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EXPLORING EARLY CARDIAC MAGNETIC RESONANCE FEATURES IN ACUTE MYOCARDIAL INFARCTION WITH BUNDLE BRANCH BLOCK

WANG Lilan[1]
Department of Endocrinology, Second Affiliated Hospital of Harbin Medical University, Harbin150086, China.
***Email**: wanglilan19980319@163.com*

LIN Yuefeng[2]
Xiamen Cardiovascular Hospital, Xiamen University, Xiamen 361000, China. School of Medicine, Xiamen University. Xiamen 361005, China.

WANG Bin[3]
Xiamen Cardiovascular Hospital, Xiamen University, Xiamen.

HONG Qiao[4]
Department of Endocrinology, Second Affiliated Hospital of Harbin Medical University, Harbin150086, China.
***Email**: qiaohong@hrbmu.edu.cn*

ABSTRACT

Objectives: To assess early cardiac magnetic resonance (CMR) features in patients with acute myocardial infarction (AMI) combined with bundle branch block (BBB).

Methods: The data of patients diagnosed with AMI and completing CMR within two weeks were included, and they were divided into the BBB group and the non-BBB group, and the acquired CMR images were post-processed by applying the CVI42 software, and the relevant CMR parameters, such as the left ventricular function, the myocardial strain (MS) and the late gadolinium enhancement (LGE), were observed and compared, and the binary logistic regression model was used to analyze the independent effects of the parameters on the patients with AMI accompanied by BBB.

Results: A total of 57 patients with AMI who completed CMR within two weeks were included in this study, of whom 19 were with BBB and 38 were without BBB. In multifactorial analysis Left ventricular ejection fraction (LVEF) (OR: 0.885; 95% CI: 0.788 to 0.994; p=0.040), LGE area (OR:1.143; 95% CI: 1.006 to 1.298; p=0.040), LGE volume (OR. 1.271; 95% CI: 1.026 to 1.576; p=0.028) and global circumferential strain (GCS) (OR. 0.775; 95% CI: 0.602 to 0.998; p=0.048) were the independently influencing CMR parameters in patients with AMI with BBB.

Conclusions: CVI42 measurement of early CMR parameters such as LVEF, GCS, and the area and volume of the LGE better responds to the impact on patients with AMI with BBB and thus guides clinical treatment.

Keywords: Acute myocardial infarction; Bundle branch block; Cardiac magnetic resonance; Myocardial strain; late gadolinium enhancement

Introduction

Coronary artery stenosis or occlusion in acute myocardial infarction (AMI) may result in dysfunction due to insufficient blood supply to the bundle branches, which manifests itself as bundle branch block (BBB) including left bundle branch block (LBBB) and right bundle branch block (RBBB). The incidence of AMI combined with BBB has been reported to be 10%~15%, which often leads to diffuse damage to the conduction system or ventricular myocardium, and can cause atrioventricular block, heart failure, malignant arrhythmia, etc., and in severe cases, it can lead to death, and the mortality rate is as high as 42%~63%[1]. Although thrombolysis-reperfusion therapy reduces mortality in patients with AMI, studies have shown that the BBB is an independent predictor of near- or long-term mortality in patients with AMI [2,3] . Previous studies have demonstrated that patients with AMI with BBB have a higher incidence of coronary triple branch lesions, a higher percentage of extensive anterior wall myocardial infarctions and Gensini scores, a larger myocardial infarct size, and a higher number of days in the hospital and adverse cardiovascular event events than those without BBB [4]. While most of the above studies have focused on clinical features, further exploration of early imaging features could help to manage this group of patients more effectively in the clinic.

Cardiac magnetic resonance (CMR) has high spatial resolution and reproducibility to accurately assess the structure and function of the heart. A large number of previous studies have explored the CMR characteristics of patients with heart failure and non-ischemic cardiomyopathy with BBB, but little has been reported on the CMR characteristics of ischemic cardiomyopathy with BBB. Therefore, in this study, we retrospectively analyzed the early CMR images of patients with AMI with BBB and analyzed their features using CVI42 post-processing software, based on the analysis of myocardial function by cine imaging, myocardial motion characteristics by MS and myocardial fibrosis by late gadolinium enhancement (LGE), expecting that we can find out the methods of predicting and preventing the poor prognosis from these images, and then intervene in the treatment as early as possible, which can provide a certain degree of clinical diagnosis and treatment as well as improve the prognosis. We expect to find out the methods to predict and prevent poor prognosis, so as to intervene early and provide certain reference value for clinical diagnosis and treatment and improve prognosis.（Delete this paragraph and modify it as follows: This study aims to explore methods for predicting and preventing adverse outcomes, and to provide reference for clinical diagnosis and treatment through early intervention, thereby improving the prognosis of patients.）

1. General information

1.1 Study population:

This was a single-center retrospective case-control study of 57 patients with AMI who underwent CMR scanning within two weeks at the Affiliated Cardiovascular Disease Hospital of Xiamen University from January 2019 to June 2023, and they were divided into the BBB group (n=19) and the non-BBB group (n=38). The study complied with nationally established ethical standards for biomedical research involving human beings and the requirements of the Declaration of Helsinki as recently revised by the World Medical Association.

1.2 Entry Criteria:

(1) patients >18 years of age with complete medical records during hospitalization; (2) patients with a diagnosis of AMI (3) patients who completed a 12-lead routine Electrocardiogram (ECG) acquisition on the day of admission; (4) patients who completed a CMR scan within two weeks of the diagnosis of AMI.

1.3 Exclusion Criteria:

(1) Severe arrhythmia, cardiomyopathy, heart valve disease, or malignancy; (2) Severe conditions such as hepatic or renal failure (GFR <30 mL/min/1.73m²), or hemodynamic instability. (3) Contraindications to CMR examination such as mental abnormalities, claustrophobia, and metal-placed devices; (4) Poor CMR image quality and incomplete scanning sequences.

1.4 Diagnostic Criteria:

In this study, patients with AMI with complete left bundle branch block (CLBBB), complete right bundle branch block (CRBBB), incomplete left bundle branch block, incomplete right bundle branch block, left anterior branch block, or left posterior branch block were included in the BBB group.

(1)In AMI with CRBBB, the electrocardiographic features of both are fully manifested and are not masked by each other. The ECG has the following characteristics: (i) the ECG diagnostic criteria for AMI and CRBBB are met; (ii) the start vector of ventricular depolarization in AMI with CRBBB is not fundamentally different from that of normal ventricular depolarization; (iii) the characteristics of the ST-segment and T-wave changes in the case of AMI with CRBBB are the same as those in the case of RBBB without RBBB; (iv) the morphology of the terminal portion of the QRS wave in the case of AMI with CRBBB is unchanged, and the Q wave is The final part of the QRS wave remains unchanged and the Q wave is not masked in AMI with CRBBB. (Shown in figure 1)

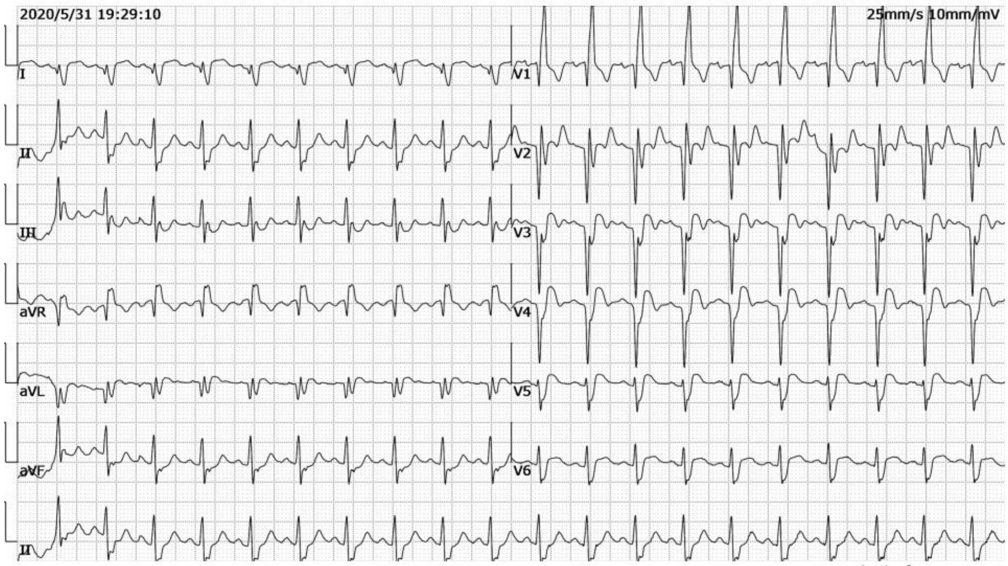


Figure 1 shows the electrocardiogram of a patient with AMI with CRBBB: sinus tachycardia, CRBBB, and acute extensive anterior wall myocardial infarction.

(2) AMI with CLBBB both ECG features mask each other and are diagnosed using Sgarbossa's new criteria published in the New England Journal of Medicine1: (i) meet the diagnostic criteria of AMI and CLBBB; (ii) ST-segment elevation ≥1 mm and in the same direction as the QRS wave main wave (5 points); (iii) ST-segment depression ≥1 mm in any of leads V1 to V3 (3 points); (iv) ST-segment elevation ≥5 mm and in the opposite direction of the RQS wave main wave (2 points).Sgarbossa total score of ≥3 points clarified the diagnosis of AMI with CLBBB. (Shown in figure 2)

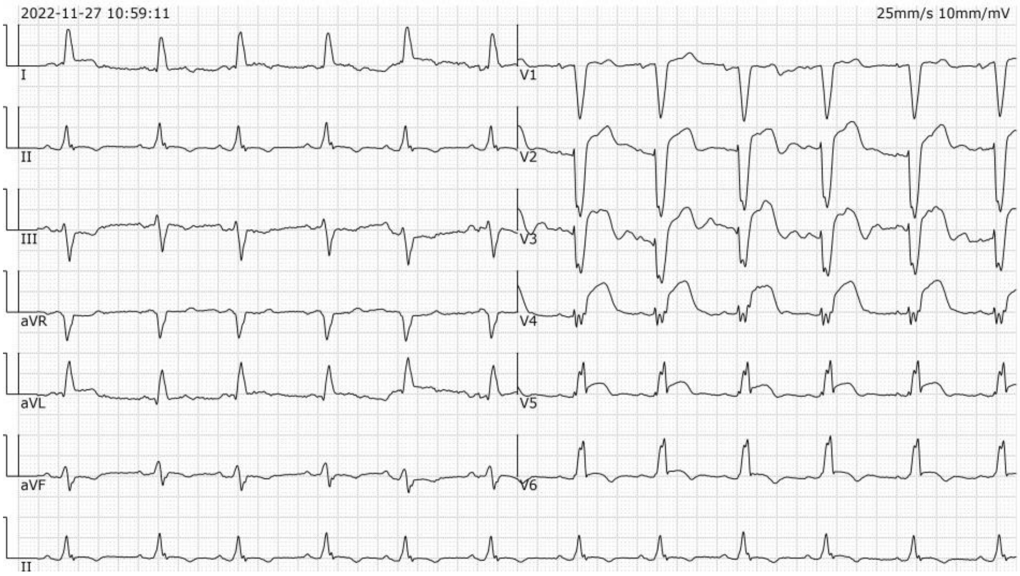


Figure 2 shows the electrocardiogram of a patient with AMI with CLBBB: sinus rhythm, CLBBB, acute extensive anterior wall myocardial infarction.

2.CMR Examination

2.1 Scanning sequence and parameters:

Imaging	Scanning sequence	Time of repetition (TR)	Time of echo (TE)	Flip angle (FA)	Field of view (FOV)
Cine imaging	Fast imaging employing steady state acquisition (FIESTA)	3.4ms	1.3ms	45°	340 ×340 mm~450×450 mm
Black blood imaging	Fast Spin Echo Sequence (FSE)	Varies with heart rate	85.4ms	100°~ 180°	340 ×340 mm~450 ×450 mm
Myocardial perfusion imaging	Fast gradient recalled echo train (FGRET)	3.4ms	Min Full	20°	128×128mm
Delayed Enhancement Imaging of the Myocardium	Phase sensitive myocardial delayed enhancement (PSMDE)	5.7ms	2.6ms	25°	320 ×320 mm~360 ×360 mm

2.2 Image Analysis:

CMR image post-processing for all patients was performed in a specialized commercial post-processing software platform CVI42 (Circle Cardiovascular Imaging Inc, Calgary, Canada, version 5.14.2) for post-processing operations. The final results will be independently evaluated by two radiologists and two clinicians, two of whom have no knowledge of the patient's clinical data.

(1) Cardiac function analysis: Choose the three-dimensional (3D) functional short-axis (SA) module for routine cardiac function parameter analysis, import the SA movie image and select the four-chamber heart (4CH) as the reference plane, click on the artificial intelligence (AI) operation button to automatically outline the endocardial and

epicardial boundaries from the base of the heart to the tip of the heart (pay attention to the exclusion of endocardial contours of the trabeculae and papillary muscles), and finally, the software analyzes the function of the myocardium automatically.

(2)Analysis of AMI with intramyocardial hemorrhage(IMH), microvascular obstruction(MVO), thrombus in the appendage or ventricular wall tumor: IMH is a phenomenon in which the integrity of the capillaries in the infarcted area is disrupted, leading to infiltration of erythrocytes into the myocardium after percutaneous coronary intervention (PCI). MVO is a phenomenon in which the microvessels cannot effectively dilate and supply enough blood to the myocardium, thus leading to myocardial ischemia, even after PCI treatment. After PCI treatment, the microvasculature is not able to effectively dilate and supply enough blood to the myocardium, resulting in myocardial ischemia. Most of the attached wall thrombi adhered to areas of myocardial scar formation, which were low-signal intraluminal filling defects without vascular tissue on LGE images and showed as black masses. Ventricular wall tumors show limited expansion and thinning of the ventricular wall in diastole and absent or discordant motion of the ventricular wall in systole on cine images. (Shown in figure 3)

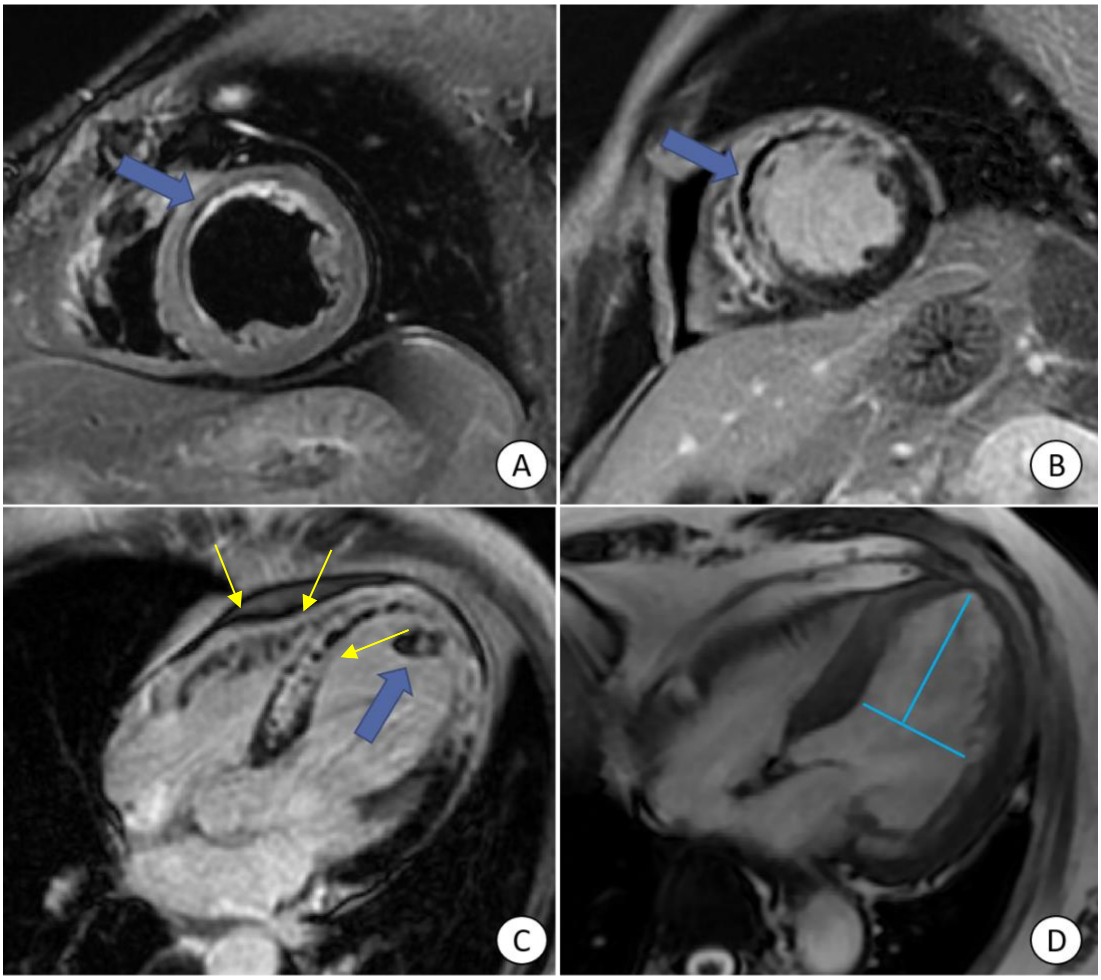


Figure 3: CMR images of patients with AMI with BBB

Note: A is IMH on T2WI image showing areas of low signal within areas of high signal (shown by blue arrows); B is MVO on LGE image showing delayed enhancement of areas of high signal within areas of nonenhancing low signal (shown by blue arrows); C is attached wall thrombus on LGE image showing marked low signal (shown by blue arrows) and surrounded by enhancing ridge plug ventricular wall (yellow arrow indicates myocardial transmural delayed enhancement); D is a ventricular wall tumor in the end-diastolic 4CH plane on the cine image, which shows the apical ventricular wall tumor of the left ventricle expanding outward.

(3) LGE and Gray zone (GZ) range analysis: By selecting the Tissue Characterization module in the CVI42 software, combined with the AI technology, the endocardium and epicardium of each layer of the image from the base to the tip of the heart were automatically outlined, and the normal myocardium was manually circled as the region of interest (ROI) at the same level in blue color, and areas with a signal intensity greater than that of the normal myocardium by 5 times the standard deviation and above were selected as LGE areas. The region with signal intensity greater than 5 times standard deviation of normal myocardium was identified as LGE region, the Grayzone Analysis option was checked, and the region with 3 times standard deviation was identified as GZ. Finally, the light yellow color was automatically displayed by the software as the range of LGE and the brown color as the range of GZ, and the area and volume of LGE and the mass and volume of GZ were automatically calculated. (Shown in figure 4)

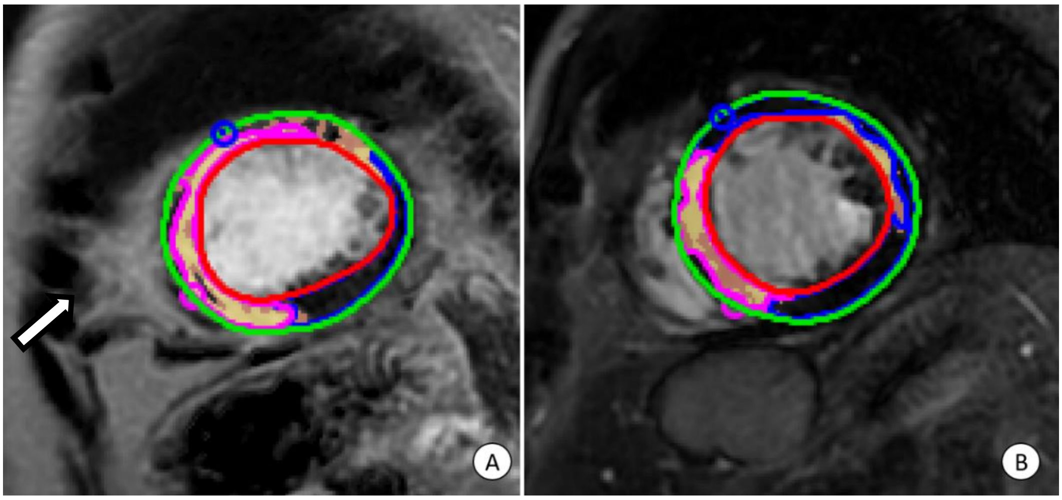
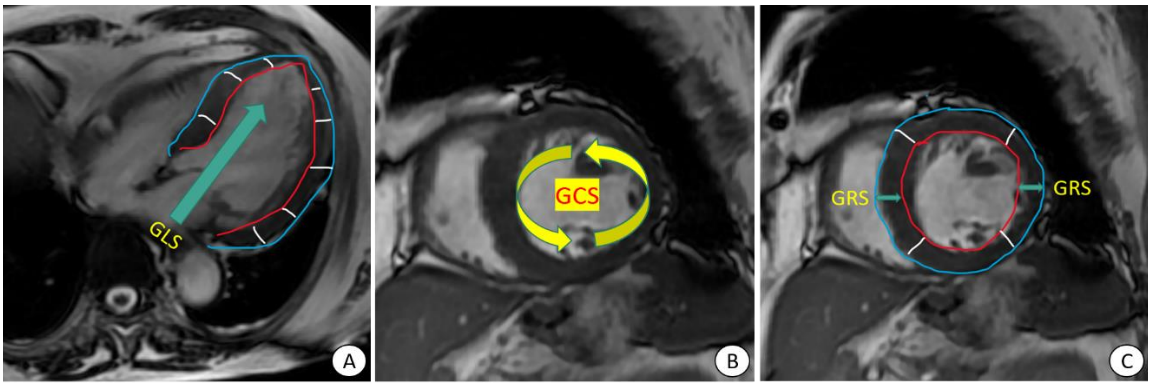


Figure 4: CVI42 measurement of LGE and GZ operating planes

Note: The light yellow area is the LGE, the tan area is the GZ, the blue area is the ROI, and the white arrow is the MVO in Fig. 4. A indicates the SA level of the patients with AMI with BBB, and B is the SA level of the patients with AMI without BBB, which was found to have smaller ranges of the LGE and the GZ than the image in A.

(4) MS analysis: The MS parameters were measured by using the tissue tracking function of CVI42 software, and the images of movie sequences were imported into the strain module of CVI42 software, and the parameters of global circumferential strain (GCS), global radial strain (GRS), and global longitudinal strain (GLS) were obtained automatically by the software. (Shown in figure 5)



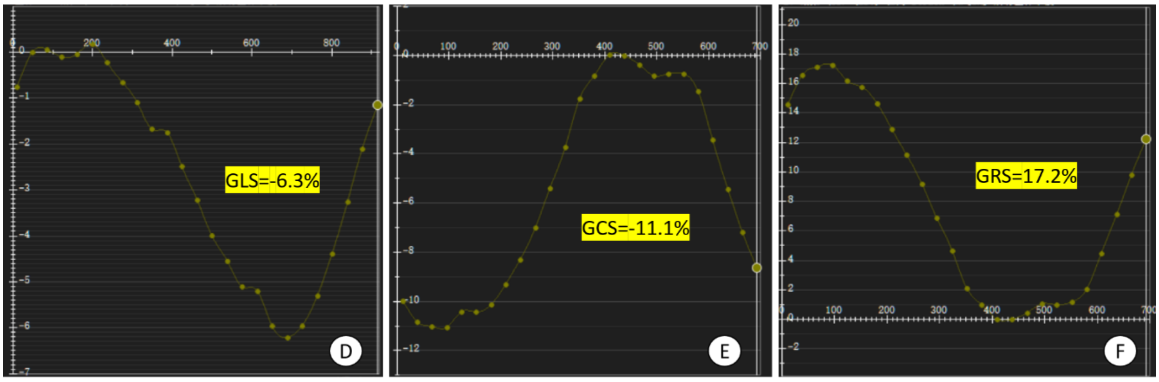


Figure 5: Overall myocardial strain profile in AMI patients with BBB

Note: A is GLS indicates the degree of myocardial stretch from the basal segment pointing in the apical direction; B is GCS indicates the degree of myocardial change in the circumferential direction; and C is GRS indicates the degree of myocardial change pointing in the direction of the center of the LV chambers.D to F show the time-overall myocardial strain curves for GLS, GCS, and GRS of the LV of the patient, in which the time (ms) is expressed on the horizontal coordinate and the myocardial strain force (%) is expressed on the the vertical coordinate, GLS and GCS are the minimum values taken on the strain curve, and GRS is the maximum value taken on the strain curve, with values of -6.3%, -11.1%, and 17.2%, respectively.

3. statistical analysis

Statistical analysis was performed using SPSS 27.0 software, and information on continuous variables in this study was tested for normality using the S-W method and Q-Q plots. Results that conformed to normal distribution were expressed as mean ± standard deviation (x ± s) using independent samples t-test; those that did not conform to normal distribution were expressed as interquartile spacing [M (P25, P75)], and rank sum test was used for both groups (Mann Whitney U). Categorical variable information packages were expressed as frequencies (n%) and tested by Fisher's exact probability method (due to small sample size). The clinically significant parameters ($P < 0.05$) were first included in the one-way logistic regression analysis, and then the clinically significant parameters ($P < 0.05$) were screened out from the one-way analysis and then subjected to the multifactorial logistic regression analysis, and finally the independent influences of AMI with BBB patients were obtained. Finally, the accuracy of the multifactorial analysis model was measured using the receiver operating characteristic curve (ROC), and the 95% confidence intervals (CI) and ratio of ratios (OR), area under the curve (AUC), optimal critical value, specificity and sensitivity were calculated.

4.Results

4.1 Baseline characteristics of patients in both groups

A total of 57 patients diagnosed with AMI and completing CMR within two weeks between January 2019 and June 2023 were included, including 19 patients with BBB and 38 patients without BBB. Patients with BBB were older and had a higher incidence of hypertension, diabetes, and peripheral vascular sclerosis compared with patients without BBB, but none were statistically significant. (Shown in table 1)

Table 1: Baseline characteristics of the two groups of patients

	BBB Group (n=19)	Non-BBB Group (n=38)	P value
CMR time (day)	8.0 (5.0， 11.0)	9.0 (6.0， 14.0)	0.41
Age (years)	57.79±8.64	53.45±7.36	0.07
Sex (female)	2 (10.5%)	6 (15.8%)	0.71
hypertensive disease	9 (47.4%)	15 (39.5%)	0.78
diabetes	6 (31.6%)	9 (23.7%)	0.54
hypercholesterolemia	5 (26.3%)	12 (30.8%)	1.00
peripheral vascular disease	10 (52.6%)	18 (47.4%)	0.78

4.2 CMR characteristics of patients in both groups

Patients with AMI with BBB had significantly lower LVEF (33.63±7.52% vs. 42.52±8.79%, P<0.001) and larger LVESV (76.11±34.17ml vs. 50.13±28.18ml, P=0.003) than those without BBB, and the difference was statistically significant. The LGE and GZ in the BBB group had a greater The range was greater in the BBB group than in the non-BBB group, LGE area (32.84±6.29% vs. 26.42±7.50%, P=0.002), GZ volume (14.84±5.93ml vs. 10.66±4.06ml, P=0.003) and GZ mass (6.71±4.14g vs. 4.91±2.15g, P=0.03) were statistically significant. GLS, GCS, and GRS were attenuated in the BBB group, with GCS attenuation being the most significant (-13.82±3.02% vs -15.94±3.34%, P=0.02). The difference in the remaining CMR parameters between the two groups was not statistically significant (P > 0.05). (Shown in table 2)

Table 2 CMR characteristics of the two groups of patients

	BBB Group (n=19)	Non-BBB Group (n=38)	P value
LAD (mm)	34.32±6.86	33.37±4.69	0.54
LVDd (mm)	55.47±6.03	52.46±7.15	0.12
mitral regurgitation	7 (36.8%)	16 (42.1%)	0.78
tricuspid regurgitation	5 (22.7%)	12 (31.6%)	0.56
pericardial effusion	6 (31.6%)	11 (28.9%）	1.00
pleural effusion	6 (31.6%)	9 (24.3%)	0.75
LVEF (%)	33.63±7.52	42.52±8.79	**＜0.001**
LVEDV (ml)	117.79±40.13	103.33±33.89	0.16
LVESV (ml)	76.11±34.17	50.13±28.18	**0.003**
SV (ml)	46.27±12.84	45.48±11.81	0.82

CO (l/min)	3.21±1.43	3.19±0.74	0.96
LV mass	129.0(113.0，146.0）	115.0（101.75，132.75）	0.44
HR (beats/min)	75.66±11.34	73.41±10.73	0.38
Transmural myocardial infarction	16(84.2%)	29(76.3%)	0.73
LGE area (%)	32.84±6.29	26.42±7.50	**0.002**
LGE volume (ml)	14.84±5.93	10.66±4.06	**0.003**
GZ area (%)	5.99±2.90	4.80±2.44	0.11
GZ mass (g)	6.71±4.14	4.91±2.15	**0.03**
MVO	3 (15.8%)	11 (28.9%)	0.34
IMH	2 (10.5%)	5 (13.2%)	1.00
ventricular wall tumor	12 (63.2%)	17 (47.2%)	0.39
thrombus in the appendage	6 (31.6%)	8 (21.1%)	0.52
GRS (%)	22.83±4.75	24.32±3.09	0.16
GCS (%)	-13.82±3.02	-15.94±3.34	**0.02**
GLS (%)	-9.59±2.49	-10.64±2.45	0.14

Notes: LVESV: Left ventricular end-systolic volume, LAD: left atrial internal diameter,; LVDd: left ventricular internal diameter; LV mass: left ventricular mass; LVEF: left ventricular ejection fraction; HR: heart rate; SV: stroke volume; CO: cardiac output; MVO: microvascular obstruction; IMH: intramyocardial hemorrhage; LGE: late gadolinium enhancement; GZ: gray zone; GCS: global circumferential strain; GLS: global longitudinal strain; GRS: global radial strain.

4.3 Univariate and multivariate logistic regression analysis of the two groups of patients

The above statistically significant parameters ($P < 0.05$) were subjected to univariate analysis, and the univariate analysis showed that AMI patients with BBB had lower LVEF and GCS, and greater LVESV, GZ mass, and late gadolinium enhanced (LGE) (LGE) area and volume than patients without BBB, and then the statistically significant parameters of the univariate results ($P < 0.05$) were subjected to multifactorial logistic regression analysis, and LVEF, GCS, and LGE area and volume were found to be independent influential CMR parameters in patients with AMI with BBB (Shown in table 3 and table 4). Finally, the screened independent influencing factors were further analyzed by drawing ROC curves (Shown in figure 6 and figure 7).

Table 3: Univariate and multivariate Logistic regression analysis of both groups of patients

	Univariate analysis		**Multivariate analysis**	
	OR (95%CI)	**P value**	**OR (95%CI）**	**P value**
LVEF (%)	0.878 (0.808，0.954)	0.002	0.885 (0.788，0.994)	**0.040**

LVESV (ml)	1.027 (1.007, 1.047)	0.008	1.028 (0.993, 1.064)	0.120
LGE area (%)	1.134 (1.038, 1.238)	0.005	1.143 (1.006, 1.298)	**0.040**
LGE volume (ml)	1.193 (1.047, 1.360)	0.008	1.271 (1.026, 1.576)	**0.028**
GZ mass (g)	1.220 (1.007, 1.479)	0.042	0.958 (0.726, 1.264)	0.762
GCS (%)	0.821 (0.686, 0.982)	0.031	0.775 (0.602, 0.998)	**0.048**

Note: LVEF, left ventricular ejection fraction; LVESV, left ventricular end-systolic volume; LGE, late gadolinium enhancement; GZ, gray zone; GCS, global circumferential strain.

Table 4: Multifactorial Logistic regression analysis of the two groups of patients

	AUC	optimal threshold	sensitivity	specificity	Jordon index
LGE area (%)	0.758	30.5%	73.7%	68.4%	0.421
LGE volume (ml)	0.720	11.5ml	73.7%	60.5%	0.342
LVEF (%)	0.780	36.5%	73.7%	71.1%	0.447
GCS (%)	0.706	-14.36%	68.4 %	73.7%	0.542

Note: LVEF, left ventricular ejection fraction; LVESV, left ventricular end-systolic volume; LGE, late gadolinium enhancement; GZ, gray zone; GCS, global circumferential strain.

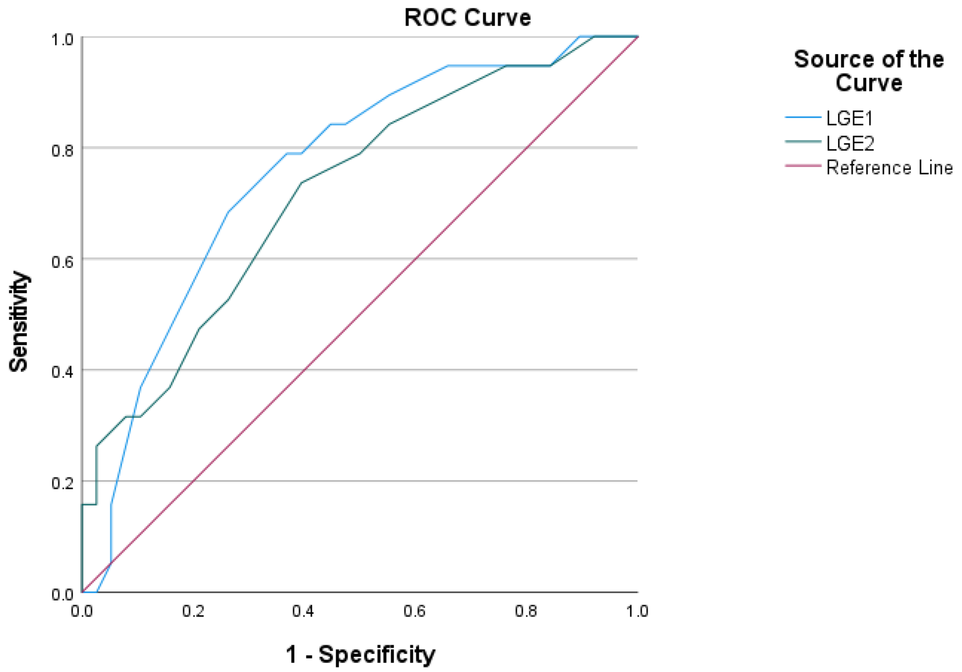


Figure 6 shows the ROC curves for LGE area (LGE1) and volume (LGE2) MR parameters

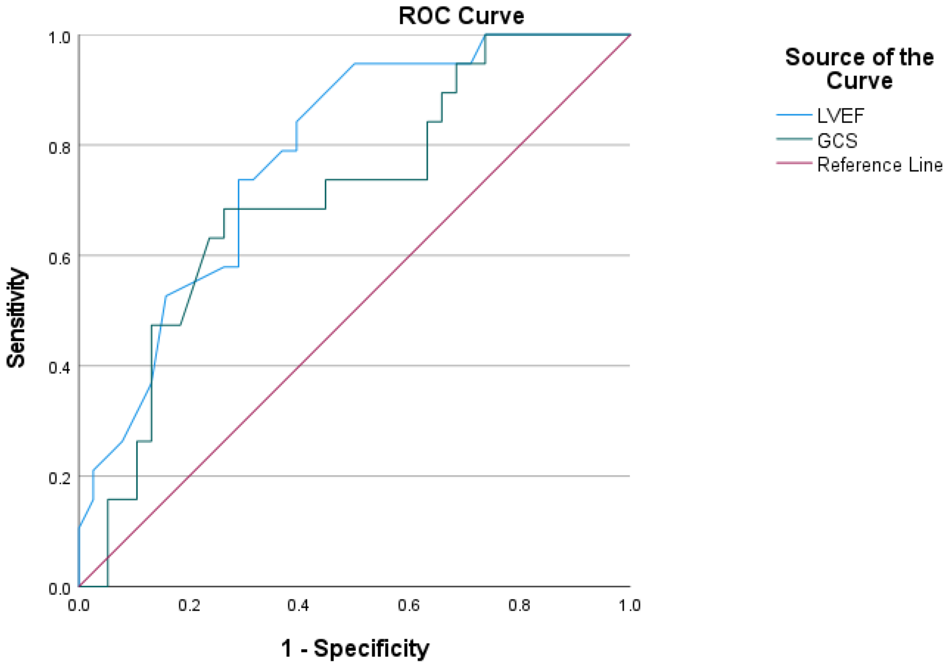


Figure 7 shows the ROC curves for LVEF and GCS MR parameters

5. Discussion

In the present study, it was found that left ventricular(LVfunction was worse, myocardial strain (MS) was lower, and the late gadolinium enhancement (LGE) was more extensive inacute myocardial infarction (AMI) patients with combined bundle branch block (BBB) compared with patients with AMI alone.

Previous studies have reported a 10%-15.4% incidence of AMI with right bundle branch block (RBBB) and a 3.2% incidence of left bundle branch block (LBBB), which has been on the rise in recent years [5]. Numerous studies have shown that patients with AMI with BBB have more extensive myocardial infarction and poorer cardiac function, which affects the conduction of cardiac electrical signals, leading to uncoordinated systole and diastole, thus affecting the pumping capacity of the heart [6], Patients with AMI with BBB are susceptible to heart failure, ventricular tachycardia, ventricular fibrillation, and high degree of atrioventricular block, and their in-hospital mortality and long-term morbidity are significantly increased [7,8]. Percutaneous coronary intervention (PCI) can achieve early perfusion, early myocardial salvage, significantly improve cardiac function and prognosis, and reduce the immediate and long-term mortality rate [9].Therefore, early identification of patients with AMI with BBB is important for their diagnosis and treatment as well as prognosis.

Left ventricular ejection fraction (LVEF) is a global indicator of overall left ventricular exercise function and a classic parameter for predicting outcome events in patients with AMI, and when LVEF is <35% it is considered to be an important indicator of severe left ventricular cardiac decompensation. Brilakis, on the other hand, examined the changes in cardiac function and the prognosis of patients with AMI in combination with BBB, and found that the LVEF of this group of patients was significantly reduced [10]. Previous studies have shown reduced LVEF in patients with coronary artery disease with BBB compared to those without BBB, which is hypothesized to be related to the impact on ventricular function [11]. In addition, the incidence and extent of severe heart failure in AMI patients with

BBB was significantly higher than in those without BBB [12]. The present study reached a similar conclusion that LVEF was significantly lower in patients with AMI with BBB than in patients without BBB, and that LVEF was an independent influence in this group of patients in the multifactorial analysis.When LVEF decreases significantly, it indicates that myocardial contractile function decreases significantly, and it also indicates that myocardial ischemia is aggravated. When the myocardium is in an ischemic state for a long period of time, it will lead to changes in the cardiac structure and reduced myocardial compliance, and it will be more likely to induce arrhythmic events such as BBB, and heart failure or even cardiogenic shock can occur in severe cases. In conclusion, conduction disorders and cardiac remodeling in patients with AMI with BBB interact with each other, cause and effect each other, and form a vicious circle, which ultimately results in a continuous deterioration of cardiac function in patients [13].

Patients with AMI with BBB often have irreversible cardiomyocyte necrosis with a wide range of LGE, resulting in reduced cardiac systolic-diastolic function. The unique intraventricular agonistic sequence of the BBB and the underlying paradoxical movement of the septum delay left ventricular depolarization, and when the left ventricle is depolarized, the septum is in a state of repolarization, and the heart's movement is uncoordinated and contraction is asynchronous, resulting in a decline in left ventricular excretion with a consequent drop in LVEF, and thus is often combined with the concomitant signs and symptoms of heart failure [14]. Previous studies have shown that when AMI occurs, ischemia starts from the subendocardium first and then progresses to the subepicardial myocardium, and the site of ischemia is susceptible to abnormal myocardial electrical activity, forming a slow conduction zone, which induces arrhythmia as an adverse cardiovascular event [15]. LGE is the "gold standard" for assessing myocardial activity and scarring, and has a decisive impact on the treatment and prognosis of patients with AMI, as it is sensitive to the visualization of myocardial fibrotic lesions. Studies have shown that the extent of LGE increases with the degree of infarcted myocardial permeability and is strongly associated with arrhythmias and left ventricular remodeling [16]. In this study, we found that the LGE area and volume were larger in patients with AMI with BBB than in those without BBB, and were statistically significant in multifactorial analysis as independent parameters affecting this group of patients. First, in general, patients with AMI are less likely to have involvement of the septum, but when the LGE area and volume are larger, it is more likely to have an effect on the bundle branches traveling to the left and right of the septum, and the probability of BBB is greater. Secondly, due to the heterogeneity of the LGE, myocardial electrical activity is abnormal and conduction pathways are impaired. When electrical activity is transmitted to this area, it is easy to form refractory loops to induce arrhythmias, and elevated ventricular wall pressure, molecular/cellular changes, and myocardial fibrosis may damage the conduction tissues, which in turn aggravates asynchronous electrical conduction. Finally, the typical pathology of AMI patients includes myocardial fibrosis, and the increased fibrous interstitium not only severely impairs normal myocardial diastolic function, but also interferes with normal myocardial electrophysiological activity, aggravates asynchronous conduction, and thus induces malignant cardiovascular events.

The diastolic motion of the left ventricle is a complex overall coordinated process, including longitudinal expansion and contraction of the long-axis, radial expansion and contraction of the short-axis plane, and circumferential rotation of the three directional changes in motion, which is graphically depicted as the "wringing of the towel" motion. LVEF is the most commonly used index to assess left ventricular systolic function in clinical practice, but it is poorly reproducible, does not reflect local myocardial function, and is not responsive to changes in myocardial strength. MS is the kinematic deformation of myocardial fibers in response to myocardial systole, diastole, and anterior and posterior loads, reflecting myocardial elongation, shortening, thickening, or thinning, and strain imaging is more sensitive to the detection of subtle systolic dysfunction than is LVEF [17]. CMR labeling imaging or feature tracking methods can accurately characterize the motion of the myocardium as a whole as well as individual segments in different directions, where global longitudinal strain (GLS) denotes longitudinal shortening from the base to the apex, global radial strain (GRS) refers to radial thickening or thinning of the myocardium toward the center of the left ventricular cavity, and global circumferential strain (GCS) refers to shortening of left ventricular myocardial fibers along the circumference under the short-view view map, which allows for the quantitative assessment of myocardial motion function through the MS in all three directions, and is of important potential value for the diagnosis of disease and for the prognosis of the stratification of the disease [18]. Previously, the results of numerous studies have shown that MS is altered before LVEF is altered, and that patients with AMI have a major involvement of the endocardium in the early stages of the disease, in which the GLS tends to be the first to be impaired, and that the GCS is not impaired in these early stages of the disease because of the preserved function of the epicardial fibers, which even compensates for the abnormalities in longitudinal systolic function in order to maintain LVEF [19]. In a study, Mordi et al. found that GCS was an independent prognostic factor for the occurrence of cardiovascular events during the follow-up period, with independent risk predictive value [20]. In the present study, we found that MS was reduced in all three directions in patients with AMI with BBB, with significant differences in GCS values. GCS is mainly related to subepicardial myocardial fibers, and its reduction suggests that the disease has progressed from endocardial to permeable infarcts, which may be attributed to the occurrence of myocardial degeneration, fibrosis, and connective tissue hyperplasia, with myocardial fibers being significantly stretched or even overstretched, resulting in limited retraction of myocardial fibers, which results in diminished circumferential myocardial motion [21]. In conclusion, the reduced GCS suggests that myocardial infarction has a high degree of wall permeability and cardiac function enters the stage of decompensation, which in turn induces the occurrence of BBB. This study is the first in China and abroad to reveal the effect of GCS on patients with AMI with BBB, and CMR-based GCS parameters provide predictive value for cardiovascular events in patients with AMI. These results may suggest that the GCS may also be subtly altered at the early stage of significant cardiac function changes in patients with AMI with BBB, but when it starts to change during the course of AMI patients is still unknown, and its exact mechanism needs to be further explored.

There are some limitations of this study: firstly, patients with AMI with BBB included in this paper could not determine whether BBB was a new lesion or not due to lack of previous Electrocardiogram (ECG) data may cause some bias to the results. Second, only a few patients in this study were scanned with new CMR sequences such as T1 and T2 mapping and four-dimensional flow magnetic resonance imaging (4D-flow MRI), which were difficult to include for statistical analysis. Moreover, this is a small-sample retrospective study conducted in a single center, and future prospective studies with large samples are needed to provide evidence-based medical evidence and further patient follow-up. Finally, the conclusions of this study are still limited in that no exact thresholds were given for clinical decision-making. This is due to the fact that MS parameters and LGE volume scores vary greatly among different centers and image processing methods, and it is difficult to form a uniform standard to guide clinical practice, and it is hoped that standardization of scanning and processing in the future will solve the problem.

5.Conclusions

Early CMR parameters such as LVEF, GCS, and area and volume of LGE measured by the CVI42 post-processing software can better respond to the impact on patients with AMI with BBB, thus guiding clinical treatment.

Perspectives

COMPETENCY IN MEDICAL KNOWLEDGE: Early CMR images of patients with AMI with BBB were analyzed using the CVI42 software and revealed that this group of patients had worse cardiac function and MS and more severe myocardial infarction, with measured LVEF, GCS, and LGE area and volume being the independently influential parameters.

TRANSLATIONAL OUTLOOK: The present study focuses on the overall myocardial MS and LGE profile, which can be further explored in the future by exploring the MS and LGE of each segment of the patient and can be investigated by combining the new techniques of CMR imaging with the new techniques of AI processing.

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Author contributions
Bin Wang and Hong Qiao designed the protocol of this study and revised important aspects of the manuscript; Lilan Wang drafted and wrote the manuscript and obtained, analyzed, or interpreted the data for this study; Yuefeng Lin, and Lilan Wang obtained, analyzed, or interpreted the data for this study and revised important aspects of the manuscript; and all authors consented to the publication of the final revised manuscript and agreed to be accountable for all aspects of this study to ensure the accuracy and integrity of the study.

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Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations
Ethics approval and consent to participate
Ethical approval was obtained and all participants gave informed consent.

Consent for publication
No identifiable individual information was included in this study.

Competing interests
The authors declare that they have no competing interests.

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