.89	2.05±0.75	0.7423

Continuous data are presented as mean ± SD or median (25th–75th percentile)

BMI, body mass index; ACEi, angiotensin-converting enzyme inhibitor; ARB, angiotensin II receptor blocker; LAD, left anterior descending; RCA, right coronary artery; LCX, left circumflex branch;

†Geometric mean (SD of log-BNP);

P-values contribute to differences between NYHA=1 and NYHA≥2;

Clinical characteristics

The baseline clinical characteristics of patients are shown in Table 1. Patients with coronary artery diameter stenosis greater than 70% and diameter greater than 2mm were included in the screening criteria. For patients with NHYA≥II after MI with aneurysm, they were more female, more diabetic, more diuretics used (62.5% vs. 32%; p=0.0167), and have higher BNP (5.76±1.28 vs. 5.03±1.33; p=0.0305), when compared with patients with NYHA I.

TABLE2: Baseline echocardiographic and MRI characteristics of NYHA=1 and NYHA≥2

	NYHA I(n=25)	NYHA II-IV(n=40)	P-value
LVEF%	43.16±7.73	36.84±7.56	0.0018
CMI LVEF%	44.28±12.11	33.67±14.20	0.0029
LVEDV	102.90±24.75	127.90±44.03	0.0118
CO(min.m^2)	3.22±0.94	2.68±0.89	0.0234
ESV(ml)	59.10±19.69	92.55±46.65	0.0012
Stroke volume(ml)	44.11±11.42	37.56±11.88	0.0318
peak ejection rate(ml/ms)	0.23±0.06	0.19±0.06	0.0261
First peak filling rate(ml/ms)	0.21±0.07	0.16±0.07	0.0168
Second peak filling rate(ml/ms)	0.22±0.08	0.17±0.09	0.0088
ventricular aneurysm basilar transverse diameter(mm)	30.56±7.97	35.21±10.30	0.0592
Ventricular aneurysm height(mm)	41.22±11.74	40.64±9.97	0.8332
Aneurismal-ED(ml)	53.48±26.15	52.31±28.32	0.8673
Aneurismal-SD(ml)	33.56±18.68	39.33±22.13	0.2827
GLS MYO %（longitudinal）	-11.89±5.14	-7.94±4.99	0.0032
GCS MYO %（longitudinal）	-15.56±4.94	-11.69±6.16	0.0102
GRS MYO %（longitudinal）	38.05±22.85	29.67±47.84	0.4164
GLS endo % （longitudinal）	-12.34±7.31	-7.68±6.11	0.0073
GCS endo % （longitudinal）	-21.31±13.49	-14.93±10.44	0.0361
Infarct Size %	21.30±10.58	22.40±8.77	0.6509

Echocardiographic and CMR characteristics

Baseline echocardiographic and CMR characteristics for the NYHA I and NYHA≥II are reported in Table2. Patients who NYHA≥II had a significant lower LVEF (43.16±7.73 vs. 36.84±7.56; p=0.0018 and cardiac output (3.22±0.94 vs. 2.68±0.89; p=0.0234). In addition, they have larger VA basilar transverse diameter and significant more impaired LV GLS、GCS、GRS(-12.34±7.31 vs. -7.68±6.11;p=0.0072, -21.31±13.49 vs. -14.93±10.44;p=0.0361, 37.13±27.87 vs. 22.00±20.05;p=0.0135) . There were no differences in infarct size or VA volume during diastole between the groups.

Table3: Multivariate regression model of left ventricular myocardial strain and NYHA

	Q1	Q2	Q3	Q4	P-value
GLS endo % （longitudinal）	1	3.86(0.86,17.32)	13.00(2.40,70.46)	14.00(2.60,75.40)	0.0015
GCS endo % （longitudinal）	1	2.20(0.52,9.30)	9.53(1.85,49.20)	10.27(2.00,52.65)	0.0028
GRS endo % （longitudinal）	1	0.31(0.05,1.94)	0.18(0.03,1.09)	0.08(0.01,0.46)	0.0013

After adjustment of age、sex、BMI、BNP、LDL

	Q1	Q2	Q3	Q4	P-value
GLS endo % （longitudinal）	1	5.83(0.95,35.82)	22.01(3.06,158.02)	22.14(3.10,158.13)	0.0007
GCS endo % （longitudinal）	1	2.70(0.52,14.00)	13.58(2.22,83.16)	13.69(2.25,83.40)	0.0014
GRS endo % （longitudinal）	1	0.30(0.05,1.91)	0.16(0.03,1.02)	0.05(0.01,0.34)	0.0012

Predictive value of left ventricular myocardial strain and NYHA

We found patients who NYHA≥II have more impaired left ventricular myocardial strain than patients NYHA=I(Table2). Then we build a multivariate model to evaluate and relation between strain and NYHA(Table3). According to the multivariate regression analysis, GLS、GCS、GRS at baseline were independent and significant indicators of NYHA after cardiac infarction with VA. (p=0.0015;p=0.0028;p=0.0013).After adjusting for age、sex、smoke、diabetes、hypertension、BNP、LDL and medicine, GLS、GCS、GRS at baseline were still independent and significant indicators of NYHA after cardiac infarction with VA. (p=0.0007; p=0.0014; p=0.0012)

Table 4: Correlation analysis of VA and left ventricular myocardial strain

	GLS endo % □longitudinal□	GCS endo % □longitudinal□	GRS endo % □longitudinal□
VA basilar transverse diameter	0.34 (0.01)	0.42 (0.00)	-0.44 (0.00)
VA height(mm)	0.18 (0.14)	0.17 (0.18)	-0.20 (0.10)
Aneurismal-ED (ml)	0.26 (0.04)	0.26 (0.03)	-0.30 (0.02)
Aneurismal-SD (ml)	0.36 (0.00)	0.31 (0.01)	-0.36 (0.00)

As shown in table 4, there were strong correlation between VA basilar transverse diameter□VA volume and parameters of ventricular strain.

Discussion

Left ventricular aneurysm is a common complication of myocardial infarction at present, which would be accompanied by arrhythmia, thrombosis, rupture, accelerated ventricular dilatation and so on and may further impair patient's cardiac function after cardiac infarction[11]. In this study, We find person with poorer cardiac function tends to have larger VA basilar transverse diameter, which is consistent with previous reports. However, there still lack indicators for risk stratification and prognosis prediction for left ventricular aneurysm after cardiac infarction[12].

Segment strain analysis with CMR-FT in cardiac infarction predicts future cardiovascular events mortality over and above LV ejection fraction and infarct size[13, 14]. A previous study have reported that GLS is an independent predictor of medium-term prognosis post STEMI[15]. However, for person with VA after AMI, there still lack evidences. Our study is the first study for studying cardiac strain in patients with VA after cardiac infarction. In our study of 65 person with left VA, we find person with poorer cardiac function have smaller GLS, GCS and GRS. GLS, GCS, GRS could predict NYHA class after AMI. This study first demonstrates the value of myocardial strain in VA and substantiated its prediction value of cardiac function in patients with VA after AMI.

One of the limitations of our study was that our population is low. So, our study may less convincing and larger population need to be enrolled. The second limitation is we do the follow-up 3-6 months after AMI, which may neglect the long-term prognosis.

In conclusion, by assessing baseline myocardial strain after AMI using CMR-FT, we observed GLS, GCS, GRS were correlated to indices of VA and could predict progress of people with VA after AMI. The analysis of VA after MI by CMR can early warn the NYHA of patients, and provide important guidance for clinicians to judge the prognosis of patients, early drugs, surgery or instrument treatment.

Abbreviations

VA: Ventricular aneurysm

MI: Myocardial infarction

CMR-FT: Cardiac magnetic resonance-feature tracking

NYHA: New York Heart Association

GLS: Global longitudinal strain

GCS: Global circumferential strain

GRS: Global radial strain

CMI: Cardiac magnetic resonance imaging

ECG: Electrocardiogram

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of Nanjing Drum Tower Hospital, affiliated hospital of Nanjing university medical school. All patients were gave written informed consent and this study protocol was performed in accordance with the declaration of Helsinki.

Availability of data and materials

The datasets used and/or analyzed during the present study are available from the corresponding author upon reasonable request.

Competing interests

The authors declare that there are no competing interests.

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Authors' contributions

D.M. and Q.L.L. designed this study and reviewed the manuscript. S.S wrote the manuscript, did the follow up work and strain analysis under the supervision of J.L.Z with J.L and J.L. B.X contributed significantly to data analysis. J.X and B.X offer clinic supports on VA. Z.W., K.W., Q.D and L.W. helped collecting clinic data from patients. J.L.Z offered technical support in CMR-FT.

Consent for publication

Not applicable.

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Supplementary File

Supplementary Files are not available with this version.

Figures

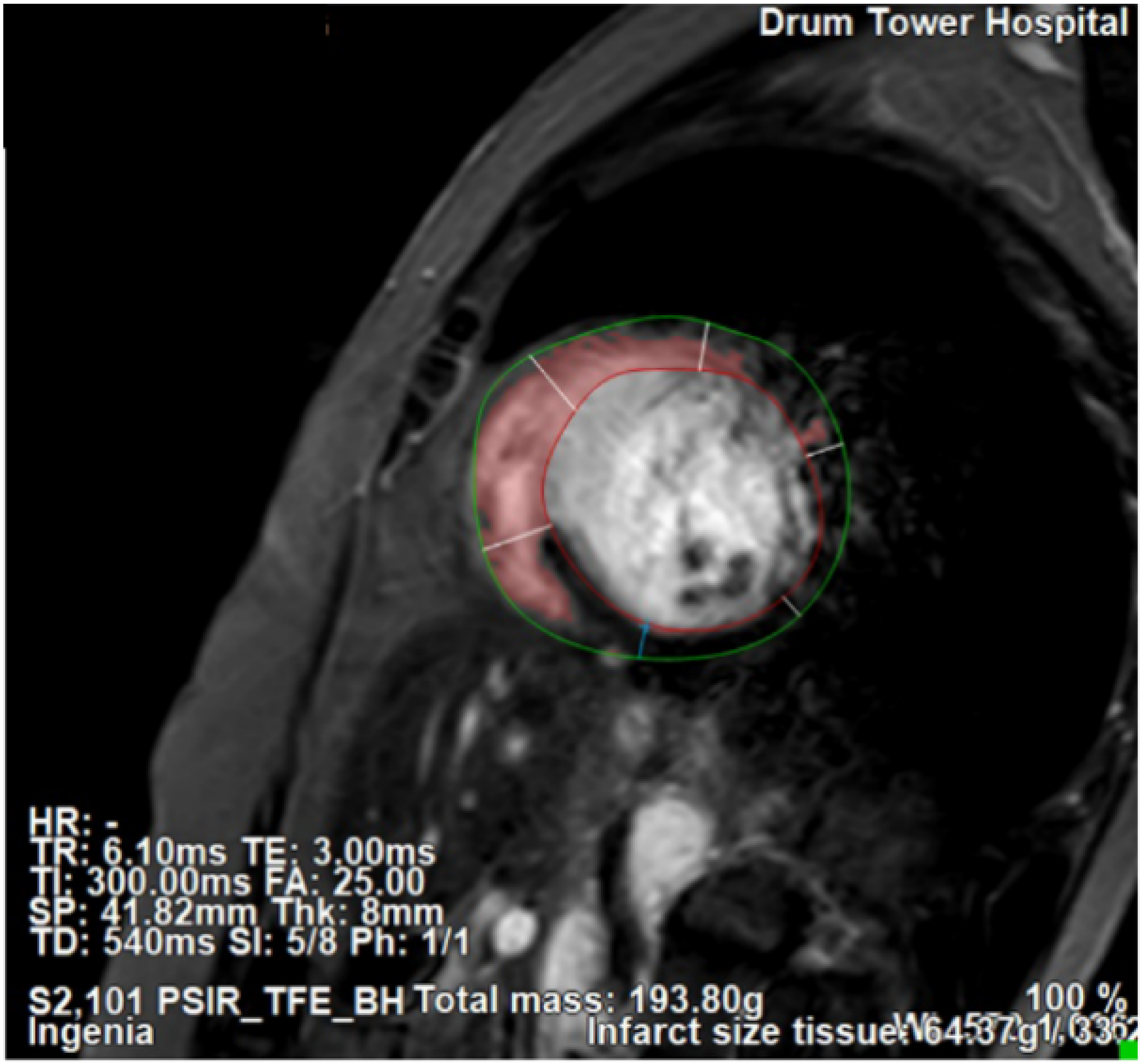

Figure 1

Representative images show measurement of infarct size (SI)

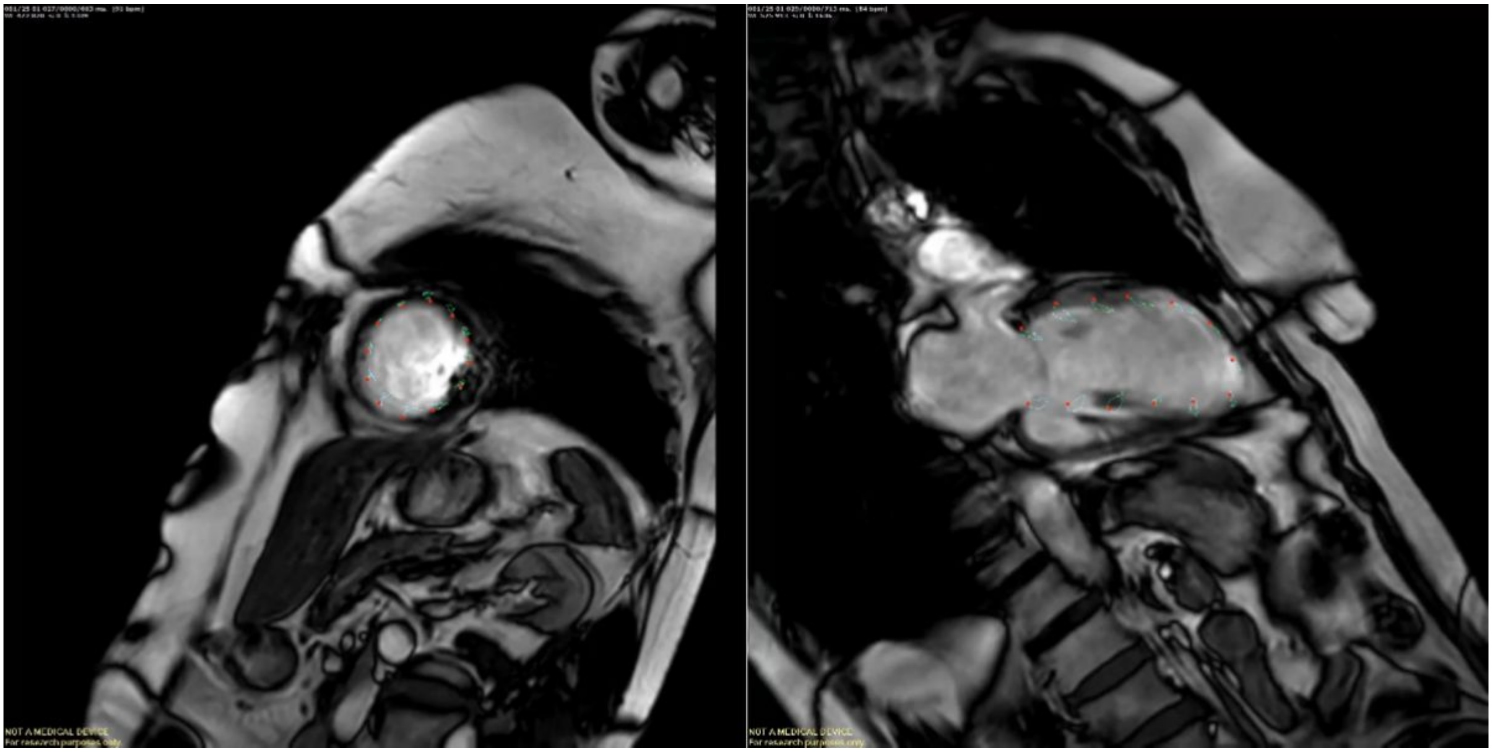

Figure 2

Representative images show the measurement of strain