Fragmented QRS as a predictor of in-hospital life-threatening arrhythmic complications in ST-elevation myocardial infarction patients

Tanawat Attachaipanich | Rungroj Kittayaphong

Division of Cardiology, Department of Medicine, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand

Correspondence

Rungroj Kittayaphong, Division of Cardiology, Department of Medicine, Faculty of Medicine Siriraj Hospital, Mahidol University, 2 Wanglang Road, Bangkoknoi, Bangkok 10700, Thailand.
Email: rungroj.kri@mahidol.ac.th

Abstract

Background: Fragmented QRS (fQRS) complex is an electrocardiographic pattern that reflects the inhomogeneity of ventricular depolarization. The aims of this study were to determine the prognostic significance of fQRS for predicting in-hospital life-threatening arrhythmic complications in ST-elevation myocardial infarction (STEMI) patients, and to identify the most appropriate duration of cardiac rhythm monitoring in STEMI patients with fQRS.

Methods: Patients diagnosed with and treated for STEMI at Siriraj Hospital (Bangkok, Thailand) during 2009–2012 were enrolled. Patients were divided according to fQRS status (having or not having fQRS) at hospital admission. The primary outcome was in-hospital life-threatening arrhythmic events, including sustained ventricular tachycardia and ventricular fibrillation. Time to last life-threatening arrhythmic event from hospital admission was recorded.

Results: Of the 452 patients that were included, 96 patients (21.2%) had fQRS. There were significantly more life-threatening arrhythmic events in the fQRS group than in the non-fQRS group (22.9% vs. 4.5%, respectively; $p < 0.001$). Median (IQR) time to last life-threatening arrhythmic event from hospital admission was significantly longer in fQRS than in non-fQRS (6.58 hr [3.08–39.34] vs. 2.59 hr [1.75–5.75], respectively; $p = 0.047$). Multivariate analysis identified fQRS as an independent predictor of in-hospital life-threatening arrhythmic events (OR: 4.162, 95% CI: 1.669–10.384; $p = 0.002$).

Conclusions: The presence of fQRS complex on admission ECG was found to be an independent predictor of in-hospital life-threatening arrhythmic events in STEMI patients. Since the time to last life-threatening arrhythmic event from admission was longer in fQRS than in non-fQRS, cardiac rhythm monitoring longer than 24–48 hr may be needed in patients with fQRS.

KEYWORDS

arrhythmic events, cardiac rhythm monitoring, fragmented QRS, in-hospital, ST-elevation myocardial infarction

1 | BACKGROUND

Although the mortality rate of ST-elevation myocardial infarction (STEMI) patients has decreased due to improvements in early revascularization, short-term mortality continues to be a concern. One of the most common causes of death during the in-hospital phase is cardiac arrhythmia, which includes ventricular tachycardia (VT) and ventricular fibrillation (VF; Priori et al., 2015; Sandau et al., 2017).

Fragmented QRS (fQRS) complex is an electrocardiographic pattern that reflects the inhomogeneity of ventricular depolarization (Das, Khan, Jacob, Kumar, & Mahenthiran, 2006). Fragmented QRS has been defined as a poor prognostic marker and a predictor of arrhythmic events in conditions that include ischemic cardiomyopathy, nonischemic cardiomyopathy, Brugada syndrome, arrhythmogenic right ventricular cardiomyopathy, and congenital heart disease (Das et al., 2010; Morita et al., 2008; Ozcan et al., 2014; Peters, Trummel, & Koehler, 2008). In patients with coronary artery disease (CAD), fQRS was reported to be a predictor of cardiac event and mortality (Das et al., 2010, 2009). Fragmented QRS was also found to be associated with all-cause mortality in acute coronary syndrome (ACS) patients (Das et al., 2009, 2007; Pietrasik, Goldenberg, Zdzienicka, Moss, & Zareba, 2007).

In Brugada syndrome, fQRS is known to be a significant predictor of recurrent syncope due to VF, whereas late potential and SCN5A mutation were not found to be predictors of recurrent syncope (Morita et al., 2008). Fragmented QRS was found to be a predictor of VT storm, need for VT ablation, and appropriate implantable cardioverter-defibrillator (ICD) shock in ischemic and nonischemic cardiomyopathy patients that received an ICD (Ozcan et al., 2014). The event-free interval to arrhythmic event was lower in the fQRS group than in the non-fQRS group (Das et al., 2010).

Our review of the literature revealed limited data relating to predictors of in-hospital arrhythmic events in STEMI patients. Improved ability to identify STEMI patients that are at high risk of developing in-hospital life-threatening arrhythmic complications may help to suggest and guide duration of cardiac rhythm monitoring and length of cardiac care unit (CCU) stay. Accordingly, the aims of this study were to determine the prognostic significance of fQRS for predicting in-hospital life-threatening arrhythmic complications in STEMI patients, and to identify the most appropriate duration of cardiac rhythm monitoring in STEMI patients with fQRS.

2 | METHODS

Patients with ST-elevation MI who were admitted to Siriraj Hospital during January 2009 to December 2012 were enrolled in this retrospective study. Patients aged 18–75 years that were diagnosed with STEMI were eligible for inclusion. There were 541 patients that met the inclusion criteria. Patients meeting one or more of the following criteria were excluded: (a) the presence of bundle branch block pattern (47 patients); (b) the absence of admission ECG (24 patients); and/or, (c) incomplete medical data (18 patients). The protocol for

this study was approved by the Siriraj Institutional Review Board (SIRB), Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand.

Diagnosis of STEMI was made based on the presence of new or presumed new ST elevation at the J point of ≥ 1 mm (0.1 mV) in any lead, except leads V_2 – V_3 , which were ≥ 2 mm (0.2 mV) in men, and ≥ 1.5 mm (0.15 mV) in women in at least 2 contiguous leads corresponding to coronary artery territory (O'Gara et al., 2013; Thygesen, Alpert, & White, 2007).

Demographic and clinical data that were collected included age, gender, current smoker (within 2 months), and previous medical history, that is, diabetes mellitus, hypertension, dyslipidemia, chronic kidney disease, prior myocardial infarction, history of heart failure, cerebrovascular event, and prior revascularization by either or both percutaneous coronary intervention (PCI) and/or coronary artery bypass graft surgery (CABG). Clinical presentation and hemodynamic status were also recorded. The Global Registry of Acute Coronary Event (GRACE) risk score was calculated using data collected by clinical assessment at hospital admission. The GRACE risk score is calculated based on the following values and factors: age, heart rate, systolic blood pressure, Killip class, serum creatinine level, ST-segment deviation, serum troponin level, and clinical of cardiac arrest (Fox et al., 2006).

In-hospital treatments that were administered within 24 after hospital admission, including antiplatelet, statin, beta-blocker, angiotensin converting enzyme inhibitor (ACEI), and/or angiotensin II receptor blocker (ARB), were recorded. Revascularization treatments, including PCI, CABG, and fibrinolytic therapy, such as streptokinase or recombinant tissue plasminogen activator (t-PA), were also recorded and included in our analysis.

Echocardiographic parameters, including left ventricular ejection fraction (LVEF) and wall motion score index (WMSI), were recorded. LVEF was calculated from apical four-chamber views according to modified Simpson's method. WMSI was calculated from the sum of all wall motion scores divided by the number of segments. Echocardiographic data that were collected within the first 72 hr after hospital admission were also recorded.

A standard 12-lead ECG (filter range 0.15–150 Hz, 25 mm/s, 10 mm/mV) was used to diagnose STEMI, the myocardial infarction site, the presence of fQRS, and the presence of pathological Q wave. Fragmented QRS (Figures 1 and 2) was defined as QRS complex with duration <120 ms with additional R wave (R'), notched R wave, notched S wave, or presence of $>1R'$ in at least 2 contiguous leads corresponding to coronary artery territory without the characteristic of bundle branch block. Coronary artery territories were defined as anterior: leads V_1 – V_5 ; inferior: leads II, III, and aVF; and, lateral: leads V_6 , I, and aVL (Das et al., 2006). Pathological Q wave was defined by the standard criteria from universal definition of myocardial infarction (Thygesen et al., 2007).

The primary outcome in this study was in-hospital life-threatening arrhythmic events, which included sustained VT and VF. Sustained VT was defined as VT that lasted longer than 30 s, or that required termination due to hemodynamic instability. The time to

FIGURE 1 Fragmented QRS complex in various patterns (a: RSR', b: rSR', c: notched R, and d: notched S)

FIGURE 2 ECG of anterior wall STEMI with fragmented QRS in inferior leads II (notched R), III (rSR'), and aVF (RSR')

last life-threatening arrhythmic event from hospital admission was noted for each patient. The secondary outcome in this study was in-hospital complications, including cardiogenic shock, AV block (second and third degree), cerebrovascular event, and all-cause mortality.

2.1 | Statistical analysis

Categorical variables are presented as frequency and percentage, and they were compared between groups using chi-square test. Continuous variables with normal distribution are presented as mean $\pm$ standard deviation (SD), and comparison between groups was performed using unpaired *t* test. Non-normally distributed data are reported as median and interquartile range (IQR), with comparisons made between groups using Mann-Whitney *U* test. Univariate and multivariate analyses were performed using binary logistic regression (backward stepwise method). A *p*-value < 0.05 was considered statistically significant for all tests. All statistical analyses were performed using SPSS Statistics version 18.0 (SPSS, Inc., Chicago, IL, USA).

3 | RESULTS

There were 452 patients included in this study. The mean age of patients was 58.31 ± 10.53 years, and 76.1% were male. From the

ECG performed at hospital admission, 96 patients (21.2%) presented with fQRS. There was no significant difference between the fQRS and non-fQRS groups for any of the evaluated demographic or clinical characteristics (Table 1). Pathological Q wave was also not significantly different between groups; however, the Killip class and GRACE risk score were both significantly higher in fQRS patients. There was no difference between groups for in-hospital treatments, except for streptokinase which was higher in the non-fQRS group. LVEF, which was evaluated within first 72 hr of hospital admission, was also not significantly different between the fQRS and non-fQRS groups. In contrast, WMSI was significantly higher in fQRS than in non-fQRS.

Regarding in-hospital complications (Table 2), the incidence of in-hospital life-threatening arrhythmic events was 38 patients (8.4%). In-hospital life-threatening arrhythmic events were significantly higher in fQRS than in non-fQRS patients. Fragmented QRS was found to be a significant predictor of cardiogenic shock, arrhythmic event, and in-hospital mortality. The median length of hospital stay was 5 days (IQR: 3–8). There was no significant difference in median length of hospital stay between the fQRS and non-fQRS groups (5 days [IQR: 3–9] vs. 5 days [IQR: 3–8], respectively; *p* = 0.821).

The presence of fQRS, GRACE risk score, Killip class, hemodynamic instability, cardiac arrest at presentation, WMSI, and early administration of beta-blocker were all identified as significant

TABLE 1 Demographic and clinical characteristics compared between STEMI patients with and without fQRS

Characteristics	Total (n = 452)	fQRS (n = 96)	Non-fQRS (n = 356)	p-value
Age (years)	58.31 ± 10.53	58.05 ± 10.72	58.38 ± 10.49	0.786
Male gender	344 (76.1%)	66 (68.8%)	278 (78.1%)	0.057
Diabetes mellitus	175 (38.7%)	35 (36.5%)	140 (39.3%)	0.609
Hypertension	271 (60.0%)	61 (63.5%)	210 (59.0%)	0.419
Dyslipidemia	299 (66.2%)	61 (63.5%)	238 (66.9%)	0.543
Current smoker	185 (40.9%)	43 (44.8%)	142 (39.9%)	0.386
Chronic kidney disease	30 (6.6%)	6 (6.2%)	24 (6.7%)	0.864
Prior myocardial infarction	28 (6.2%)	8 (8.3%)	20 (5.6%)	0.327
Prior revascularization	29 (6.4%)	7 (7.3%)	22 (6.2%)	0.693
History of heart failure	22 (4.9%)	8 (8.3%)	14 (3.9%)	0.075
Cerebrovascular event	22 (4.9%)	4 (4.2%)	18 (5.1%)	1.000
Anterior wall MI	265 (58.6%)	64 (66.7%)	201 (56.5%)	0.072
Inferior wall MI	183 (40.5%)	32 (33.3%)	151 (42.4%)	0.108
Lateral wall MI	43 (9.5%)	8 (8.3%)	35 (9.8%)	0.657
Pathological Q wave	266 (58.8%)	54 (56.2%)	212 (59.6%)	0.560
Killip class	1.76 ± 1.17	2.40 ± 1.37	1.59 ± 1.05	<0.001
GRACE risk score	124.17 ± 35.97	138.97 ± 40.70	120.18 ± 33.55	<0.001
Aspirin	446 (98.7%)	94 (97.9%)	352 (98.9%)	0.612
Clopidogrel	423 (93.6%)	88 (91.7%)	335 (94.1%)	0.388
Statin	416 (92.0%)	85 (88.5%)	331 (93.0%)	0.154
Beta-blocker	259 (57.3%)	47 (49.0%)	212 (59.6%)	0.063
ACEI/ARB	326 (72.1%)	65 (67.7%)	261 (73.3%)	0.277
PCI	329 (72.8%)	70 (72.9%)	259 (72.8%)	0.974
CABG	43 (9.5%)	10 (10.4%)	33 (9.3%)	0.734
Streptokinase	55 (12.2%)	6 (6.2%)	49 (13.85%)	0.046
t-PA	50 (11.1%)	10 (10.4%)	40 (11.2%)	0.820
LVEF	52.45 ± 13.54	49.97 ± 13.99	53.03 ± 13.39	0.082
WMSI	1.60 ± 0.43	1.69 ± 0.46	1.58 ± 0.42	0.039

Note. Data presented as number and percentage or mean ± standard deviation. A *p*-value < 0.05 (bold) indicates statistical significance.

ACEI: angiotensin converting enzyme inhibitor; ARB: angiotensin II receptor blocker; CABG: coronary artery bypass graft surgery; fQRS: fragmented QRS; GRACE: Global Registry of Acute Coronary Events; LVEF: left ventricular ejection fraction; MI: myocardial infarction; PCI: percutaneous coronary intervention; STEMI: ST-elevation myocardial infarction; t-PA: tissue plasminogen activator; WMSI: wall motion score index.

predictors of in-hospital life-threatening arrhythmia in this study (Table 3). Of those, multivariate analysis revealed both presence of fQRS and GRACE risk score to be independent predictors of in-hospital life-threatening arrhythmic events.

The last life-threatening arrhythmic event occurred at a median 4.50 hr (IQR: 2.00–19.83) after hospital admission. The median time to the last life-threatening arrhythmic event was significantly longer in fQRS patients than in non-fQRS patients (6.58 hr [IQR: 3.08–39.34] vs. 2.59 hr [IQR: 1.75–5.75], respectively; *p* = 0.047).

Fragmented QRS presented at anterior wall, inferior wall, and lateral wall in 47 (49.0%), 49 (51.0%), and 14 (14.6%) patients, respectively.

Compared to the non-fQRS group, inferior wall fQRS was identified as a significant predictor of both in-hospital life-threatening arrhythmic events and in-hospital mortality (odds ratio [OR]: 4.781, 95% confidence interval [CI] 1.983–11.526; *p* < 0.001, and OR: 4.116, 95% CI: 1.918–8.835; *p* < 0.001, respectively). Lateral wall fQRS was associated with arrhythmic complication, but not with in-hospital mortality (OR: 8.500, 95% CI: 2.403–30.065; *p* < 0.001, and OR: 3.462, 95% CI: 0.909–13.188; *p* = 0.069, respectively). Anterior wall fQRS was associated with arrhythmic complication, but not with in-hospital mortality (OR: 6.493, 95% CI: 2.800–15.056; *p* < 0.001, and OR: 1.857, 95% CI: 0.722–4.780; *p* = 0.199).

TABLE 2 In-hospital complications compared between STEMI patients with and without fQRS

Complications	fQRS (n = 96) n (%)	non-fQRS (n = 356) n (%)	OR (95% CI)	p-value
Life-threatening arrhythmic events	22 (22.9)	16 (4.5)	6.318 (3.165–12.612)	<0.001
Sustained VT	16 (16.7)	11 (3.7)	6.273 (2.804–14.034)	<0.001
VF	11 (11.5)	10 (2.8)	4.478 (1.841–10.889)	0.001
Cardiogenic shock	30 (31.2)	37 (10.4)	3.919 (2.262–6.790)	<0.001
AV block (second and third degree)	15 (15.6)	19 (5.3)	3.285 (1.600–6.742)	0.001
Cerebrovascular event	3 (3.1)	7 (2.0)	1.608 (0.408–6.340)	0.497
Death	19 (19.8)	26 (7.3)	3.132 (1.649–5.948)	<0.001

Note. A p -value<0.05 (bold) indicates statistical significance.

AV block, atrioventricular block; CI, confidence interval; fQRS, fragmented QRS; OR, odds ratio; STEMI, ST-elevation myocardial infarction; VF, ventricular fibrillation; VT, ventricular tachycardia.

TABLE 3 Univariate and multivariate analysis to identify predictors of in-hospital life-threatening arrhythmic events in STEMI patients

Characteristics	Univariate analysis		Multivariate analysis	
	OR (95% CI)	p-value	OR (95% CI)	p-value
Presence of fQRS	6.318 (3.165–12.612)	<0.001	4.162 (1.669–10.384)	0.002
GRACE risk score	1.034 (1.023–1.045)	<0.001	1.020 (1.001–1.039)	0.040
Killip class	2.353 (1.790–3.092)	<0.001	—	—
Hemodynamic instability	2.792 (1.358–5.739)	0.005	—	—
Cardiac arrest at presentation	6.452 (2.681–15.527)	<0.001	—	—
LVEF (10% interval decrease)	1.293 (0.971–1.723)	0.079	—	—
WMSI	3.212 (1.389–7.426)	0.006	—	—
Beta-blocker	0.312 (0.153–0.636)	0.001	—	—
Age (10-year interval increase)	0.996 (0.736–1.347)	0.979	—	—
Pathological Q wave	1.218 (0.613–2.423)	0.573	—	—
Diabetes mellitus	1.312 (0.672–2.562)	0.427	—	—
Hypertension	1.026 (0.520–2.025)	0.940	—	—
Prior myocardial infarction	1.334 (0.383–4.639)	0.651	—	—
History of heart failure	1.094 (0.246–4.871)	0.906	—	—

Note. A p -value<0.05 (bold) indicates statistical significance.

CI, confidence interval; fQRS, fragmented QRS; GRACE, Global Registry of Acute Coronary Events; LVEF, left ventricular ejection fraction; OR, odds ratio; STEMI, ST-elevation myocardial infarction; WMSI, wall motion score index.

4 | DISCUSSION

The key findings of this study are that presence of fQRS at hospital admission is an independent predictor of in-hospital life-threatening arrhythmic events in STEMI patients, the time to last life-threatening arrhythmic event is significant longer in fQRS patients than non-fQRS patients, and fQRS is also a significant predictor of in-hospital mortality.

In-hospital life-threatening arrhythmic event occurred in 8.4% of STEMI patients in this study, which is consistent with previously reported findings (Ibanez et al., 2017; Mehta et al., 2009; Priori et al., 2015). This relatively high incidence of in-hospital life-threatening arrhythmia in STEMI patients, and the fact that it was found

to be significantly associated with in-hospital mortality highlights the clinical importance of this condition (Priori et al., 2015; Sandau et al., 2017). Acute myocardial infarction (AMI) patients are at increased risk of developing cardiac arrhythmia that originates from the peri-infarct area. The peri-infarct area is an arrhythmogenic substrate due to the impulse conduction velocity delay, reentrant circuit, and also increased risk of automaticity due to the infiltration of fibroblasts. The occurrence of VT is associated with the proportion of peri-infarct area in STEMI patients (Robbers et al., 2013).

The present study identified fQRS as an independent predictor of in-hospital life-threatening arrhythmic events in patients with

STEMI. Fragmented QRS originates from myocardial scarring that causes reentry circuit and conduction barrier, both anatomically and functionally, that alters the depolarization vector and QRS complex morphology and is related to the arrhythmogenesis of the peri-infarct area (Das et al., 2007; Flowers, Horan, Thomas, & Tolleson, 1969; Gardner, Ursell, Fenoglio, & Wit, 1985; Mahenthiran, Khan, Sawada, & Das, 2007; Michael, El Masry, Khan, & Das, 2007; Varriale & Chrysos, 1992). Fragmented QRS is commensurately correlated with the size of the infarct and the peri-infarct area, both of which can be assessed by cardiac magnetic resonance imaging (MRI) and peak creatine kinase (CK) level (Lorgis et al., 2014).

The time from hospital admission to the last life-threatening arrhythmic event was significantly longer in fQRS patients than in non-fQRS patients. In fQRS patients, if cardiac rhythm monitoring was performed at 24, 48, and 72 hr after hospital admission, life-threatening arrhythmia could have been detected in 16 (72.7%), 18 (81.8%), and 19 (86.4%) patients, respectively. In non-fQRS patients, if cardiac rhythm monitoring was performed at 24, 48, and 72 hr, life-threatening arrhythmia could have been detected in 14 (87.5%), 15 (93.8%), and 16 (100%) patients, respectively. These findings suggest that cardiac rhythm monitoring longer than 24–48 hr after hospital admission may be required in patients with fQRS. The current recommendation for duration of cardiac rhythm monitoring in STEMI is at least 24–48 hr, and the duration is longer in intermediate to high-risk patients (Ibanez et al., 2017; Sandau et al., 2017). Taken together, these findings suggest that extended cardiac monitoring be strongly considered in patients with STEMI that present with fQRS given the higher likelihood that life-threatening arrhythmia could develop.

Fragmented QRS was identified as a significant predictor of in-hospital mortality in this study, which is consistent with the results of previous study that found fQRS to be associated with all-cause mortality in ACS patients (Das et al., 2009, 2007; Pietrasik et al., 2007). Myocardial ischemia or scar is known to be a poor prognosis marker, with associated increase in mortality due to ventricular arrhythmia and heart failure (Bello et al., 2005; Flowers et al., 1969; Mahenthiran et al., 2007; Varriale & Chrysos, 1992). Fragmented QRS is associated with increased mortality as fQRS is correlated with the size of the infarct area and the presence of myocardial scar (Das et al., 2009; Lorgis et al., 2013; Pietrasik et al., 2007).

Regarding the relationship between fQRS and echocardiographic parameters, our study showed that patients with fQRS had a slightly lower LVEF compared to those without fQRS at a borderline significant *p*-value. Although LVEF was slightly lower in patients with life-threatening arrhythmic event, it was not statistical significance and LVEF was not independent predictor for life-threatening arrhythmic event in the multivariate model. In patients with AMI, VT may be related to the abnormal area in the peri-infarction region and previous studies have shown that LVEF was not found to be associated with the proportion of the peri-infarct area or with in-hospital VT event (Bello et al., 2005; Robbers et al., 2013). Due to the complex structure of the heart, LVEF may not reflect the performance of the myocardium in the longitudinal axis or in the deformity.

Subtle systolic dysfunction may present as preserved ejection fraction, which suggests that LVEF may not be a reliable parameter for detecting early systolic dysfunction. Strain echocardiography may be an improved method for assessing left ventricular function (Leung & Ng, 2010; Nesbitt & Mankad, 2009). In patients with CAD with preserved LVEF (LVEF >45%), fQRS was associated with significantly lower strain rate and global, longitudinal, radial, and circumferential strain (Yan et al., 2012). As such, fQRS may be a sensitive marker for detecting subtle systolic dysfunction.

In this study, the prevalence of fQRS on the hospital admission ECG was 21.2%, which is lower than the 28%–53% rates reported in AMI patients with fQRS (Das et al., 2009; Lorgis et al., 2013; Pietrasik et al., 2007; Uslu et al., 2015). Fragmented QRS presented most often at the inferior wall in the present study (51.0%). The results of this study identified presence of fQRS at the myocardial wall as an independent predictor of life-threatening arrhythmic event. Moreover, this study found inferior wall fQRS to be a predictor of in-hospital mortality, whereas anterior wall and lateral wall fQRS were not found to associate with in-hospital death. Previous study reported that fQRS was most often detected by inferior ECG leads (57%) (Lorgis et al., 2013). Inferior lead fQRS was found to be a predictor of sudden cardiac death and all-cause mortality in both ischemic cardiomyopathy (ICM) and nonischemic cardiomyopathy (NICM) chronic heart failure patients (Pei et al., 2012).

This study has some mentionable limitations. First and consistent with the retrospective nature of this study, some patient data may have been missing or incomplete. Second, the size of the study population was relatively small. As a result, our study may have lacked sufficient power to identify all significant differences and associations. Third, the patients enrolled in this study were from a single center. Fourth, our center is Thailand's largest tertiary referral hospital, which means that we are often referred patients with complicated and intransigent conditions. As such, it is possible that our findings may not be generalizable to patients with the same condition in other settings. Finally, it is possible that a longer follow-up period would help to determine the prognostic significance of fQRS relative to long-term arrhythmic risk in patients with STEMI.

5 | CONCLUSION

The presence of fQRS complex on hospital admission ECG was found to be an independent predictor of in-hospital life-threatening arrhythmic events in STEMI patients. Since the time to last life-threatening arrhythmic event from admission was longer in fQRS than in non-fQRS, cardiac rhythm monitoring longer than 24–48 hr may be needed in patients with fQRS.

ACKNOWLEDGMENTS

The authors gratefully acknowledge Khemajira Karaketklang of the Department of Medicine, Faculty of Medicine Siriraj Hospital for assistance with statistical analysis.

CONFLICT OF INTEREST

Both authors declare no personal or professional conflicts of interest, and no financial support from the companies that produce and/or distribute the drugs, devices, or materials described in this report.

ORCID

Rungroj Kittayaphong <http://orcid.org/0000-0001-8684-2361>

REFERENCES

- Bello, D., Fieno, D. S., Kim, R. J., Pereles, S., Passman, R., Song, G., ... Goldberger, J. J. (2005). Infarct morphology identifies patients with substrate for sustained ventricular tachycardia. *Journal of the American College of Cardiology*, 45(7), 1104–1108. <https://doi.org/10.1016/j.jacc.2004.12.057>
- Das, M. K., Khan, B., Jacob, S., Kumar, A., & Mahenthiran, J. (2006). Significance of a fragmented QRS complex versus a Q wave in patients with coronary artery disease. *Circulation*, 113(21), 2495–2501. <https://doi.org/10.1161/Circulationha.105.595892>
- Das, M. K., Maskoun, W., Shen, C., Michael, M. A., Suradi, H., Desai, M., ... Bhakta, D. (2010). Fragmented QRS on twelve-lead electrocardiogram predicts arrhythmic events in patients with ischemic and nonischemic cardiomyopathy. *Heart Rhythm: the Official Journal of the Heart Rhythm Society*, 7(1), 74–80. <https://doi.org/10.1016/j.hrthm.2009.09.065>
- Das, M. K., Michael, M. A., Suradi, H., Peng, J., Sinha, A., Shen, C. Y., ... Kovacs, R. J. (2009). Usefulness of Fragmented QRS on a 12-Lead Electrocardiogram in Acute Coronary Syndrome for Predicting Mortality. *American Journal of Cardiology*, 104(12), 1631–1637. <https://doi.org/10.1016/j.amjcard.2009.07.046>
- Das, M. K., Saha, C., El Masry, H., Peng, J., Dandamudi, G., Mahenthiran, J., ... Zipes, D. P. (2007). Fragmented QRS on a 12-lead ECG: A predictor of mortality and cardiac events in patients with coronary artery disease. *Heart Rhythm: the Official Journal of the Heart Rhythm Society*, 4(11), 1385–1392. <https://doi.org/10.1016/j.hrthm.2007.06.024>
- Flowers, N. C., Horan, L. G., Thomas, J. R., & Tolleson, W. J. (1969). The anatomic basis for high-frequency components in the electrocardiogram. *Circulation*, 39(4), 531–539. <https://doi.org/10.1161/01.CIR.39.4.531>
- Fox, K. A. A., Dabbous, O. H., Goldberg, R. J., Pieper, K. S., Eagle, K. A., Van de Werf, F., ... Investigators, G. (2006). Prediction of risk of death and myocardial infarction in the six months after presentation with acute coronary syndrome: Prospective multinational observational study (GRACE). *BMJ*, 333(7578), 1091–1094. <https://doi.org/10.1136/bmj.38985.646481.55>
- Gardner, P. I., Ursell, P. C., Fenoglio, J. J. Jr., & Wit, A. L. (1985). Electrophysiologic and anatomic basis for fractionated electrograms recorded from healed myocardial infarcts. *Circulation*, 72(3), 596–611. <https://doi.org/10.1161/01.CIR.72.3.596>
- Ibanez, B., James, S., Agewall, S., Antunes, M. J., Bucciarelli-Ducci, C., Bueno, H., ... ESC Scientific Document Group. (2017). 2017 ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation: The Task Force for the management of acute myocardial infarction in patients presenting with ST-segment elevation of the European Society of Cardiology (ESC). *European Heart Journal*, 39(2), 119–177. <https://doi.org/10.1093/eurheartj/ehx393>
- Leung, D. Y., & Ng, A. C. (2010). Emerging clinical role of strain imaging in echocardiography. *Heart, Lung & Circulation*, 19(3), 161–174. <https://doi.org/10.1016/j.hlc.2009.11.006>
- Lorgis, L., Cochet, A., Chevallier, O., Angue, M., Gudjoncik, A., Lalande, A., ... Cottin, Y. (2014). Relationship between fragmented QRS and no-reflow, infarct size, and peri-infarct zone assessed using cardiac magnetic resonance in patients with myocardial infarction. *Canadian Journal of Cardiology*, 30(2), 204–210. <https://doi.org/10.1016/j.cjca.2013.11.026>
- Lorgis, L., Jourda, F., Hachet, O., Zeller, M., Gudjoncik, A., Dentan, G., ... RICO Survey Working Group. (2013). Prognostic value of fragmented QRS on a 12-lead ECG in patients with acute myocardial infarction. *Heart & Lung*, 42(5), 326–331. <https://doi.org/10.1016/j.hrtlng.2013.05.005>
- Mahenthiran, J., Khan, B. R., Sawada, S. G., & Das, M. K. (2007). Fragmented QRS complexes not typical of a bundle branch block: A marker of greater myocardial perfusion tomography abnormalities in coronary artery disease. *Journal of Nuclear Cardiology*, 14(3), 347–353. <https://doi.org/10.1016/j.nuclcard.2007.02.003>
- Mehta, R. H., Starr, A. Z., Lopes, R. D., Hochman, J. S., Widimsky, P., Pieper, K. S., ... APEX AMI Investigators. (2009). Incidence of and outcomes associated with ventricular tachycardia or fibrillation in patients undergoing primary percutaneous coronary intervention. *JAMA*, 301(17), 1779–1789. <https://doi.org/10.1001/jama.2009.600>
- Michael, M. A., El Masry, H., Khan, B. R., & Das, M. K. (2007). Electrocardiographic signs of remote myocardial infarction. *Progress in Cardiovascular Diseases*, 50(3), 198–208. <https://doi.org/10.1016/j.pcad.2007.05.003>
- Morita, H., Kusano, K. F., Miura, D., Nagase, S., Nakamura, K., Morita, S. T., ... Wu, J. (2008). Fragmented QRS as a marker of conduction abnormality and a predictor of prognosis of Brugada syndrome. *Circulation*, 118(17), 1697–1704. <https://doi.org/10.1161/CIRCULATIONAHA.108.770917>
- Nesbitt, G. C., & Mankad, S. (2009). Strain and strain rate imaging in cardiomyopathy. *Echocardiography*, 26(3), 337–344. <https://doi.org/10.1111/j.1540-8175.2008.00867.x>
- O'Gara, P. T., Kushner, F. G., Ascheim, D. D., Casey, D. E., Chung, M. K., de Lemos, J. A., ... Members, W. C. (2013). 2013 ACCF/AHA guideline for the management of ST-elevation myocardial infarction a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. *Circulation*, 127(4), E362–E425. <https://doi.org/10.1161/CIR.0b013e3182742cf6>
- Ozcan, F., Turak, O., Canpolat, U., Avci, S., Tok, D., Isleyen, A., ... Aydogdu, S. (2014). Fragmented QRS predicts the arrhythmic events in patients with heart failure undergoing ICD implantation for primary prophylaxis: More fragments more appropriate ICD shocks. *Annals of Noninvasive Electrocardiology*, 19(4), 351–357. <https://doi.org/10.1111/anec.12141>
- Pei, J., Li, N., Gao, Y., Wang, Z., Li, X., Zhang, Y., ... Pu, J. (2012). The J wave and fragmented QRS complexes in inferior leads associated with sudden cardiac death in patients with chronic heart failure. *Europace*, 14(8), 1180–1187. <https://doi.org/10.1093/europace/eur437>
- Peters, S., Trummel, M., & Koehler, B. (2008). QRS fragmentation in standard ECG as a diagnostic marker of arrhythmogenic right ventricular dysplasia-cardiomyopathy. *Heart Rhythm: the Official Journal of the Heart Rhythm Society*, 5(10), 1417–1421. <https://doi.org/10.1016/j.hrthm.2008.07.012>
- Pietrasik, G., Goldenberg, I., Zdzienicka, J., Moss, A. J., & Zareba, W. (2007). Prognostic significance of fragmented QRS complex for predicting the risk of recurrent cardiac events in patients with Q-wave myocardial infarction. *American Journal of Cardiology*, 100(4), 583–586. <https://doi.org/10.1016/j.amjcard.2007.03.063>
- Priori, S. G., Blomstrom-Lundqvist, C., Mazzanti, A., Blom, N., Borggrefe, M., Camm, J., ... ESC Scientific Document Group. (2015). 2015 ESC Guidelines for the management of patients with ventricular arrhythmias and the prevention of sudden cardiac death The Task Force for the Management of Patients with Ventricular Arrhythmias and the Prevention of Sudden Cardiac Death of the European Society of

- Cardiology (ESC) Endorsed by: Association for European Paediatric and Congenital Cardiology (AEPC). *European Heart Journal*, 36(41), 2793–2867. <https://doi.org/10.1093/eurheartj/ehv316>
- Robbers, L. F. H. J., Delewi, R., Nijveldt, R., Hirsch, A., Beek, A. M., Kemme, M. J. B., ... van Rossum, A. C. (2013). Myocardial infarct heterogeneity assessment by late gadolinium enhancement cardiovascular magnetic resonance imaging shows predictive value for ventricular arrhythmia development after acute myocardial infarction. *European Heart Journal-Cardiovascular Imaging*, 14(12), 1150–1158. <https://doi.org/10.1093/ehjci/jet111>
- Sandau, K. E., Funk, M., Auerbach, A., Barsness, G. W., Blum, K., Cvach, M., ... Council on Cardiovascular Disease in the Young. (2017). Update to practice standards for electrocardiographic monitoring in hospital settings: A scientific statement from the American Heart Association. *Circulation*, 136(19), e273–e344. <https://doi.org/10.1161/CIR.0000000000000527>
- Thygesen, K., Alpert, J. S., & White, H. D. (2007). Universal definition of myocardial infarction. *Circulation*, 116(22), 2634–2653. <https://doi.org/10.1161/Circulationaha.107.187397>
- Uslu, N., Gul, M., Cakmak, H. A., Atam, A., Pusuroglu, H., Satilmisoglu, H., ... Eksik, A. (2015). The assessment of relationship between fragmented QRS complex and left ventricular wall motion score index in patients with ST elevation myocardial infarction who underwent primary percutaneous coronary intervention. *Annals of Noninvasive Electrocardiology*, 20(2), 148–157. <https://doi.org/10.1111/anec.12180>
- Varriale, P., & Chryssos, B. E. (1992). The RSR' complex not related to right bundle branch block: Diagnostic value as a sign of myocardial infarction scar. *American Heart Journal*, 123(2), 369–376. [https://doi.org/10.1016/0002-8703\(92\)90648-F](https://doi.org/10.1016/0002-8703(92)90648-F)
- Yan, G. H., Wang, M., Yiu, K. H., Lau, C. P., Zhi, G., Lee, S. W. L., ... Tse, H. F. (2012). Subclinical left ventricular dysfunction revealed by circumferential 2D strain imaging in patients with coronary artery disease and fragmented QRS complex. *Heart Rhythm*, 9(6), 928–935. <https://doi.org/10.1016/j.hrthm.2012.01.007>

How to cite this article: Attachaipanich T, Krittayaphong R. Fragmented QRS as a predictor of in-hospital life-threatening arrhythmic complications in ST-elevation myocardial infarction patients. *Ann Noninvasive Electrocardiol*. 2019;24:e12593. <https://doi.org/10.1111/anec.12593>