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ORIGINAL ARTICLE

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QRS score: A simple marker to quantify the extent of myocardial scarring in patients with chronic total arterial occlusion

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Abstract

Background: Chronic total occlusion (CTO) is a critical and unique subgroup of coronary lesions. This study aimed to investigate the correlation between the Selvester QRS score and late gadolinium enhancement cardiac magnetic resonance imaging (LGE-CMRI) in quantifying myocardial scarring to provide a simple and feasible method for treating CTO.

Methods: The medical records of 134 patients with absolute CTO who underwent coronary angiography between May 1, 2014 and December 30, 2017 were retrospectively reviewed. All patients were grouped according to the CTO location (right coronary artery [RCA] CTO, left artery descending [LAD] CTO, left circumflex [LCX] CTO, and multivessel CTO groups). The degree of myocardial scarring was determined according to the Selvester QRS score and using the LGE-CMRI. All patients were followed up for at least 12 months.

Results: Among the 62 CTO patients, 55 had occlusion of a single vessel and seven had occlusion of multiple vessels, of which 27 (43.55%) were in the RCA CTO group, 16 (25.81%) in the LAD CTO group, 12 (19.35%) in the LCX CTO group, and 7 (11.29%) in the multivessel CTO group. The area under the receiver operating characteristic curve for the QRS score that was used to determine the degree of myocardial scarring was 0.806, with a sensitivity and specificity of 94.7% and 42.1%, respectively. The Selvester QRS score and LGE-CMRI measures of scar size were correlated in the RCA CTO, LCX CTO, and multivessel CTO groups ($r = 0.466$, 0.593, and 0.775, respectively).

Conclusion: The Selvester QRS score was feasible for detecting myocardial scarring in patients with CTO.

KEYWORDS

chronic total occlusion, late gadolinium enhancement cardiac magnetic resonance imaging, myocardial scar, Selvester QRS score

Hongzhou Guo and Xuan Zhou contributed equally to this work.

1 | INTRODUCTION

Chronic total occlusion (CTO) is commonly encountered in the clinic with a detection rate of approximately 20% by coronary angiography.[1] During severe occlusion of the coronary artery, some non-occluded vessels form a collateral circulation to alleviate occlusion of the distal myocardial vasculature. However, although good collateral circulation supplies the blocked myocardial vasculature, under drug-loading conditions, less than 10% of the collateral circulation can achieve a normal coronary flow reserve.[2] Clinical symptoms, ischemic burden, and viable myocardium are mainly assessed for revascularization.[3,4] Although the viable myocardial area of the CTO blood supply area is rarely evaluated in clinical practice, some studies have shown that myocardial viability may be associated with prognosis. Methods in evaluating myocardial survival include positron emission tomography, ^{201}Tl and ^{99m}Tc scintigraphy, dobutamine stress echocardiography, and late gadolinium enhancement cardiac magnetic resonance imaging (LGE-CMRI).[5–9] LGE-CMRI is the gold standard for the evaluation of myocardial survival and scarring. However, many hospitals cannot perform this examination because of the long duration of the procedure, respiratory function requirements of patients, accuracy of existing magnetic resonance analyzers, and configuration of the software.

Electrocardiography (ECG) is the most commonly used method for the clinical diagnosis of acute and chronic myocardial infarction (MI) due to its rapid availability, low price, and lack of damage to patients. By simulating the depolarization vector ring of the heart caused by MI of different parts and sizes, a corresponding electrocardiogram was obtained on the body surface. Thus, a set of criteria can be formulated to locate and estimate the degree of myocardial scarring in the left ventricle, called the QRS score, which is composed of 57 scoring items and 32 points in total, with each point representing 3% of the myocardial scar area in the left ventricle. The QRS score that was updated in 2009[10] has been revised several times to include adjustments of the score items, as well as the patient's age and sex. Most current studies used LGE-CMRI as a standard to assess the usefulness of the QRS score in locating and diagnosing myocardial scars and in assessing the extent of myocardial scarring in the left ventricle. The score correctly calculates the area of myocardial scarring related to the location and type of MI and the type of ECG conduction. In addition, to locate and estimate the proportion of myocardial scars, studies have reported that the QRS score can also predict some clinical events.[11,12] Higher scores are associated with a greater risk of ventricular arrhythmia, long-term all-cause mortality, and sudden cardiac death. Currently, there have been few studies on the estimation of the extent of myocardial scarring in patients with CTO using the QRS score. Therefore, this study aimed to determine the sensitivity and specificity of the QRS score, as compared with LGE-CMRI, in determining the extent of myocardial scarring in the left ventricle of patients with CTO.

2 | METHODS

2.1 | Ethical approval

The study protocol was reviewed and approved by the First Affiliated Hospital of Dalian Medical University. All participants provided informed consent before the study was conducted.

2.2 | Study population

The medical records of 134 patients with CTO who were admitted to the First Affiliated Hospital of Dalian Medical University from May 1, 2014 to December 30, 2017 were retrospectively reviewed. The flow chart of this study was presented in Figure 1. In total, 62 patients (49 men and 13 women) who met the inclusion criteria were enrolled in this study. According to the type of coronary heart disease (CHD), 26 patients had a definite history of MI, including eight with ST-segment elevated myocardial infarction (STEMI), 18 with non-ST segment elevated myocardial infarction (NSTEMI), and four with secondary MI. Meanwhile, 26 patients had stable angina pectoris (SAP). The ECG of six patients indicated abnormal Q waves, but none developed clinical manifestations of CHD.

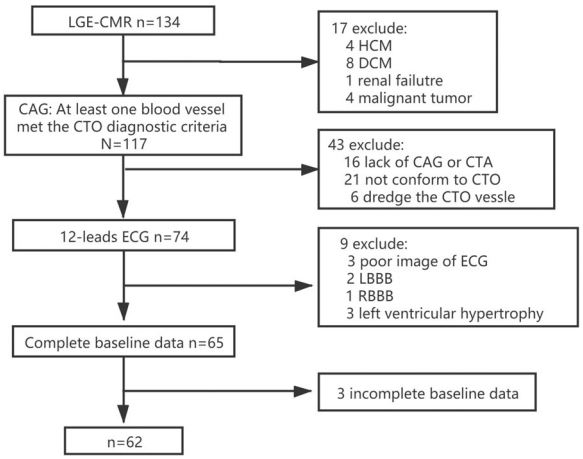

FIGURE 1 A flowchart of the exclusion and inclusion criteria. CAG, coronary angiography; CTA, computed tomography angiography; CTO, chronic total occlusion; DCM, dilated cardiomyopathy; ECG, electrocardiogram; HCM, hypertrophic cardiomyopathy; LBBB, left bundle branch block; LGE-CMRI, late gadolinium enhancement cardiac magnetic resonance imaging; RBBB, right bundle branch block

2.3 | Definitions and end points

According to the 2012 European CTO Club consensus, CTO is the complete occlusion with a thrombolysis in myocardial infarction (TIMI) score of 0 for a period of more than 3 months. As the clinical definition of time is inaccurate, there are three methods for defining time: (1) definite time for CTO with a TIMI score of 0, as confirmed by coronary angiography 3 months ago; (2) possible time of CTO of 3 months with objective evidence showing that MI in the occluded vascular area did not extend to other vessels; and (3) undetermined timing of CTO, where coronary angiography suggests a TIMI score of 0 with prolonged occlusion, SAP lasting more than 3 months, or evidence of ischemic MI. The inclusion criteria were as follows: (1) coronary angiography confirmation of at least one vessel with absolute CTO and non-CTO stenosis of <90% in the case of multiple vascular lesions, and (2) diagnosis of CTO and cardiac MRI performed within 1 week. Patients undergoing percutaneous coronary intervention (PCI) should undergo LGE-CMRI before interventional therapy; if combined with acute MI, MRI should be performed at 1 month after MI and before CTO revascularization. The exclusion criteria were as follows: (1) ECG showing left bundle branch block, right bundle branch block (RBBB), left anterior branch block, and ventricular hypertrophy; (2) chronic heart failure New York Heart Association (NYHA) Functional Classification of IV or acute left heart failure; (3) combination of various types of cardiomyopathy, including dilated cardiomyopathy, hypertrophic cardiomyopathy, rheumatic heart disease, dense insufficiency cardiomyopathy, arrhythmia cardiomyopathy, myocarditis, and coronary arteritis; (4) severe electrolyte disturbance that has not been corrected; (5) secondary hypertension, severe hepatic insufficiency (aspartate aminotransferase/alanine aminotransferase ratio of three-fold greater than normal), severe renal insufficiency (estimated glomerular filtration rate of <30 ml/min/1.73 m^2; (6) patients with malignant tumors or accompanied by cancer, immune system diseases, hematological disease, use of glucocorticoid drugs within 2 weeks, use of immunosuppressive drugs, and cerebral infarction; (7) acute and chronic infection, surgery, or external injury within 1 month; and (8) refusal to sign an informed consent or to undergo a cardiac MRI examination.

2.4 | QRS scoring

All patients underwent a standard 12-conductor electrocardiography on admission. Patients with acute MI were selected 30 days after the onset of chest pain, while those with SAP were selected immediately after admission. Changes to the cardiac cycle may lead to different scores; thus, the ECG with the most stable QRS waveform and the least amount of disturbance was selected to determine the QRS score (the equipotential line is the closest to the level, no anterior contraction). If necessary, the ECG was amplified, and the same ECG was scored by two physicians blinded to the patient's condition and cardiac nuclear magnetic results. If the score was inconsistent, the average value was used for the analysis. The 2009 version of the QRS score was used for all the evaluations. Ten leads, including III and aVR, were assessed, with a total of 53 criteria and 32 points, where each point represented approximately 3% of the left ventricular area. The corresponding scoring criteria were selected according to the ECG type before grading. On V1, the main wave of QRS was downward, representing rS or QS, and the type of ECG was selected according to Figure 2. R or R' is represented by an upward trend in the main QRS wave. The type of ECG was selected according to Figure 3. Several types of ECG were used for screening: left bundle branch block, left anterior fascicular block (LAFB), left anterior branch block, RBBB, left ventricular hypertrophy (LVH), LAFB + RBBB, and normal ECG. The standard amplitude and time limits were adjusted according to the patient's sex and age. At 55 years old, for every 1 year younger, the amplitude standard of each lead was increased by 1%; for every 1 year older, the amplitude standard for each lead was reduced by 1%.

2.5 | Late gadolinium enhancement cardiac magnetic resonance imaging

LGE-CMRI was used to evaluate the ratio of the myocardial scar area. MRI was performed using a Signa™ HDxt 1.5 T magnetic resonance scanner (General Electric Medical Systems, Waukesha, WI, USA), routine CMR scanning, perfusion-weighted imaging (PWI), and delayed contrast enhancement (DCE) scanning. The scan sequences included FIESTA, PWI, and DCE. The specific FIESTA scanning parameters were as follows: repetition time, 3.6 ms; echo time, 1.6 ms; field of view,

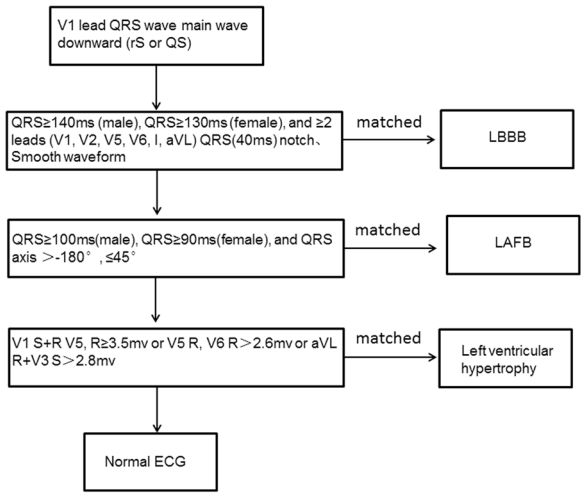

FIGURE 2 A flowchart of ECG type screening when the QRS main wave is downward. ECG, electrocardiogram; LAFB, left anterior fascicular block; LBBB, left bundle branch block

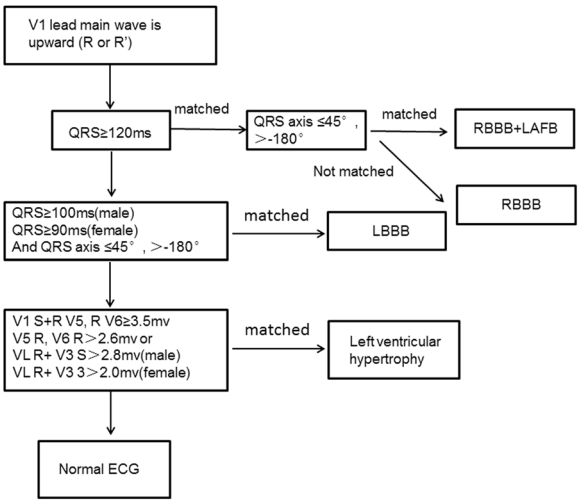

FIGURE 3 A flowchart of ECG type screening when the QRS main wave is upward. ECG, electrocardiogram; LAFB, left anterior fascicular block; LBBB, left bundle branch block; RBBB, right bundle branch block

350 × 350 mm; matrix, 192 × 224; layer thickness, 10 mm; and layer spacing, 0. Then, the first perfusion image of the myocardium was obtained using the intravenous gadolinium as the contrast agent at 0.1 ml/kg and a flow rate of 5 ml/s. Finally, myocardial LGE imaging was performed. At the end of the first resting perfusion scan, the gadolinium contrast agent was injected intravenously at 0.1 ml/kg and a flow rate of 2 ml/s. DCE scanning was completed 7–10 min after the second infusion using an EEG-triggered reversion recovery-rapid gradient echo sequence (ir-fgr), tr-6.Imsec, with an echo time of 2 ms. After completing the scanning, a postprocessing workstation and ReportCARD 4.0 software (GE Healthcare, Chicago, IL, USA) were used for data analysis, aiming to observe whether there was delayed myocardial enhancement on the image and to calculate the extent of myocardial scarring. Imaging software operations and evaluations were performed by specialized technicians who were blinded to the procedures and objectives of this study.

2.6 | Analysis of scoring results

To improve the accuracy of the analysis, all scoring results were carefully reviewed and analyzed by two professional doctors. Twenty lesions were randomly selected and evaluated by these two doctors and another senior doctor to test the consistency of the scores.

2.7 | Statistical analysis

All statistical analyses were performed using IBM SPSS Statistics for Windows (version 19.0; IBM Corporation, Armonk, NY, USA). The enumeration data were expressed as frequencies and percentages and were assessed using Fisher's exact test. Continuous measurement data are presented as the mean ± SD. A *t*-test was used to analyze normally distributed data; otherwise, a *t*-prime test was performed. The correlation between the QRS score and the extent of myocardial scarring, as determined by LGE-CMRI, was tested using Spearman's rank correlation coefficient. The diagnostic value of the QRS score was determined based on the subject's working characteristic curve (receiver operating characteristics [ROC] curve). A post-hoc sample size calculation was performed based on sensitivity and specificity.

3 | RESULTS

3.1 | Baseline clinical data of CTO patients

The baseline clinical data of the enrolled patients are shown in Table 1. Of the 62 patients who met the inclusion criteria, 49 (79.0%) were men and 13 (21.0%) were women. The average patient age was 62.37 ± 10.22 years. Of the 62 patients, 21 (33.9%) had diabetes, 44 (71.0%) had hypertension, 26 (41.9%) were admitted for MI, 8 (12.9%) had STEMI, 18 (29.0%) had NSTEMI, 26 (41.9%) had SAP, and 4 (6.5%) had a second MI. The interobserver score showed excellent repeatability (κ: 0.708), according to the analysis and scoring by the two doctors. In six cases, ECG showed abnormal Q waves, but there was no clinical manifestation. There were 55 cases of single CTO, including 27 (43.6%) RCA CTO, 16 (25.8%) LAD CTO, and 12 (19.35%) LCX CTO, and 7 (11.3%) cases of multiple CTO. LGE-CMRI revealed that 14 (22.6%) patients had no myocardial scarring, and 53 (85.5%) patients had a QRS score of ≥1. The median percentage of left ventricular myocardial scarring, as calculated by the QRS score, was 18% (6 points); thus, the patients were assigned to one of the two groups: myocardial scarring ≤18% or >18%. The baseline data between the two groups were compared. There were more male patients in the QRS score ≤6 group ($p = 0.025$), while there was no statistically significant difference between the two groups in terms of age, diabetes, hypertension, low-density lipoprotein cholesterol, total cholesterol, congenital heart defect type, and CTO location.

3.2 | Determining the extent of myocardial scarring using the LGE-CMRI analysis

The mean value of the percentage of the left ventricle with myocardial scarring was 5.48% ± 7.12% and LVEF% was 54.75% ± 13.80%, as measured by CMRI. Myocardial

TABLE 1 Baseline clinical characteristics of patients stratified by the QRS score ($n = 62$)

Variables	QRS ≤ 6 ($n = 41$)	QRS > 6 ($n = 21$)	p values
Age (years)	64.4 ± 8.85	58.68 ± 11.42	0.056
Male	29 (46.77)	20 (32.30)	0.025
Diabetes	14 (22.58)	7 (11.29)	0.949
Hypertension	31 (50.00)	14 (22.58)	0.455
LDL-C (mmol/L)	2.30 ± 0.67	2.05 ± 0.88	0.252
TC (mmol/L)	4.02 ± 1.18	3.59 ± 1.06	0.500
Type of CHD			
STEMI	4 (6.45)	4 (6.45)	0.426
NSTEMI	14 (22.58)	4 (6.45)	0.215
SAP	20 (32.30)	6 (9.68)	0.127
Abnormal Q wave, no clinical manifestations	2 (3.23)	4 (6.45)	0.167
Twice history of MI	1 (1.61)	3 (4.83)	0.108
The position of CTO			
LAD	9 (14.51)	7 (11.29)	0.748
LCX	8 (12.91)	4 (6.45)	0.472
RCA	21 (33.87)	6 (12.9)	0.943
Multiple CTO	3 (4.8)	4 (6.45)	0.680
LVEF (%)	58.60 ± 11.62	47.24 ± 14.87	0.004
Percentage of scar area (% LV) by the QRS score	3.63 ± 2.4	15.57 ± 7.33	0.001
Percentage of scar area (%, LV) by LGE-CMRI	4.32 ± 6.4	7.38 ± 8.15	0.001

Note: Data are shown as mean ± SD or n (%).

Abbreviations: CHD: coronary heart disease; CTO: chronic total occlusion; LAD: left artery descending; LCX: left circumflex; LDL-C: low-density lipoprotein cholesterol; LGE-CMRI: late gadolinium enhancement cardiac magnetic resonance imaging; LV: left ventricle; LVEF: left ventricular ejection fraction; MI: myocardial infarction; NSTEMI: non-ST segment elevated myocardial infarction; RCA: right coronary artery; SAP: stable angina pectoris; STEMI: ST-segment elevated myocardial infarction; TC: total cholesterol.

scarring was detected in 46 (74.2%) patients. In 11 patients, there was no myocardial scarring, but the QRS score was >0, with an average of 5.75% among 10 cases of SAP and one case of NSTEMI.

3.3 | Determining the extent of myocardial scarring using the QRS score analysis

The mean percentage of left ventricular myocardial scarring, as determined by the QRS score, was 7.88% ± 7.45%. The QRS score of 8 (12.9%) patients was

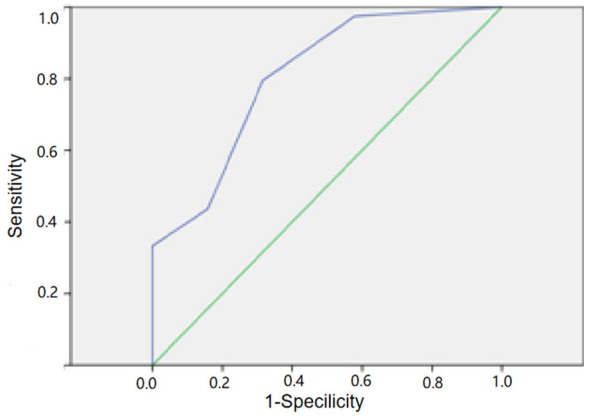

FIGURE 4 The area under the ROC curve of the QRS score was 0.806 (95% confidence interval = 0.686–0.927, $p < 0.001$). ROC, receiver operating characteristics

0, but myocardial scarring could be detected by CMRI, with an average of 3.7% (range, 0.2%–13.5%), which included five cases of SAP and three cases of NSTEMI. The scar area measured in a patient by the QRS score and CMRI showed a large difference of 13.5% and 9.6%, respectively. The average myocardial scarred area of the remaining patients was 1.4%, which was less than 3% of the left ventricle area; thus, these patients were assigned 1 point.

3.4 | Sensitivity and specificity of the QRS score in measuring myocardial scarring

Myocardial scarring was not detected by either method in one patient. The QRS score correctly detected myocardial scarring in 40 (83.3%) patients, while 13 (92.9%) patients without myocardial scarring were incorrectly diagnosed. The area under the ROC curve for the QRS score was 0.806 (95% confidence interval = 0.686–0.927, $p < 0.001$), with a sensitivity of 97.4% and specificity of 42.1% (Figure 4).

3.5 | Correlation between the QRS score and percentage of myocardial scarring as measured by LGE-CMRI

The patients were grouped according to the type of CHD: SAP group, NSTEMI group, STEMI group, ECG with abnormal Q wave but without clinical manifestation group, and a group with a history of two MI episodes. The correlation between the percentages of myocardial scarring by the two methods is shown in Table 2. For the 26 patients in the SAP group, the average percentages of myocardial scarring, as measured by LGE-CMRI and the QRS score, were 3.3% and 5.4%, respectively ($r = 0.021$, $p = 0.919$). However, the

difference was not statistically significant. For the 18 patients in the NSTEMI group, the average percentages of myocardial scarring, as measured by LGE-CMRI and the QRS score, were 4.5% and 5.1%, respectively ($r = -0.268$, $p = 0.992$), without statistically significant difference. Of the eight patients in the STEMI group, the average percentages of myocardial scarring, as measured by LGE-CMRI and the QRS score, were 9.7% and 11.3%, respectively ($r = 0.332$, $p = 0.422$), without statistically significant difference. For the six patients in the ECG with abnormal Q wave but without clinical manifestation group, the average percentages of myocardial scarring, as measured by LGE-CMRI and the QRS score, were 3.9% and 12.0%, respectively ($r = 0.371$, $p = 0.468$), without statistically significant difference. For the four patients with a second incidence of MI, the average percentages of myocardial scarring, as measured by LGE-CMRI and the QRS score, were 17.4% and 15.8%, respectively ($r = 0.600$, $p = 0.400$), without statistically significant difference.

The area of myocardial scarring measured by the QRS score was larger than the area calculated by LGE-CMRI among the different groups, but the difference was statistically significant only in the abnormal Q-wave group ($n = 6$, $p = 0.091$). Once grouped according to the location of the occlusion, the correlation between the extent of myocardial scarring was determined (Table 3). For the 16 patients with LAD CTO, the average percentages of myocardial scarring, as measured by LGE-CMRI and the QRS score, were 7.7% and 7.2%, respectively ($r = 0.353$, $p = 0.237$), without statistically significant difference. For the 12 patients in the LCX CTO group, the average percentages of myocardial scarring, as measured by LGE-CMRI and the QRS score, were 3.6% and 8.5%, respectively ($r = 0.593$, $p = 0.042$), showing a significant difference. In the RCA CTO group, the mean percentages of myocardial scarring, as measured by LGE-CMRI and the QRS score, were 4.3% and 5.8%, respectively ($r = 0.466$, $p = 0.009$), with a statistically significant difference. The mean percentages of myocardial scarring, as measured by LGE-CMRI and the QRS score, were 17.4% and 15.8%, respectively ($r = 0.775$, $p = 0.041$), indicating that the difference was statistically significant. The calculated areas of myocardial scarring were all greater than those of the nuclear magnetic group, but it was only statistically significant in the LCX CTO group ($n = 9$, $p = 0.036$).

For CHD patients with at least one occluded artery, the QRS score detected myocardial scarring (AUC = 0.806) with a sensitivity of 97.4% and specificity of 42.1%. When determining the proportion of myocardial scarring, as compared with LGE-CMRI, the two methods used in the RCA CTO and LCX CTO groups showed a moderate correlation (RCA CTO: $r = 0.466$, $p = 0.009$; LCX CTO: $r = 0.593$, $p = 0.042$), and there was a high correlation with occlusion of multiple vessels ($r = 0.775$, $p = 0.041$). The area of myocardial scarring was larger when measured using the QRS score as opposed to LGE-CMRI.

TABLE 2 Correlation between the QRS score and LGE-CMRI evaluation of the area of myocardial scarring

Groups	*n*	LGE-CMRI (%)	QRS (%)	*r*	*p* values
RCA CTO	27	4.30 ± 4.63	5.8 ± 6.75	0.466	0.009
LAD CTO	16	7.69 ± 7.04	7.15 ± 6.60	0.353	0.237
LCX CTO	12	3.62 ± 3.07	8.54 ± 8.14	0.593	0.042
Multiple CTO	7	17.39 ± 9.04	15.75 ± 8.26	0.775	0.041

Note: Data are shown as the mean ± SD.

Abbreviations: CTO, chronic total occlusion; LAD, left artery descending; LCX, left circumflex; LGE-CMRI, late gadolinium enhancement cardiac magnetic resonance imaging; RCA, right coronary artery.

3.6 | Follow-up results

Major adverse cardiac events (MACEs) included acute MI, revascularization, rehospitalization, heart failure, and cardiac death. Over a mean follow-up period of 12 ± 5 months, the MACE rates were 16% (10 patients). The QRS score as a continuous variable was significantly correlated

TABLE 3 Correlation between QRS scores and LGE-CMRI evaluation of the area of myocardial scarring in CTO patients with different types of CHD

Groups	*n*	LGE-CMRI (%)	QRS (%)	*r*	*p*
STEMI	8	9.67 ± 9.45	11.25 ± 8.71	−0.332	0.422
NSTEMI	18	4.52 ± 5.55	5.12 ± 4.34	−0.268	0.992
SAP	26	3.26 ± 4.75	5.40 ± 5.88	0.021	0.919
Twice history of MI	4	17.39 ± 7.83	15.75 ± 7.15	0.600	0.400
Abnormal Q wave, no clinical manifestations	6	3.91 ± 3.62	12.0 ± 9.33	0.371	0.468

Note: Data are shown as the mean ± SD.

Abbreviations: LGE-CMRI, late gadolinium enhancement cardiac magnetic resonance imaging; MI, myocardial infarction; NSTEMI, non-ST segment elevated myocardial infarction; SAP, stable angina pectoris; STEMI, ST-segment elevated myocardial infarction.

with MACEs (hazard ratio [HR] = 1.079; 95% confidence interval = 1.018–1.144; $p = 0.011$). After adjusting for baseline characteristics, the QRS score remained the only significant risk factor in the multivariable model (HR = 1.075; 95% confidence interval = 1.009–1.145; $p = 0.026$).

4 | DISCUSSION

The results of this primary study showed that the QRS score might be a feasible marker for evaluating the extent of myocardial scarring and the prognosis of patients with CTO. Early studies confirmed that the QRS score could accurately locate myocardial scars and accurately determine the extent of myocardial scarring, with histopathology as a reference standard.[13–15] Most recent studies have used the first delayed LGE-CMRI as a standard in testing the ability of the QRS score to correctly diagnose and accurately measure the extent of myocardial scarring. However, the gold standards adopted by the two studies are inconsistent. The area under the ROC curve of the QRS score for the diagnosis of myocardial scar varied from 0.66 to 0.91,[11,12] which was related to the types of MI and electrocardiogram conduction. The present study found that the area under the ROC curve for the measurement of myocardial scarring was 0.806, with a sensitivity of 97.4% and a specificity of 42.1%. Although 8 (12.9%) patients had a QRS score of 0, myocardial scarring was detected by CMRI (mean, 3.7%; range, 0.2%–13.5%). After removing the difference between the two methods, the mean was 1.4%, which was less than the area ratio of 1 point.

The myocardial thickness of each layer of the cardiac MRI scan in the present study was approximately 8 mm, which is sufficient to detect very small myocardial scars. However, diagnosis in the past was based on the anatomy of the heart. Along the long shaft, the heart is divided into 5–7 areas, and images of the myocardial sections are obtained after amplifying the boundaries of the infarction and measuring their thickness. However, the resolution of the heart using this method is less than that of MRI. Therefore, for a small area of myocardial scarring, estimates based on the QRS score are not very accurate.

In this study, 11 patients were incorrectly diagnosed with myocardial scarring using the QRS score. In one study of chronic anterior wall MI,[16] the QRS score was used to determine the extent of myocardial scarring at the highest position in the middle of the front wall. For most of the false-positive results, scarring at the bottom of the heart was determined using the Q wave with leads V1 and V2. The results of the present study were similar. Among the false-positive patients, the QRS scores of six patients were based on Q waves using the V1 and V2 leads. After myocardial cell necrosis, the QRS wave patterns became abnormal due to the absence of electrical activity at the corresponding sites. Therefore, scoring criteria for the localization and extent of myocardial scarring was developed, namely the QRS score.

The cited studies mostly reported STEMI and cardiomyopathy, which are well correlated with the extent of myocardial scarring as measured by CMR. However, in the present study, myocardial scarring in patients with occlusion of a single or multiple vessels and non-occlusive vascular stenosis varied between 75% and 90%. Vascular stenosis and occlusion can lead to differences in the corresponding areas of myocardial ischemia and fibrosis formation, as these areas fail to produce normal electrical activity. If only two parts have electrical activity, an offset vector ring cannot be produced, and there is no corresponding change on the electrocardiogram; therefore, MRI should be conducted to detect myocardial scarring, despite a QRS score of 0. Further analysis with two types of methods should be performed to evaluate areas of myocardial scarring and the anatomy of the offset vector loop.

In previous studies, reperfusion therapy was not applied after MI, while currently, patients with STEMI typically receive direct PCI.[11] When the proportion of myocardial scarring is calculated by nuclear MRI and ECG after 3 months, the correlation was 0.41. However, among patients with a history of STEMI, most received direct PCI, which was associated with a small sample size ($n = 8$) in addition to the reperfusion factors. It was also reported that each point representing myocardial scarring accounts for 2% of the left ventricle after reperfusion therapy for MI, because reperfusion therapy could reduce the area of myocardial necrosis. In addition, the accuracy of the QRS score was high, which requires accuracy up to 10 ms and 0.1 mV. Even if the ECG is amplified several times, there will still be errors with the use of Vernier calipers, resulting in inaccurate scores.

The present study had some limitations. First, according to the sample size calculation, 38 patients with myocardial scar and 235 patients without myocardial scar are needed, and the increase in the number of samples will enable the verification of the effectiveness of the QRS score. However, the present study was unable to enroll the number of patients necessary. Second, this study was retrospective in nature and without random sampling, and the scoring results were analyzed only by two professional doctors. Therefore, a follow-up prospective multicenter clinical trial should be conducted to confirm the results of our study.

In conclusion, the Selvester QRS score is a potential feasible method for determining the presence and extent of myocardial scarring in patients with CTO.

CONFLICT OF INTERESTS

The authors declare no conflict of interest.

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