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Research Article

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

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Abstract

Objective: Limited evidence for assess the risk of LV aneurysms after cardiac infarction. This study investigated the association of left ventricular strain by cardiac magnetic resonance-feature tracking (CMF-FT) in patients with left ventricular aneurysm (LV aneurysms) after myocardial infarction (MI) and investigated the potential prognostic value beyond LV aneurysms volume and clinical features.

Methods: Patients with LV aneurysms after MI from January 2018 to December 2019 in Drum Tower Hospital Affiliated by Nanjing University Medical School were recruited for this study. Overall and segmental left ventricular myocardial strain in patients with aneurysm was acquired by CMR-FT after cardiac infarction. Clinical and CMR features were analyzed.

Results: Patients from group B have larger LV aneurysms 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 using CMR-FT provides an independent predictor over clinical features, LVEF, and cardiac infarct size, LV aneurysm volume in patients with LV aneurysm after MI. CMR-FT may serve as a novel marker to improve risk stratification in LV aneurysm after MI.

Keywords: Strain analysis; CMR-FT; LV aneurysm; MI

Abbreviations: LV aneurysms: Left 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; RS: Global Radial Strain; CMI: Cardiac Magnetic Resonance Imaging; ECG: Electrocardiogram

Background

Ventricular aneurysm 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 LV aneurysms 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 LV aneurysms [2]. CMR cine images are 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 showed some limits in early do not 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 f LV aneurysms is still un know.

Materials and Methods

Study population

For the current study, all the patients suspected with LV aneurysm by echocardiography after MI from January 2018 to December 2019 in Drum Tower Hospital, Affiliated Hospital of Nanjing University medical school was further received a CMR examination. Cardiac infarction was confirmed base on the standard criteria. Patients were recruited in this study only if the CMR suggestive of LV aneurysms after MI. Finally, 65 people were included in this study. 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 LV aneurysms includes the apical, lateral, anterior and inferior walls of the left ventricle. Patients were received an follow-up one year after MI.NYHA classes presented in this study was classified by a standard protocol for reporting on consultations, which includes a detailed description of exercise capacity, exercise training, and effort limitation (e.g. distance or time able to walk on the flat, run, orclimb stairs). Patients death during this year was recorded as NYHA-IV.

Clinical data

Clinical and demographic characteristics of patients were recorded as previous reported7. 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.

CMR protocol

CMR examinations were performed using an Ingenia CX 3.0T system (Philips Healthcare, Best, and 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), 1.47m s; 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 (260~350 ms), the scanning parameters are as follows: TR, 6 ms; TE, 3 ms; 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°.

Cardiac function analysis

The CMR images were analyzed on Cardiac MR Analysis module of IntelliSpace Portal V7 workstation (Philips Medical System, Best, the Netherlands). The LV epicardial and endocardial contour were delineated semi-automatically based on SA cine images. The left ventricularend-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 was 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 LV aneurysms in the cine images. The Infarct Size (IS) was calculated as previous described **[8].** Briefly, the infracted 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 was shown in **Figure 1 (A-B).**

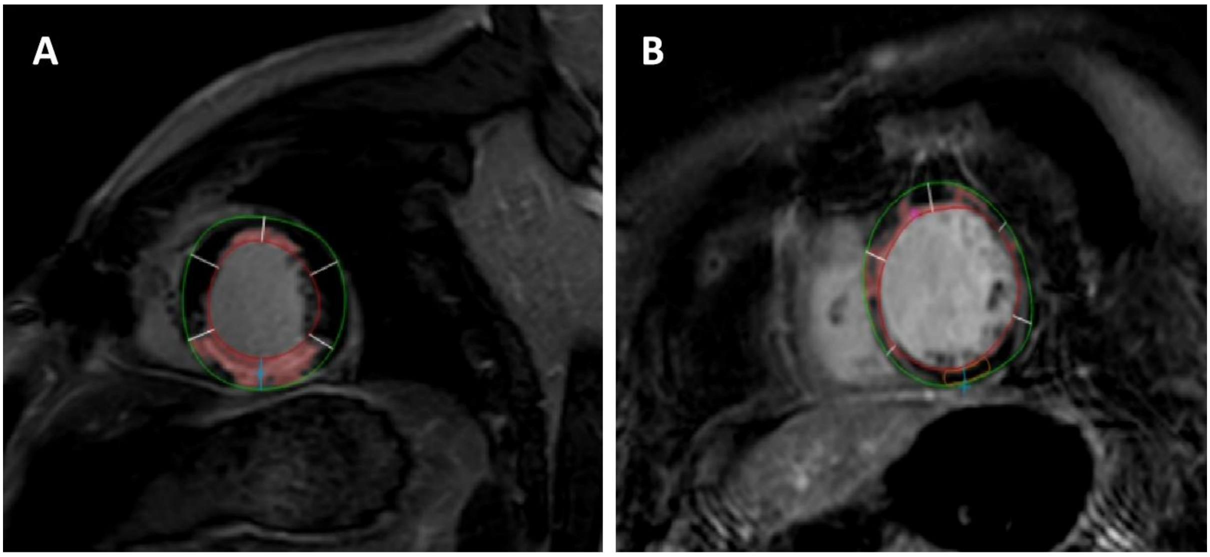

Figure 1: IS measurement.

The measurement of the parameters of LV aneurysms is mainly based on cine images. The largest plane showing the largest LV aneurysms during systole is selected as the measurement slice. The diameter of LV aneurysms 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 LV aneurysms 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 LV aneurysms (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.

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 core lab 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 > 5 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 inter observer agreement was 0.97 (95% CI 0.89 to 0.99; $p<0.005$). A representative figure shows strain measurements were shown in **Figure 2.**

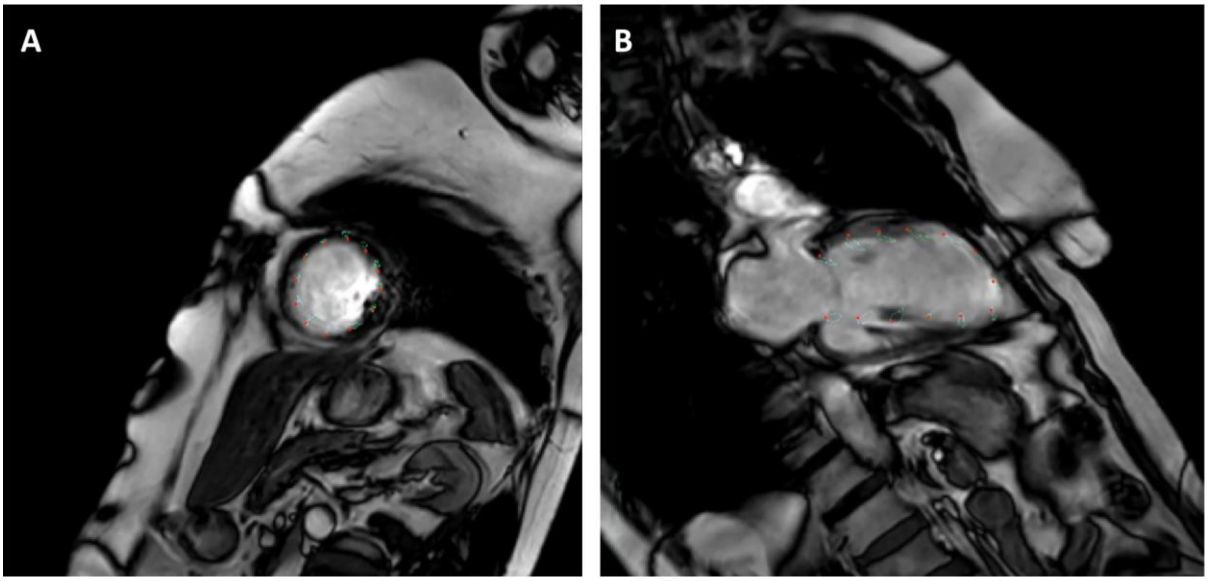

Figure 2: Strain measurement.

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.

Statistical analyze method

Data were processed as previous described **[10]** Continuous variables were expressed as means ± standard deviation (normal distribution) or median with interquartile range (non normal 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 (non normal 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 LV aneurysms were included in this study. 25 cases of NYHA I as group A and 40 cases of NYHA II-IV as group B.

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 2 mm 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.

Table 1: Clinical characteristics of the total population and subgroups 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.

	Group A (n=25)	Group B (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%) Culprit vessel	5(20)	18(45)	0.0403
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

Echocardiographic and CMR characteristics

Baseline echocardiographic and CMR characteristics for the NYHA I and NYHA≥II are reported in Table 2. 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 LV aneurysms basilar transverse diameter and significant more impaired LV GLS, GCS (-12.34±7.31 vs. -7.68±6.11; p=0.0072, -21.31±13.49 vs. -14.93±10.44; p=0.0361) .There were no differences in infarct size or LV aneurysms volume during diastole between the groups.

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 **(Table 2).** Then we build a multivariate model to evaluate and relation between strain and NYHA **(Table 3).** According to the multivariate regression analysis, GLS, GCS, GRS at baseline were independent and significant indicators of NYHA after cardiac infarction with LV aneurysms (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 LV aneurysms (p=0.0007; p=0.0014; p=0.0012) **(Table 4).**

Table 2: Baseline echocardiographic and MRI characteristics of NYHA=1 and NYHA≥2. LVEDV, left ventricular end-diastolic volume; ESV, End-systolic volume.

	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

Table 3-1: 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

Table 3-2: Multivariate regression model of left ventricular myocardial strain and NYHA 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

Table 4: Correlation analysis of LV aneurysms and left ventricular myocardial strain.

As shown in **Table 4,** there were strong correlation between LV aneurysms basilar transverse diameter、LV aneurysms volume and parameters of ventricular strain.

	GLS endo % (longitudinal)	GCS endo % (longitudinal)	GRS endo % (longitudinal)
LV aneurysms basilar transverse diameter (mm)	0.34 (0.01)	0.42 (0.00)	-0.44 (0.00)
LV aneurysms 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)

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 LV aneurysms 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 has reported that GLS is an independent predictor of medium-term prognosis post STEMI **[15].** However, for person with LV aneurysms after AMI, there still lack evidences. Our study is the first study for studying cardiac strain in patients with LV aneurysms after cardiac infarction. In our study of 65 person with left LV aneurysms, 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 LV aneurysms and substantiated its prediction value of cardiac function in patients with LV aneurysms 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.

Conclusion

Myocardial strain (GLS, GCS, GRS) determined by CMR-FT in patients with LV aneurysms after cardiac infarction were significantly associated with indices of LV aneurysms and incidence of heart failure. The prognostic information provided by myocardial strain was independent and incremental to the volume of LV aneurysms and major CMR prognosis markers of the risk stratification for LV Aneurysm. CMR-FT may therefore represent a useful technique for optimized risk stratification in survivors of STEMI with LV Aneurysm.

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