Received: 14 October 2024 | Revised: 18 November 2024 | Accepted: 25 November 2024

DOI: 10.1002/joa3.13199

Journal of Arrhythmia Open Access WILEY

ORIGINAL ARTICLE

Impact of prolonged QTc interval on mortality risk with hypertrophic cardiomyopathy

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Abstract

Background: The association between corrected QT (QTc) interval and life-threatening cardiac events in patients with hypertrophic cardiomyopathy (HCM) remains unclear. This study sought to investigate whether the prolonged QTc was associated with HCM-related death in patients with HCM.

Methods: We included 445 patients with HCM (mean age 51 ± 16 years, 67% men). The QTc interval was measured at the time of the initial evaluation and the patients were classified into those with and without QTc prolongation, which was defined as a QTc interval >450 ms. HCM-related death was defined as a combined endpoint of sudden death or potentially lethal arrhythmic events, heart failure-related death, and stroke-related death.

Results: Prolonged QTc interval was found in 120 patients (26.4%) at the time of enrollment. Over a median (IQR) follow-up period of 8.1 (4.6–11.9) years, a total of 67 patients (15.1%) experienced HCM-related deaths including 57 (12.8%) with the endpoint of sudden death or potentially lethal arrhythmic events. In a multivariable analysis that included prolonged QTc interval and the risk factors for life-threatening events, prolonged QTc interval was independently associated with an HCM-related death (adjusted hazard ratio [HR]: 1.91; 95% confidence interval [CI]: 1.16–3.16; $p = .011$) and this trend also persisted for the combined endpoint of sudden death or potentially lethal arrhythmic events (adjusted HR: 2.01: 95% CI: 1.17–3.46; $p = .012$).

Conclusions: In this cohort of patients with HCM, QTc prolongation may be associated with HCM-related death, including the endpoint of sudden death or potentially lethal arrhythmic events.

KEYWORDS
hypertrophic cardiomyopathy, QTc interval, risk stratification, sudden cardiac death

1 | INTRODUCTION

Hypertrophic cardiomyopathy (HCM) is a prevalent genetic cardiomyopathy, affecting approximately 1 in 500 individuals.[1,2] The clinical course of HCM varies widely, from asymptomatic states with normal life expectancy to severe heart failure, embolic events, and sudden cardiac death because of arrhythmias.[3–8]

Current guidelines emphasize stratifying the risk of life-threatening events based on several factors to determine the indication for ICD implantation therapy to prevent sudden death.[3,4] Despite these measures, predicting life-threatening events remains challenging as a result of certain number of poor prognoses in low-risk patients.[9,10]

Prolonged corrected QT (QTc) is generally associated with cardiovascular mortality.[11,12] While some studies suggest a correlation between prolonged QTc and prognosis in patients with HCM, specific data on Asian population and long-term outcomes are limited.[13–15] Therefore, the aim of this study was to evaluate the prognostic significance of prolonged QTc for life-threatening events in a relatively large, longitudinal cohort of HCM patients.

2 | MATERIALS AND METHODS

2.1 | Study population

The study population included 445 patients clinically diagnosed with HCM at Tokyo Women's Medical University Hospital, Tokyo, Japan, from April 1, 2004, to March 31, 2017. The initial evaluation was the first clinical evaluation in which patients were diagnosed with HCM by echocardiography at our hospital. HCM was diagnosed based on the echocardiographic evidence of a hypertrophied nondilated left ventricle in the absence of any other cardiac or systemic disease capable of producing a similar degree of hypertrophy.[3,4] Medical records were also reviewed to obtain demographic and clinical data. Implantable cardioverter defibrillators (ICD) were implanted during the follow-up period according to standard practice, and the criteria for detection and treatment of ventricular arrhythmias were programmed at the discretion of the implanting electrophysiologists.

This study was conducted in accordance with the principles of the Declaration of Helsinki, and the study protocol was approved by our hospital's ethics committee; the requirement for informed consent was waived.

2.2 | Measurement of QTc interval

All patients underwent standard 12-lead ECG (25 mm/s, 10 mm/mV) at the time of the initial evaluation. The QT interval was measured from the beginning of the QRS complex to the end of the T wave and corrected for heart rate using the Bazett formula: $QTc = QT/\sqrt{(R\text{-}R\ interval)}$. The QTc interval was initially transcribed from the 12-lead ECG's computer interpretation. Subsequently, experienced cardiologists, blinded to the combined endpoints, reviewed all results to check for discrepancies. In cases where discrepancies were found, QTc intervals were manually measured using digital calipers, and corrected QTc intervals were determined. Additionally, for patients with abnormal T waves, such as negative T waves, the QTc interval was assessed across multiple leads (e.g., II, V5, and V6) to select a lead with a stable T wave. U waves were excluded by examining multiple leads to ensure that the end of the QT interval was accurately identified at the end of the true T wave. QTc prolongation was defined as a QTc interval of >450 ms.[13]

2.3 | Echocardiography

Patients underwent transthoracic echocardiography using commercially available equipment. The left atrial dimension (LAD) was measured in the parasternal long-axis view as the anteroposterior linear diameter at end systole. The left ventricular (LV) end-diastolic diameter was obtained from M-mode and 2-dimensional images obtained in the same parasternal long-axis view. The ratio of peak E velocity to average peak e' velocity (E/e' ratio) was calculated using tissue Doppler imaging at the septal side of the mitral annulus. Maximum left ventricular wall thickness was defined as the greatest thickness in a single segment. Sites of left ventricular intracavitary obstruction were localized by color Doppler echocardiography and pulsed-wave Doppler echocardiography. The definition of left ventricular outflow tract obstruction (OTO) was based on previous studies.[3,4,6]

2.4 | Study endpoints

The endpoint of the study was HCM-related death, which was defined by the following three types of cardiac events: (1) a composite endpoint of sudden death (unexpected death without symptoms or within 1 h of symptom onset in patients with a relatively stable or uneventful course), successful resuscitation from cardiac arrest (ventricular fibrillation or ventricular tachycardia with pulseless collapse), or appropriate ICD shocks, (2) heart failure-related death associated with progressive cardiac decompensation within 1 year of death, especially if complicated by pulmonary edema or progression to end-stage disease, and advanced refractory heart failure in patients who underwent heart transplantation, which were considered equivalent to HCM-related heart failure death in this analysis, and (3) stroke-related death in patients who died as a result of ischemic stroke.[5–7]

2.5 | Statistical analysis

We retrospectively analyzed the clinical characteristics, the QTc interval at the time of the initial evaluation, and the results during the follow-up period. Results are presented as mean ± standard

deviation, median (interquartile range [IQR]), or frequency (percentage). Student *t*-tests were used to compare normally distributed continuous variables, and Mann–Whitney *U* tests to compare skewed continuous or ordinal variables between groups. Nominal variables were compared using χ^2 tests or Fisher exact tests (when the expected value was <5). Event-free curves were estimated using the Kaplan–Meier method, and differences between curves were assessed using log-rank tests. Univariate and multivariate Cox proportional hazards models were used to assess the association of prolonged QTc interval with HCM-related death and the composite endpoint of sudden death or potentially lethal arrhythmic events. Variables with a *p*-value of <.05 for the univariate associations were entered into a stepwise multivariate Cox proportional hazards model to identify any independent predictors. To include all potential confounders in a multivariable model despite the small number of endpoints, we calculated the risk score for sudden cardiac death according to the 2014 ESC guidelines and used it as a single variable (combining seven variables such as age at the time of the initial evaluation, family history of sudden death, maximum left ventricular wall thickness, nonsustained ventricular tachycardia, unexplained syncope, OTO, and LAD into a single variable). In addition, to investigate the influence of potential causes of QTc prolongation, the presence of antiarrhythmic medications such as β-blockers, calcium channel antagonists, and amiodarone was investigated. All tests were two-sided, and statistical significance was set at a value of $p < .05$. All statistical analyses were performed with SPSS software version 23.0 (SPSS Inc., Chicago, IL).

3 | RESULTS

3.1 | Distribution of the QTc interval

Histogram of the QTc interval in patients with and without HCM-related death are shown in Figure 1. The mean QTc in patients with HCM-related death (449.9 ± 39.5 ms) and those with the endpoint of sudden death or potentially fatal arrhythmic events (450.5 ± 38.2 ms) was significantly longer than that in patients without HCM-related death (433.2 ± 27.9 ms).

During a median follow-up of 8.1 (4.6–11.9) years, 67 patients (15.1%) experienced HCM-related death. Of these, 57 patients (12.8%) met the composite endpoint of sudden death or potentially lethal arrhythmic events, including 18 patients (4.0%) with sudden death, 11 (2.5%) with successfully resuscitated cardiac arrest (seven with documented ventricular fibrillation and four with documented ventricular tachycardia with pulseless collapse), and 28 (6.3%) with appropriate ICD shocks. Of the remaining 10 patients, 8 (1.8%) experienced heart failure-related death, including 2 (0.4%) with heart transplantation, and 2 (0.4%) experienced stroke-related death. The median time from initial evaluation to HCM-related death was 6.1 (2.9–9.9) years.

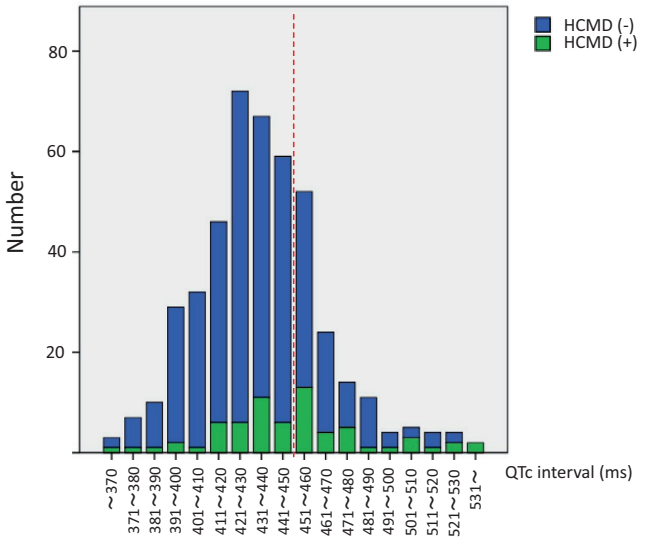

FIGURE 1 Distribution of the QTc in the HCM patients with and without HCM-related death. HCM, hypertrophic cardiomyopathy.

3.2 | Baseline characteristics according to patients with or without QTc prolongation

All patients were divided into two groups based on the presence of a prolonged QTc interval >450 ms at the time of the initial evaluation. A total of 120 patients (27.0%) had prolonged QTc while 325 (73.0%) did not (Figure 1). Baseline clinical characteristics of the two groups are summarized in Table 1. Patients with prolonged QTc had a higher prevalence of OTO, longer QRS duration, longer PR interval, higher NYHA functional class, complete right bundle branch block, and were more likely to use amiodarone compared to those without prolonged QTc. However, baseline age, sex, calculated HCM risk score for sudden cardiac death, and median follow-up were not significantly different between the two groups.

3.3 | Clinical outcomes according to the presence of prolonged QTc interval

During the follow-up period, 31 of the 120 patients with prolonged QTc (25.8%) and 36 of the 325 patients without prolonged QTc (11.1%) experienced unplanned hospitalizations for progressive heart failure with an increase to NYHA functional class 3 or 4 ($p < .001$). In addition, new-onset stroke occurred in nine of the 120 patients with prolonged QTc (7.5%) and 11 of the 325 patients without prolonged QTc (3.4%) ($p = .06$) (Figure 2).

During the follow-up period, 32 of the 120 patients with prolonged QTc (26.7%) experienced HCM-related death. Of these, 28 patients (23.3%) had sudden death or potentially lethal arrhythmic events, including seven patients (5.8%) who experienced sudden death, five (4.2%) who were resuscitated from cardiac arrest (one with documented ventricular tachycardia with pulseless collapse

TABLE 1 Baseline characteristics.

	QTc interval >450 ms (*N* = 120)	QTc interval ≤450 ms (*N* = 325)	*p* value
Age of the initial evaluation (years)	50.5 ± 15.9	51.0 ± 16.1	.74
Male gender (%)	78 (65)	218 (67)	.68
Outflow tract obstruction (%)	35 (29)	57 (18)	.007
History of atrial fibrillation (%)	37 (31)	84 (26)	.29
Family history of sudden cardiac death (%)	16 (13)	45 (14)	.89
Non-sustained ventricular tachycardia (%)	49 (41)	105 (32)	.09
Unexplained syncope (%)	25 (21)	47 (15)	.11
New York Heart Association functional class			
I (%)	47 (39)	186 (57)	<.001
II (%)	62 (52)	130 (40)	
III (%)	11 (9)	9 (3)	
Maximum left ventricular wall thickness (mm)	19.2 ± 5.3	19.2 ± 5.0	.98
Left ventricular ejection fraction (%)	55.2 ± 10.0	53.3 ± 10.8	.13
Left atrial dimension (mm)	40.4 ± 9.1	38.9 ± 8.3	.11
E/e' at the septal mitral annulus	14.8 ± 6.9	16.1 ± 7.6	.14
Calculated HCM Risk-SCD at 5 years[a]			
Low risk <4% (%)	79 (66)	246 (76)	.10
Moderate risk 4 to <6% (%)	19 (16)	41 (13)	
High risk ≥6% (%)	22 (18)	38 (12)	
PR interval (mm)[b]	186.6 ± 36.0	177.3 ± 36.1	.02
QRS axis (degrees)	40.9 ± 64.9	35.2 ± 46.3	.31
QRS duration (ms)	120.4 ± 25.7	99.8 ± 15.1	<.001
R wave amplitude (V5) (mm)	24.6 ± 16.3	23.7 ± 13.0	.59
Complete left bundle branch block (%)	5 (4)	5 (1)	.10
Complete right bundle branch block (%)	19 (13)	21 (6)	.002
Treatment			
β-blockers (%)	91 (73)	219 (67)	.09
Calcium-channel antagonist (%)	16 (13)	65 (20)	.11
Amiodarone (%)	23 (20)	29 (8)	.003
Oral anticoagulant (%)	40 (33)	90 (28)	.25
Follow-up duration (years)	8.0 ± 4.5	8.3 ± 4.1	.54

Note: All data are expressed as the mean ± SD or *n* (%).

Abbreviations: e', early diastolic mitral annular velocity; E, early transmitral filling velocity; HCM, hypertrophic cardiomyopathy; SCD, sudden cardiac death.

[a]2014 European Society of Cardiology guideline recommendation on an implantable cardioverter defibrillator implantation.

[b]Thirty-seven patients were excluded from the analysis as a result of atrial fibrillation rhythm.

and four with documented ventricular fibrillation), and 16 (13.3%) with appropriate ICD shocks. Four patients (3.3%) had heart failure-related deaths, including two (1.7%) with heart transplantation. There were no stroke-related deaths in this group.

In contrast, 35 of the 325 patients without prolonged QTc (10.8%) experienced HCM-related death. Of these, 29 patients (8.9%) reached sudden death or potentially lethal arrhythmic events, including 12 patients (3.7%) with sudden death, six (1.8%) resuscitated from cardiac arrest (three with documented ventricular tachycardia with pulseless collapse and three with documented ventricular fibrillation), and 11 (3.4%) with appropriate ICD shocks. Four patients (0.6%) experienced heart failure-related deaths. There were two patients (0.6%) with stroke-related deaths. The median time from initial evaluation to HCM-related death was 5.1 (2.6–8.1) years in patients with prolonged QTc and 7.0 (4.2–10.4) years in patients without prolonged QTc. ICDs were ultimately implanted in 29 of the 120 patients with prolonged QTc (24.1%), including 26 for primary prevention and three for secondary prevention, and in 51 of the 325 patients without prolonged QTc (15.6%), including 44 for primary prevention and seven for secondary prevention ($p = .05$).

In univariate analysis using the Kaplan–Meier method, patients with prolonged QTc had a significantly higher likelihood of

HCM-related death than those without prolonged QTc (log-rank $p < .001$) (Figure 3A). The probability of sudden death or potentially lethal arrhythmic events was also significantly higher in patients with prolonged QTc than in those without prolonged QTc (log-rank $p < .001$) (Figure 3B). In a multivariable analysis including potential clinical predictors of life-threatening cardiac events, prolonged QTc was found to be an independent predictor of either HCM-related death (adjusted hazard ratio [HR]: 1.91; 95% confidence interval [CI]: 1.16–3.16; $p < .001$) or the combined endpoint of sudden death or potentially lethal arrhythmic events (adjusted HR: 2.01; 95% CI: 1.17–3.46; $p < .001$) (Table 2). The established risk factors for sudden cardiac death in the study patients with HCM, with and without sudden death or potentially lethal arrhythmic events, are listed in Table 3. Although 19 of the 57 patients (33.3%) with the endpoint had no established risk factors for sudden death, 13 of these 19 patients had prolonged QTc and only six of the 57 patients (10.5%) were missed by the combination of established risk factors and the presence of prolonged QTc.

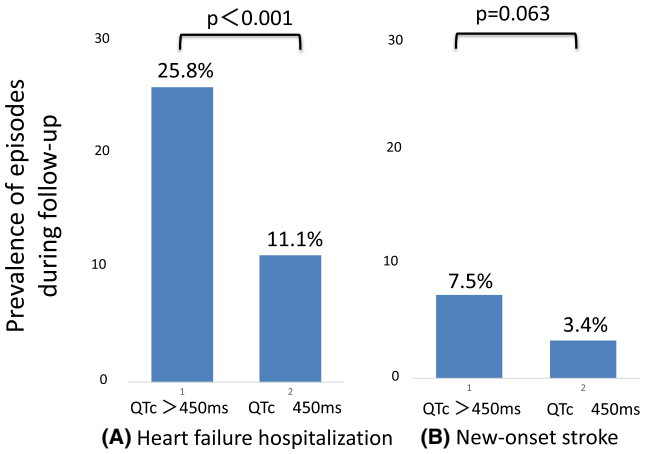

FIGURE 2 The prevalence of events that occurred during the follow-up period according to the HCM patients with and without prolonged QTc. (A) Heart failure hospitalization, (B) new-onset stroke. HCM, hypertrophic cardiomyopathy.

4 | DISCUSSION

This study highlights that prolonged QTc may be an important predictor of sudden death or potentially lethal arrhythmic events in Asian population with HCM, independent of previously established risk factors. Although the AHA and ESC guidelines are widely used for risk stratification of sudden death in HCM, their predictive capability remains limited, partly because of exclusion of electrical markers such as QTc.[3,4,9,10] Notably, electrocardiographic abnormalities, including QTc prolongation, have been associated with phenotypic abnormalities observed through cardiac magnetic resonance (CMR) imaging in HCM patients.[16] We previously reported that PR prolongation, another electrical marker on ECG, is an independent prognostic predictor for HCM-related death.[6]

Prolonged QTc, indicative of myocardial repolarization abnormalities, is more commonly observed in patients with HCM than in healthy controls. While prevalence rates vary, using a QTc cutoff >480 ms, approximately one in eight HCM patients show prolonged QTc compared to fewer than one in 200 in healthy individuals.[17] The association between QTc prolongation and HCM severity, particularly related to left ventricular hypertrophy and myocyte disorganization, provides insight into its potential role as a prognostic marker.[18]

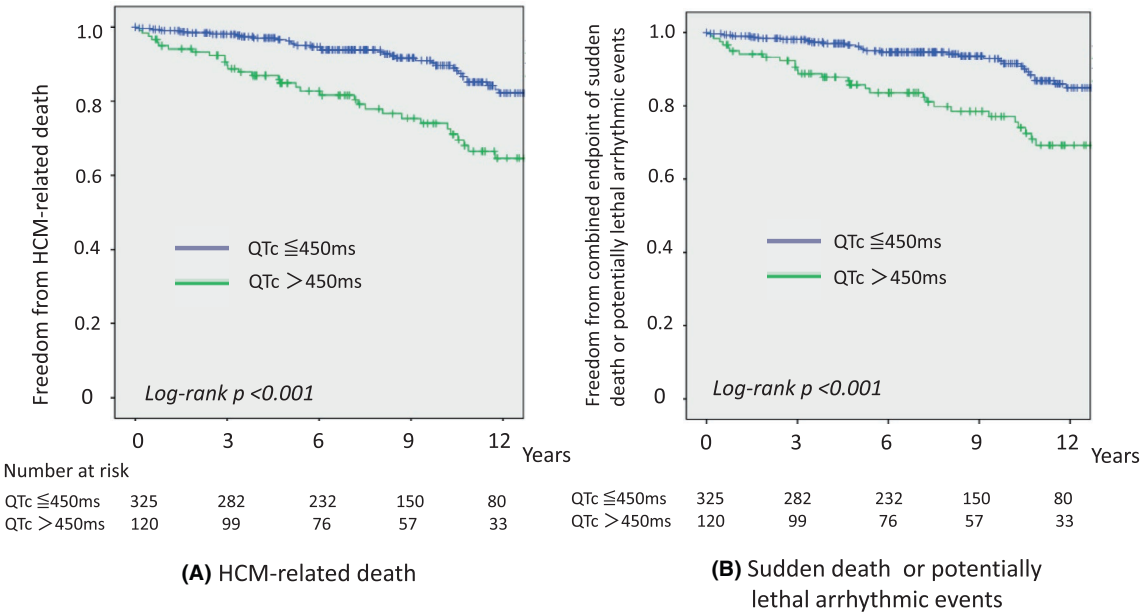

FIGURE 3 Kaplan–Meier estimates of the proportions of patients with HCM-related death in 120 patients with prolonged QTc and 325 patients without prolonged QTc. Cumulative probability of (A) HCM-related deaths and (B) the composite endpoint of sudden death or potentially lethal arrhythmic events in patients with and without prolonged QTc. HCM, hypertrophic cardiomyopathy.

TABLE 2 Adjusted hazard ratios for HCM-related death and the combined endpoint of sudden death or potentially lethal arrhythmic events associated with QTc prolongation.

	HCM-related death				The combined end point of sudden death or potentially lethal arrhythmic events			
	Univariate		Multivariate		Univariate		Multivariate	
Variables	HR (95% CI)	*p* value	HR (95% CI)	*p* value	HR (95% CI)	*p* value	HR (95% CI)	*p* value
Male gender	0.73 (0.44–1.20)	.210			0.88 (0.51–1.53)	.65		
Risk score for SCD at 5 years	1.10 (1.07–1.14)	<.001	1.08 (1.05–1.12)	<.001	1.11 (1.07–1.14)	<.001	1.09 (1.05–1.13)	<.001
Atrial fibrillation	1.36 (0.83–2.21)	.224			1.22 (0.71–2.09)	.480		
Left ventricular ejection fraction	1.02 (1.00–1.05)	.095			1.02 (1.00–1.05)	.098		
Septal E/e' ratio	1.01 (0.98–1.04)	.641			1.01 (0.97–1.05)	.688		
NYHA functional class	2.24 (1.49–3.38)	<.001	1.68 (1.09–2.59)	.019	2.26 (1.45–3.52)	<.001	1.67 (1.05–2.65)	.032
Complete right bundle branch block	0.54 (0.17–1.72)	.298			0.42 (0.10–1.71)	.224		
RV5	0.99 (0.97–1.01)	.301			0.99 (0.97–1.01)	.210		
Amiodarone use	1.03 (0.49–2.1)	.926			1.25 (0.59–2.65)	.54		
QTc interval >450 ms	2.52 (1.56–4.06)	<.001	1.91 (1.16–3.16)	.011	2.66 (1.58–4.47)	<.001	2.01 (1.17–3.46)	.012

Abbreviations: CI, confidence interval; e', early diastolic mitral annular velocity; E, early transmitral filling velocity; HCM, hypertrophic cardiomyopathy; HR, hazard ratio; NYHA, New York Heart Association; QTc, corrected QT; SCD, sudden cardiac death.

TABLE 3 Established risk factors for sudden death in the study patients with HCM with and without the combined endpoint of sudden death or potentially lethal arrhythmic events.

	With the endpoint (*N* = 57)	Without the endpoint (*N* = 388)	*p* value
Left ventricular wall thickness ≥30 mm	5 (9)	18 (5)	.188
Family history of sudden cardiac death	16 (28)	45 (12)	.001
Unexplained syncope	13 (23)	59 (15)	.146
Non-sustained ventricular tachycardia	29 (51)	125 (32)	.006
Number of established risk factors			<.001
0	19 (33)	194 (50)	
1	16 (28)	147 (38)	
2	18 (32)	41 (11)	
3	4 (7)	6 (12)	
QTc >450 ms	28 (46)	95 (25)	<.001
QTc >450 ms without an established risk factor	13 (19)	45 (12)	.032

Note: All data are expressed as the *n* (%).

Abbreviation: HCM, hypertrophic cardiomyopathy.

Several studies have reinforced the prognostic value of QTc prolongation in HCM. For instance, Ali et al. reported that 43.2% of their cohort of 74 HCM patients had late gadolinium enhancement (LGE) on CMR, and these patients exhibited significantly higher QTc intervals, Tp-e intervals, and 5-year sudden cardiac death (SCD) risk scores compared to those without LGE.[19] Philipple et al. found that QRS fragmentation and QTc prolongation were independent prognostic factors for ventricular arrhythmias and sudden death in a study of 195 HCM patients.[14] Patel et al. demonstrated that QTc prolongation was an independent risk factor for sudden death, although their study had a shorter mean follow-up of 2.6 years compared to our median follow-up of 8.1 years.[13] Gray et al. also observed that among 162 HCM patients with ICD implantation, QTc prolongation predicted the need for appropriate ICD shock therapy.[15]

Recent studies have also explored the genetic aspects of risk stratification in HCM.[20,21] Uchiyama et al. demonstrated that certain mutations in HCM were associated with prolonged QTc, even in the

absence of left ventricular hypertrophy (LVH), suggesting that genetic factors may contribute to the association between prolonged QTc and HCM. This finding implies that patients who might not be identified through conventional risk stratification could potentially be detected by a simple QTc measurement.[22] While abnormal QTc is typically an indicator of repolarization abnormalities, these reports suggest that it may also reflect underlying structural abnormalities, myocardial fibrosis, and cellular-level repolarization abnormalities caused by genetic mutations. These findings support the utility of QTc prolongation as a marker for detecting structural and functional abnormalities in HCM patients, reinforcing its role as a risk factor for sudden death. This study is particularly valuable because of its long-term observation of a cohort of Asian HCM patients, with a median follow-up of 8.1 years and a median time from initial evaluation to HCM-related death of 6.1 years.

In a large cohort of 744 patients with HCM, Maron et al. previously reported an annual event rate of 1.40% for HCM-related death.[5] In contrast, the current study showed an improvement, with an annual HCM-related mortality rate of 0.53%, and 0.79% of events being treated as potentially lethal events, such as appropriate ICD intervention, heart transplantation, and resuscitated out-of-hospital cardiac arrest.[7] The present study observed an incidence of HCM-related death at 1.86% per year, which included 1.11% aborted events, consistent with the potentially lethal events in the recent studies. These results suggest consistency and generalizability while offering additional epidemiological insights into the relationship between prolonged QTc and HCM-related death rates in a relatively large longitudinal cohort of Asian HCM patients.

QTc assessment holds several advantages; it is easily and quickly measured in clinical settings, in cost-effective and offers high reproducibility. As such QTc measurement could be a valuable tool for generalists in determining the need for referral to tertiary centers for HCM management. Additionally, newly identified QTc prolongation may indicate silent disease progression and serve as a valuable marker for optimizing decisions regarding ICD therapy in cases with ambiguous indications.

5 | LIMITATIONS

The present study has several limitations that should be considered. First, it was based on the retrospective enrollment of individual patients with HCM, which is a common limitation in large-scale clinical studies of this condition. This retrospective design may introduce biases related to the selection and documentation of patient data. Second, the study was conducted at a single tertiary referral center in Japan, which introduces selection bias because of the highly specific patient population being studied. This setting may limit the generalizability of our findings, as the population may not be representative of all HCM patients. Consequently, while our study suggests that prolonged QTc could be a significant risk stratification marker for sudden death, it does not definitively establish its superiority over conventional risk markers. Despite the use of multivariable analyses to adjust for confounders, residual confounding by unmeasured variables may still affect the observed association between prolonged QTc and adverse cardiovascular outcomes. Additionally, the relatively small number of patients who reached the endpoint of HCM related-death (67 cases) may have reduced the statistical power of our multivariable analysis. Furthermore, the small number of patients with specific endpoints, such as heart failure-related death and stroke-related death, limited our ability to evaluate the association between prolonged QTc and these outcomes separately. Thus, further population-based, multicenter, and multinational studies are needed to confirm and expand upon our findings. Third, myocardial fibrosis was not measured by contrast-enhanced CMR at the time of initial evaluation for all study patients with HCM. The absence of this data may limit our understanding of the relationship between myocardial fibrosis and prolonged QTc. Finally, QTc duration was assessed only at a single timepoint rather than during follow-up, which may not fully capture the dynamic nature of QTc changes over time. Although amiodarone use was not identified as an independent prognostic factor in our study, we cannot entirely exclude the influence of additional medications administered after the initial evaluation or other factors that could affect QTc duration. Moreover, the diurnal variation of QTc in HCM patients remains unclear, which could also impact the findings.

6 | CONCLUSIONS

In this cohort of patients with HCM, prolonged QTc was associated with an increased risk of HCM-related morality, including sudden death or potentially lethal arrhythmias. These findings suggest that QTc prolongation could serve as a valuable marker for identifying patients at higher risk of life-threatening cardiac events. However, to confirm and extend these observations, further prospective, multicenter studies with larger sample sizes are needed. Such studies will help to solidify the role of QTc prolongation in risk stratification and potentially guide more tailored therapeutic strategies for HCM patients.

CONFLICT OF INTEREST STATEMENT

We have no conflicts of interest to declare.

ETHICS STATEMENT

The study followed the Declaration of Helsinki principles and was approved by our hospital's ethics committee, with informed consent waived.

INFORMED CONSENT

Informed consent was waived because the research involved minimal risk to participants.

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How to cite this article: Hasegawa S, Higuchi S, Minami Y, Sakai M, Matsui Y, Shirotani S, et al. Impact of prolonged QTc interval on mortality risk with hypertrophic cardiomyopathy. J Arrhythmia. 2025;41:e13199. https://doi.org/10.1002/joa3.13199