Late Gadolinium Enhancement on Cardiac MRI Correlates with QT Dynamicity Represented by QT/RR Relationship in Patients with Ventricular Arrhythmias

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Background: The distribution of late gadolinium enhancement (LGE) on the cardiac MRI (CMR) indicates myocardial fibrosis and provides information of possible reentry substrates. QT dynamicity reflecting repolarization abnormalities has gained attention as a potential prognostic predictive factor.

Objective: To clarify the correlation between the LGE distribution on CMR and QT dynamicity represented by the QT/RR relationship.

Methods: CMR and QT/RR analyses using Holter monitoring were performed in 34 patients (24 males, 60 ± 11 years) with ventricular tachycardia (VT) and/or ventricular fibrillation (VF). The LGE on CMR was scored using a 4-point score in 17 left ventricular segments. The sum of the LGE scores was calculated for each patient. The QT/RR slope and daytime/nighttime QT/RR ratio (day/night ratio) were calculated. The correlation between the slope or the day/night QT/RR ratio and late enhancement findings was analyzed.

Results: All patients were divided into 23 LGE positive (LGE(+)) and 11 LGE negative (LGE(-)) patients. The slopes of the QT_{Te}/RR and QT_a/RR were significantly steeper in the LGE(+) than in LGE(-) patients (0.21 ± 0.03 vs 0.13 ± 0.02 ; $P < 0.001$, 0.19 ± 0.03 vs 0.13 ± 0.02 ; $P < 0.001$, respectively), and both slopes were significantly correlated with the total LGE scores ($r = 0.83$, $P < 0.001$; $r = 0.71$, $P < 0.001$, respectively). In the LGE(+) patients, the QT_{Te} day/night (1.37 ± 0.38 vs 0.91 ± 0.33 ; $P = 0.002$) and QT_a day/night ratios (1.33 ± 0.26 vs 1.06 ± 0.30 ; $P = 0.011$) were significantly greater than those in the LGE(-) patients.

Conclusion: The LGE distribution was closely related to the QT dynamicity, suggesting that a combination of these markers can be a powerful tool for understanding the background pathophysiology.

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QT dynamicity; cardiac MRI; late gadolinium enhancement; ventricular tachycardia; ventricular fibrillation; sudden cardiac death

Myocardial fibrosis is present in both ischemic and nonischemic cardiomyopathies, and it provides a substrate for reentry leading to ventricular tachycardia and fibrillation. Recently, it has been shown that fibrosis and scar tissue can be detected as a late gadolinium enhancement (LGE) on contrast-

enhanced cardiac magnetic resonance imaging (CMR) and that the degree of the LGE is a predictive factor of cardiac sudden death (SCD)^{1,2} Moreover, the presence of myocardial scar as detected by LGE has been described as a good independent predictor of all-cause and cardiac mortality.^{3,4}

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Ventricular tachyarrhythmias are typically caused by depolarization and/or repolarization abnormalities. To detect these abnormalities for the purpose of risk stratification, various noninvasive markers such as heart rate variability, heart rate turbulence, T-wave alternans, late potentials, and QT dispersion have been proposed.⁵ Regarding the repolarization abnormalities, QT dispersion has been suggested to be one of the important markers for risk stratification. However, the ability of QT dispersion to identify cardiac patients at high risk for sudden death remains undetermined due to the fact that static ECG parameters poorly reflect the complexity of the ventricular repolarization process which depends on different dynamic components, such as the transmembrane ionic currents, heart rate, and autonomic nervous system activity.^{5,6} In its place, the QT/RR slope, analyzed based on long-term Holter recordings, which can evaluate the QT adaptation to a changing heart rate, has gained attention as one of the most popular methods for detecting repolarization abnormalities. Indeed, it has been shown that the QT/RR slope is significantly increased in patients with organic heart disease⁶⁻¹⁰ whereas it is remarkably decreased in patients with idiopathic ventricular fibrillation.¹¹⁻¹⁴ Thus, both CMR imaging and QT dynamicity are expected to be powerful tools for risk stratification of SCD.

In this study, we attempted to clarify the correlation between the LGE distribution and QT/RR relationship in patients with severe ventricular arrhythmias and to discern whether or not the combination of these parameters can be useful for understanding the background pathophysiology.

METHODS

Study Patients

CMR and QT/RR analyses using Holter monitoring were simultaneously performed in 34 patients (24 males, 60 ± 11 years) with ventricular tachycardia (VT) and/or ventricular fibrillation (VF). Of the 34 patients, 7 (21%) had sustained VT, 17 (50%) nonsustained VT, and 10 (29%) had VF. Nonsustained VT was defined as three or more consecutive premature complexes with a heart rate of >120 beats/min. All participants gave written informed consent. Table 1 shows the detailed parameters of the CMR, QT, and QT/RR data in the

study population. The study patients were divided into two groups; the organic disorder group ($n = 23$) including nonischemic cardiomyopathy and ischemic heart diseases, and idiopathic disorder group including idiopathic ventricular fibrillation and Brugada syndrome ($n = 11$). The relevant data in patients with no history of VT or VF were also evaluated as a control group ($n = 55$). The control patients were free of organic heart disease but most did not undergo CMR scans. Regarding the drugs used, no medications were prescribed in the idiopathic-disorder group; in the organic disorder group however, 11 patients received β -blockers and 9 antiarrhythmic agents (7 patients received amiodarone, 1 mexiletine, and 1 both amiodarone and mexiletine).

CMR protocol and Analysis

A 1.5-T scanner (Magnetom Sonata, Siemens Japan K.K., Tokyo, Japan) was used for all CMR examinations. The CMR protocol included a functional study of the left ventricle (LV) using an ECG-triggered breath-hold segmented steady-state free-precession cine sequence with a slice thickness of 8 mm. After three standard long-axis slices were obtained, contiguous short-axis slices were acquired to cover the entire LV without any interslice gap. The LGE images were obtained 5–15 min after intravenous administration of 0.15 mmol/kg of gadolinium-DTPA (Magnevist, Bayer Yakuhin, Ltd., Osaka, Japan) with a breath-hold two dimensional segmented inversion-recovery sequence (TI: 200–400 ms), acquired in the same orientation as the cine images.

The LV volumes, mass, ejection fraction, and LGE status, were assessed via standard planimetry techniques with semiautomated computer software (QMass MR version 7.2.2, Medis Medical Imaging Systems, Leiden, The Netherlands) by two independent readers blinded to all patient information. We manually traced the LV endocardial border on all short-axis images. Using a semiautomatic detection algorithm, we applied a signal-intensity threshold of 4 SDs above a reference remote myocardial region on the same slice to define areas of LGE. The left ventricular wall was divided into four walls: septal, anterior, lateral, and inferior; in turn, the 4 walls were divided into 17 segments: 6 basal, 6 mid, 4 apical, and 1 apex (Figure 1). For each segment, the area and distribution of the LGE were assessed. The segments were classified into

Table 1. Characteristics of 34 Patients with or without LGE

	All Patients (n = 34)	LGE Status			ANOVA P Value
		Idiopathic Disorder Group LGE (–) (n = 11)	Organic Disorder Group LGE (+) (n = 23)	Control (n = 55)	
Male	24 (71%)	9 (82%)	15 (65%)	40 (73%)	
Age, years	60 ± 11	53 ± 9	63 ± 10	55 ± 17	
CMR parameters				Not done	
LVEF, %	45 ± 15	59 ± 4 ^{\$}	39 ± 14 ^{\$}		
LVEDV, mL	160 ± 74	114 ± 38 [¶]	181 ± 78 [¶]		
LVESV, mL	96 ± 71	48 ± 18 [‡]	119 ± 75 [‡]		
Total LGE score, pts.	18 ± 15	0	27 ± 9		
ECG parameters					
HR, beats/min	62 ± 7	59 ± 6	64 ± 7	67 ± 10	
QT, ms	432 ± 36	413 ± 25 [¶]	441 ± 37 [¶]	397 ± 34	<0.001 ^b
QTc, ms	439 ± 34	409 ± 25 ^{\$}	452 ± 29 ^{\$}	420 ± 22	<0.001 ^{a,b}
QTe/RR slope	0.18 ± 0.05	0.13 ± 0.02 ^{\$}	0.21 ± 0.03 ^{\$}	0.16 ± 0.03	<0.001 ^{a,b,c}
QTa/RR slope	0.17 ± 0.04	0.13 ± 0.02 ^{\$}	0.19 ± 0.03 ^{\$}	0.16 ± 0.03	<0.001 ^{a,d,e}
Day/night ratio (QTe/RR slope)	1.22 ± 0.42	0.91 ± 0.38 [‡]	1.37 ± 0.38 [‡]	1.15 ± 0.38	0.011 ^{f,g}
Day/night ratio (QTa/RR slope)	1.24 ± 0.30	1.06 ± 0.30 [¶]	1.33 ± 0.26 [¶]	1.24 ± 0.43	0.044
Ventricular arrhythmias					
VT	23 (68%)	1 [‡] (9%)	22 [‡] (96%)	0	
VF	11 (32%)	10 [‡] (91%)	1 [‡] (4%)	0	

Values are n (%) or mean ± SD.

The P values reflect the comparison of the patients with LGE versus those without LGE (*P < 0.05, †P < 0.01, §P < 0.001).

CMR = cardiac magnetic resonance; LVEF = left ventricular ejection fraction; LVEDV = left ventricular end-diastolic volume; LVESV = left ventricular end-systolic volume; LGE = late gadolinium enhancement; VT = ventricular tachycardia; VF = ventricular fibrillation; O = organic disorder group; I = idiopathic disorder group; C = control group.

^aO vs I, P < 0.001.^bO vs C, P < 0.001.^cI vs C, P = 0.015.^dO vs C, P = 0.001.^eI vs C, P = 0.014.^fO vs I, P = 0.008.^gI vs C, P = 0.046.

Figure 1. The myocardial segments and late gadolinium enhancement (LGE) score on cardiac MRI are illustrated.

those with enhancement (LGE-positive) and those without (LGE-negative). To measure the transmural extent of the LGE, radial lines extending from the epicardium to the endocardium were drawn in each sector and the proportion of each line that intersected the LGE area was automatically calculated. The average transmural extent of the enhancement in each segment was expressed by using the following scale (transmural score): 0 = none, 1 = 1–25%, 2 = 26–50%, 3 = 51–75%, and 4 = 76–100% of the wall thickness. The sum of LGE transmural scores (total LGE score) was calculated in each patient.

QT/RR Measurement and Analysis

A 24-hour ambulatory ECG was obtained on a 2-channel Holter recording system (with NASA and CM5 leads) and analyzed by Synetec Holter analysis software (ELA Medical, Sorin Group, Paris, France). The QT interval was assessed in the lead with the best-defined T wave. (The QT measurement was performed only if the amplitude of the T wave was >0.15 mV.) The 24-hour recordings were converted into 2880 templates sampled at 30-second intervals. The intervals with $\leq 80\%$ eligible QRS complexes were considered as ectopy or noise and therefore eliminated. The averaged QT intervals were then measured automatically at the apex (QTa) of the T wave, where the peak of the parabola was fitted to the highest amplitude change after the QRS, and at the end of the T wave (QTe), defined as the intersection of the tangent to the downslope of the T-wave and

the isoelectric line. The average RR interval in each template was measured. For each template, the mean QT apex and QT end values were plotted against the mean RR of the 30-second interval. The slopes of the QTa/RR and QTe/RR were automatically measured for the entire 24 hours as well as during the daytime (6:00 to 22:00) and night time (22:00 to 6:00). The QT-RR relationship obtained from the 24-hour Holter recordings was analyzed and the QT-RR day/night ratio was also calculated.

CMR, QT, and QT/RR Analyses

The QT and QTc data were obtained from the 12-lead ECG. The QT and QTc was compared between the late gadolinium enhancement (LGE) positive (LGE(+)) and negative (LGE(-)) patient groups. The QTe/RR slope, QTa/RR slope, QTe-RR day/night, and QTa-RR day/night ratio was compared between the LGE(+) and LGE(-) groups and the correlation between the QTe/RR slope or QTa/RR slope and Total LGE score was analyzed. Further, the QT, QT/RR slope, and QT/RR day/night ratio between the three (LGE(-), LGE(+), and control) groups were also analyzed using one-way analysis of variance (ANOVA) with Tukey's post hoc tests.

Statistical Analysis

The continuous variables are expressed as the range and mean $\pm$ SD. Variable differences between the two groups were analyzed using a Student's *t*-test or Mann-Whitney test, and a probability value of <0.05 was considered statistically significant. The variable differences between the three groups were analyzed using the one-way analysis of variance (ANOVA) with Tukey's post hoc tests was used. All probability values reported are two-sided, and a probability value of <0.05 was considered statistically significant. All statistical analyses were performed using SPSS statistical software (version 15.0 for Windows, SPSS, Inc., Chicago, IL, USA).

RESULTS

Table 1 summarizes the parameters of the CMR, QT, and QT/RR data in the study population. LGE was demonstrated in 23/34 cases and the average LGE score was 18 ± 15 . There were significant

Figure 2. Correlation between the QTc/RR slope or QTa/RR slope and the total LGE score.

differences in the QT or QTc values on the 12-lead ECG between the LGE(+) and LGE(-) groups ($P = 0.029$ and $P < 0.001$, respectively). Table 1 also shows the QT, and QT/RR data in 55 control subjects (55 ± 17 years) without organic heart disease who did not show VT or VF as a reference. Regarding the LVEF (left ventricular ejection fraction), LVEDV (left ventricular end-diastolic volume), and LVESV (left ventricular end-systolic volume), the LVEF was significantly lower, and the LVEDV and LVESV were significantly higher in the LGE(+) group compared to the LGE(-) group.

The slopes of the QTc/RR and QTa/RR were significantly steeper in the LGE(+) than LGE(-) patients (0.21 ± 0.03 vs 0.13 ± 0.02 ; $P < 0.001$, 0.19 ± 0.03 vs 0.13 ± 0.02 ; $P < 0.001$, respectively), and both slopes were significantly correlated with the total LGE scores ($r = 0.83$, $P < 0.001$; $r = 0.71$, $P < 0.001$, respectively) (Figure 2). In contrast, the slopes of the QTc/RR and QTa/RR in the control group showed moderate values (0.16 ± 0.03 and 0.16 ± 0.03).

It has been shown that, in healthy individuals,¹⁵ the QT/RR slope is normally steeper in the daytime than at night. Thus, we compared the day/night ratio of the QT/RR slope. In the LGE(+) patients, the QTc day/night (1.37 ± 0.38 vs 0.91 ± 0.33 ; $P = 0.002$), and QTa day/night ratios (1.33 ± 0.29 vs 1.06 ± 0.30 ; $P = 0.011$) were significantly greater than those in the LGE(-) patients (Table 1). In contrast, the QTc day/night and QTa day/night

ratios in the control group showed moderate values (1.15 ± 0.38 and 1.24 ± 0.43).

Table 1 also shows the ANOVA with Tukey's post hoc tests analysis in the three (LGE(-), LGE(+), and control) groups. Regarding QT and QTc, there were significant differences among the three groups in the slopes of the QTc/RR and QTa/RR, and the QTc day/night and QTa day/night ratios. In the post hoc analysis, the QTc for organic heart disease had significantly longer values compared to the control or idiopathic VF groups. Also, QTc/RR and QTa/RR in the organic heart disease group had significantly larger values compared to the control or idiopathic VF groups, whereas those in the idiopathic VF group had significantly smaller values compared to the control group. Furthermore, the QTc day/night ratio in the organic heart disease group had significant larger values compared to the idiopathic VF group, whereas that in the idiopathic VF group had significant smaller values compared to the control group.

Figure 3 shows a representative example from a 67-year-old woman who was referred to our department in a hemodynamically collapsed state due to ventricular fibrillation, which was treated with a direct current shock. Her QTa/RR slope and QTc/RR slope had large values and her LGE score was also high. Her QT/RR day/night ratio was high. She was diagnosed with cardiac sarcoidosis.

Figure 4 shows a representative example from a 54-year-old man who was referred to our

Figure 3. A representative example of the cardiac MRI (CMR) and QT/RR analysis in a 67-year-old woman who was referred to our department due to ventricular fibrillation. She was diagnosed with sarcoidosis. The contrast image (A) from a basal short axial slice was divided into six segments. The endocardial (red) and epicardial (green) borders were manually traced. A computer-assisted algorithm applied signal-intensity thresholds of >4 SDs above the normal myocardial segment to delineate the scar (red region). The average transmural extent of the enhancement in each segment was scored using a 4-point score. The total LGE score was 38. Both the QTa/RR slope and QTe/RR slope had large values (B) and the QT/RR day/night ratio in this patient was high (C).

department for ventricular fibrillation. His QTa/RR slope and QTe/RR slope showed small values and his LGE score was zero. His QT/RR day/night ratio was low. He was diagnosed with idiopathic ventricular fibrillation.

Figure 5 shows a representative example from a 62-year-old man who was referred to our department due to sustained ventricular tachycardia. His QTa/RR slope and QTe/RR slope showed large values and his LGE score was also high. His QT/RR day/night ratio was high. He was diagnosed with hypertrophic cardiomyopathy.

DISCUSSION

In this study, we demonstrated that the transmural distribution of the LGEs was strongly related to the QT dynamicity in addition to the diurnal QT/RR variability. That is, the myocardial scar demonstrated by the LGE was correlated with the repolarization abnormality, which could also be modified by autonomic tone, causing severe ventricular arrhythmias.

To the best of our knowledge, this is the first study to investigate the relationship between the

Figure 4. A representative example of the CMR and QT/RR analysis in a 54-year-old man who was referred to our department due to ventricular fibrillation. He was diagnosed with idiopathic ventricular fibrillation. The contrast image (A) from a basal short axial slice was divided into six segments and the total LGE score was zero. Both the QTa/RR slope and QTe/RR slope had small values (B) and the QT/RR day/night ratio in this patient was low (C).

LGE on CMR and the QT dynamicity, to gain insight into the possible mechanisms. In recent years the use of CMR has been explored in the assessment of myocardial scar burden to predict mortality and arrhythmic events. For example, in the setting of an acute myocardial infarction, a number of investigators have demonstrated that tissue heterogeneity in the peri-infarct zone, as detected by contrast-enhanced CMR, is likely to signify a proarrhythmic substrate and is one of the strongest predictors of ventricular arrhythmias and the appropriate ICD therapies.^{16,17} That is, the infarct tissue heterogeneity determined by magnetic resonance imaging identifies enhanced cardiac arrhythmia susceptibility in patients with left ventricular dysfunction.

We demonstrated that both the QTa/RR slope and QTe/RR slope were significantly correlated with the LGE score. Since a steeper slope indicates inappropriate shortening of the QT interval at higher rates and excessive lengthening of the QT during low heart rates, these results suggest that the degree of myocardial fibrosis detected by CMR in organic heart disease is correlated with the action potential changes under the altered autonomic tone.

We found a second pattern of the QT/RR relationship in the LGE(−) group: a flat pattern where there was impaired prolongation of the QT interval during bradycardia, which was quite opposite from the first pattern (steep QT/RR relationship). This QT/RR relationship was seen

Figure 5. A representative example of the cardiac MRI (CMR) and QT/RR analysis in a 62-year-old man who was referred to our department due to sustained ventricular tachycardia. He was diagnosed with hypertrophic cardiomyopathy. The contrast image (A) from a basal short axial slice was divided into six segments and the total LGE score was 18. Both the QTa/RR slope and QTe/RR slope had large values (B) and the QT/RR day/night ratio in this patient was high (C).

in patients with no apparent organic heart disease including Brugada syndrome and idiopathic VF with early repolarization, and the main mechanism was explained by an increase in the outward current (such as the Ito or ATP sensitive potassium current [IK ATP]) or a decrease in the inward current, such as the ICa.^{12,18–21} In addition, one of the most striking differences between idiopathic VF and organic VT or VF is the autonomic modulation. Namely, organic VT or VF is frequently induced by hypersympathetic activity whereas idiopathic VF is induced by vagal activation mainly during the nighttime. Although idiopathic VF is defined as VF without any structural heart disease, J waves have been shown

to be associated with various pathological states such as hypothermia and ischemia.^{22–24} Hence, in addition to routine examinations including echocardiography and coronary angiography, the combined evaluation of the QT/RR with CMR might be a powerful tool for understanding the background pathophysiology.

In the QT/RR analysis, a significant correlation between the QTa/RR and QTe/RR has been reported. On the other hand, there is a report showing that the QTa was less and did not remain significantly associated with arrhythmic events in the multivariate analysis.⁴ The peak of the T wave represents the end of the epicardial action potential (AP) and the terminal portion of the T wave

represents the end of the longest AP in transmural tissue, which exists in the subendocardial layer (M cells). Therefore, the LGE scores, which may reflect the degree of transmural fibrosis, are expected to correlate with the transmural action potential changes. Theoretically, an increase in the QT/RR slope (particularly in QTe/RR) could reflect action potential prolongation caused by an alteration in the K currents contributing to the final phase of repolarization such as IKr, IKs in diseased myocardium or scar border zone tissue. In contrast, a decrease in the QT/RR slope (particularly in QTa/RR) could reflect epicardial action potential shortening mainly caused by enhancement of the Ito or IK ATP as typically seen in idiopathic VF. Our data did not show a significant difference between the QTa/RR and QTe/RR slopes in the LGE negative group. However, our results showing that the QTe/RR was more strongly related to the LGE than QTa/RR strengthens the following hypothesis: in contrast to the QTa reflecting the epicardial action potential, the QTe reflecting the M cells' action potential may be much more useful for evaluating the ventricular repolarization abnormality in organic heart disease.⁴ In our study, the average QT/RR slope for the organic heart disease patients with VT/VF was greater than 0.18, whereas that for idiopathic VF was consistently lower than 0.13. The ability to test such a threshold would be useful for evaluating the background pathophysiology.

It is well known that the QT/RR slope is steeper in the daytime than at night, which is also thought to be due to autonomic nervous modulation.¹⁵ Indeed, β -blockers decrease the QT/RR slope in daytime, and not at nighttime, whereas sympatho-excitation increases the QT/RR slope.^{14,25} In our study, in the LGE(+) patients, the QTe day/night and QTa day/night ratios were significantly greater than those in the LGE(-) patients. On the other hand, low QTe day/night and QTa day/night ratios were observed in the LGE(-) patients. These results suggest that the background autonomic tone is different, namely, sympathetic overactivation is observed in the LGE(+) group and vagal overactivation in the LGE(-) group. Thus, both mechanisms would significantly contribute to the risk of arrhythmic events, and therefore the combined evaluation of the CMR and QT/RR might be a useful tool for understanding the pathophysiology in lethal ventricular arrhythmias.

Clinical Implications and Study Limitations

The results of this study should be interpreted in light of their limitations. First, the number of patients in the study group was small. Second, although we demonstrated the relationship between the repolarization abnormality and LGE, we did not show any direct evidence that this abnormality was associated with ventricular tachyarrhythmias. However, we believe that the information provided in this study, showing that the LGE on the CMR imaging had a close relationship to the repolarizing electrical damage, is quite valuable for evaluating patients with lethal arrhythmias. Third, the Holter recording was performed in the presence of drugs in some cases because of underlying structural heart disease and primary prevention of lethal arrhythmias. Although amiodarone prolongs the QT and might modify the QT/RR relationship, whereas β -blockers might decrease QT/RR slope, the overall arrhythmic risk and relationship between the LGE score and QT/RR parameters could be evaluated in the absence or presence of prophylactic drugs for lethal arrhythmias, and it is believed to be worthy for evaluating as in the previous clinical trials. Fourth, the numerous cardiac medications used for the study patients might affect not only the ECG findings but also the CMR findings in terms of fibrosis regression. Fifth, the arrhythmogenic substrate in nonischemic cardiomyopathy, ischemic heart disease, and idiopathic VF is thought to be heterogeneous. Although we analyzed the association of QT dynamicity with LGE patterns in this heterogeneous cohort due to the limited numbers in each case, our QT/RR analysis is considered to be a useful tool for risk stratification for various organic heart disease and idiopathic VF since VT/ VF can be triggered by maladaptation of QT. Similarly, LGE on CMR is also useful in various heart diseases such as ischemic heart disease and cardiomyopathy which can share similar mechanisms underlying scar tissue or a scar-like lesion. Furthermore, when evaluating the combined parameters of CMR and the QT/RR in VT/VF patients, an LGE(+) and large QT/RR slope would indicate organic heart disease whereas an LGE(-) and small QT/RR slope would indicate idiopathic VT/VF. Thus, we consider it is worthy for reporting even if various heterogeneous diseases are combined. Finally, in this study, a control group of healthy participants, or matched

patients without ventricular arrhythmia were not presented for comparison because our CMR protocol was basically scheduled for subjects with organic heart disease or suspected organic heart disease. However, in such control subjects, although the available number was small, no subject showed any LGE, and the QT/RR data also showed suspected normal values ranging from 0.13 to 0.18. Thus, the evaluation of both LGE and QT/RR is considered to be a worthy means of assessment in the detection of organic heart disease.

CONCLUSION

This study demonstrated that the magnitude of LGE was significantly correlated with the corresponding repolarizing electrical damage as reflected by the QT dynamicity. The combined evaluation of CMR and QT/RR might be a useful tool for understanding the background pathophysiology in patients with severe ventricular arrhythmias.

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