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Risk assessment model for predicting ventricular tachycardia or ventricular fibrillation in ST-segment elevation myocardial infarction patients who received primary percutaneous coronary intervention

Jiabing Huang, MD, PhD, Xiaofan Peng, MD, PhD, Zhenfei Fang, MD, PhD, Xinqun Hu, MD, PhD, Shenghua Zhou, MD, PhD*

Abstract

Ventricular tachycardia/ventricular fibrillation (VT/VF) is a kind of malignant arrhythmia in ST-segment elevation myocardial infarction (STEMI) patients who received primary percutaneous coronary intervention (PPCI). However, there are no risk assessment tools to anticipate the occurrence of VT/VF.

This study is to build a risk assessment model to predict the possibility of VT/VF onset in STEMI patients undergoing PPCI.

A retrospective study was conducted to analyze the patients who underwent PPCI from January 2006 to May 2015. Subjects were divided into VT/VF group and no VT/VF group based on whether VT/VF had occurred or not. In addition, the VT/VF group was further separated into early-onset group (from the time that symptoms began to before the end of PPCI) and late-onset group (after the end of PPCI) based on the timing of when VT/VF happened. Multivariate regression analysis was carried out to distinguish the independent risk factors of VT/VF and an additional statistical method was executed to build the risk assessment model.

A total of 607 patients were enrolled in this study. Of these patients, 67 cases (11%) experienced VT/VF. In addition, 91% (61) of patients experienced VT/VF within 48 h from the time that the symptoms emerged. Independent risk factors include: age, diabetes mellitus, heart rate, ST-segment maximum elevation, ST-segment total elevation, serum potassium, left ventricular ejection fraction (LVEF), culprit artery was right coronary artery, left main (LM) stenosis, Killip class > I class, and pre-procedure thrombolysis in myocardial infarction (TIMI) flow zero grade. Risk score model and risk rank model have been established to evaluate the possibility of VT/VF. Class I: ≤ 4 points; Class II: > 4 points, ≤ 5.5 points; Class III: > 5.5 points, < 6.5 points; and Class IV ≥ 6.5 points. The higher the class, the higher the risk.

The incidence of VT/VF in STEMI patients undergoing PPCI is 11% and it occurs more frequently from the time that symptoms begin to before the end of PPCI, which, in most cases, occurs within 48 h of the event. Our risk assessment model could predict the possible occurrence of VT/VF.

Abbreviations: ACEI = angiotensin converting enzyme inhibitor, ARB = angiotensin receptor blocker, AVIR = accelerated idioventricular rhythms, CAG = coronary angiography, CHD = coronary heart disease, ECG = electrocardiogram, IABP = intra-aortic balloon pump, IRA = infarct-related artery, LAD = left anterior descending, LCX = left circumflex, LM = left main, LMWH = low molecular weight heparin, LVEF = left ventricular ejection fraction, MI = myocardial infarction, PCI = percutaneous coronary intervention, PPCI = primary percutaneous coronary intervention, RAAS = renin-angiotensin-aldosterone-system, RCA = right coronary artery, SCD = sudden cardiac death, STEMI = ST segment elevation myocardial infarction, TIMI = thrombolysis in myocardial infarction, VF = ventricular fibrillation, VPBs = ventricular premature beats, VT = ventricular tachycardia.

Keywords: acute myocardial infarction, malignant ventricular arrhythmia, primary percutaneous coronary intervention

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Department of Cardiovascular medicine, The Second Xiangya Hospital of Central South University, Changsha, China.

** Correspondence: Shenghua Zhou, Department of Cardiovascular medicine, The Second Xiangya Hospital of Central South University, No.139, middle Ren-min road, Changsha, Hunan 410011, China (e-mail: zhoushenghua@csu.edu.cn).*

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1. Introduction

Malignant arrhythmia, such as sustained ventricular tachycardia (VT) and ventricular fibrillation (VF), is the most common cause of sudden cardiac death (SCD). Coronary heart disease (CHD) is the most frequent etiology of SCD, with approximately 70% of SCD cases due to CHD, and CHD is the most common etiology of ventricular arrhythmia.[1,2] As for the acute stage of ST-segment elevation myocardial infarction (STEMI), VT/VF has brought challenges to reperfusion therapy. There have been numerous studies over the years to detect the risk factors of VT/VF. In the thrombolytic therapy era, ventricular premature beats (VPBs) and accelerated idioventricular rhythms (AVIR) frequently suggested myocardial reperfusion, which is called reperfusion arrhythmia. However, some researchers used AVIR as a marker of myocardial necrosis.[3] Post-thrombolytic VT/VF, no matter when it occurred, has been deemed to be associated with adverse outcomes.[4–7] With the advent of percutaneous coronary intervention (PCI) as the main reperfusion therapy of myocardial infarction (MI), the culprit artery reperfusion rate improved largely. The incidence and prognosis of VT/VF has significantly changed. Rajendra H et al[8] conducted the 1st large retrospective study to seek risk factors of VT/VF during primary percutaneous coronary intervention (PPCI); however, the study only enrolled low-risk patients without renal dysfunction and cardiogenic shock, and it only focused on arrhythmia during PPCI. Some studies[9–15] that focused on pre-PPCI, intra-PPCI, and pro-PPCI have accomplished this as well, with diversified objects and findings. The APEX-AMI study[16] accomplished a related overall examination of VT/VF in STEMI patients; however, inferior myocardial infarction and pre-thrombolytic patients were excluded. In addition, a variety of risk assessment tools are well known, such as thrombolysis in myocardial infarction (TIMI)-score, GRACE-score, CRUSADE-score, STS-score, are required to identify high-risk patients, nevertheless none of the researchers have built a risk assessment model to distinguish the patients at high risk for VT/VF. We wanted to build a scoring system to evaluate the potential occurrence of VT/VF to offer more precise care to STEMI patients.

2. Methods

This study was approved by the Ethical Review Committee of the Second Xiangya Hospital of Central South University (Changsha, Hunan, China). A retrospective study was conducted to analyze patients who underwent PPCI in the Second Xiangya Hospital of Central South University (Changsha, Hunan, China) from January 1, 2006 to May 31, 2015 and who experienced the onset of symptoms (including sustained ischemic chest pain, heart failure, malignant arrhythmia, and unstable hemodynamics) within 12 h and the onset of symptoms between 12 and 24 h. All of the patients met the diagnosis criteria mentioned in the 2013 AHA/ACC guidelines for STEMI management.[17] The exclusion criteria were: patients who underwent coronary angiography (CAG) and those treated via intra-aorta balloon pump (IABP), temporary pacemaker implantation without the infarct-related artery (IRA) intervention process, rescue PCI after fibrinolytic therapy, and pacemaker implantation before PPCI, as well as patients with critical data missing. The patients enrolled in study were divided into 2 groups (the VT/VF group and the no VT/VF group) based on whether VT/VF had occurred or not. In addition, the VT/VF group was further separated into the early-onset group (from the time that symptoms began to before the end of PPCI) and late-onset group (after the end of PPCI) based on when VT/VF happened according to Mehta's study[16] (Fig. 1).

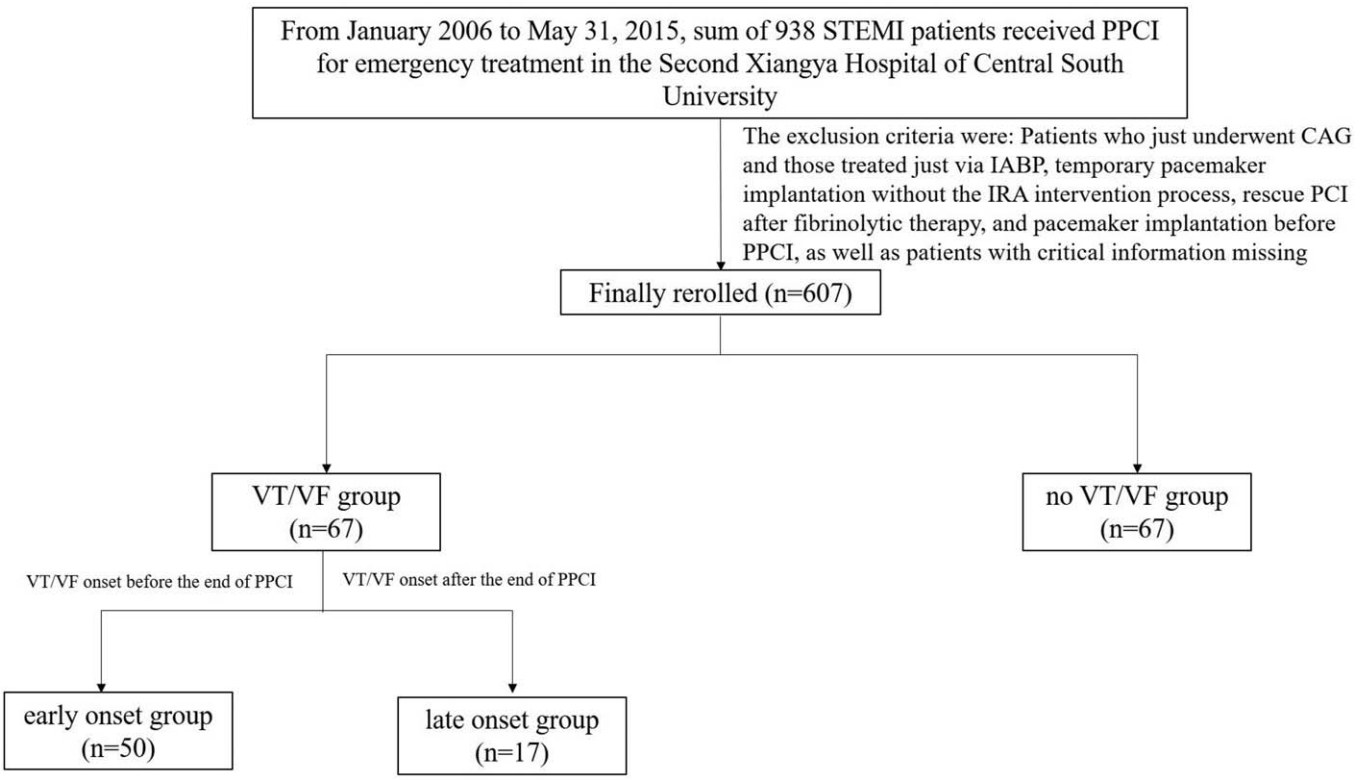

Figure 1. Filter group flowchart of the study.

After data were gathered, SPSS 22.0 was utilized to conduct the statistical analysis. For continuous quantitative data, the K-s normal test is used to check whether the normal distribution is obeyed; the distribution is described by the mean value and standard deviation for the normal distribution data. The difference between groups was determined by the Independent Sample *t* Test, and the distribution is described by the median and 4-digit spacing for the discrepancy from the normal distribution data. We used the Mann–Whitney *U* test to compare differences between groups for the classification data. The card-side test was adopted to compare the differences between groups and multifactor logistic regression analysis was used for multifactor analysis. According to the differences and the condition regression tree analysis results, the continuity variable was divided into the classification variable to build the risk assessment model. The risk grading score and the total sample training were used as predictor variables, with 60% of samples randomly sampled as training sets, and 40% of samples used as test sets for the cross-verification of the model prediction value. All of the tests used in this paper are bilateral tests, with statistical significance set to $P < .05$.

3. Results

Out of a total of 938 cases, we enrolled 607 patients in the study. Excluded cases included: 142 patients without IRA treatment, 66 patients with rescue PCI, 26 patients with critical data missing, and 97 for pre-process pacemaker implantation. Of the final 607 included patients, 467 (77%) were males and 140 (23%) were females. There were 67 (about 11%) patients who suffered from VT/VF. Of these VT/VF patients, 55 (82%) were males and 12 (18%) were females. Moreover, 91% (61) of VT/VF cases occurred within 48 h and 9% (6) occurred after 48 h. According to the methods mentioned above, 50 patients were placed in the early-onset group and 17 patients were placed in the late-onset group. Even in the late-onset group, most of the patients (about 75%) had VT/VF within 48 h.

3.1. Demographic and baseline clinical characteristics

Compared with the no VT/VF group, the VT/VF group showed a trend with patients who were elderly and smokers, had pre-myocardial infarction, diabetes, a quick heart rate, low systolic pressure, Killip Class > I, low creatinine clearance, low left ventricular ejection fraction (LVEF), etc (Table 1). The infarct area was also associated with VT/VF onset, and inferior MI has a greater VT/VF occurrence rate (36.7% vs 55.22%, $P < .001$) (Table 1). Moreover, the VT/VF group had a higher CK-MB level (285.8 u/L vs 320.9 u/L, $P = .041$) and magnitude of ST-segment elevation (Table 1). Comparing the early-onset group and the late-onset group, atrial fibrillation pre-process (6% vs 29.41%,

Table 1

Demographic and baseline clinical characteristics.

	Occurrence situation			Occurrence time		
Factors	No VT/VF group (n = 540)	VT/VF group (n = 67)	*P*	Early onset group (n = 50)	Late onset group (n = 17)	*P*
Sex						
Male	412 (76.3%)	55 (76.9%)	.355	39 (78%)	16 (94.12%)	.270
Female	128 (23.7%)	12 (23.1%)		11 (22%)	1 (5.88%)	
Age	61.99 ± 11.65	66.9 ± 9.97	.001	67 ± 9.49	66.59 ± 11.56	.884
Weight	65.78 ± 9.93	66.51 ± 9.13	.563	65.92 ± 9.04	68.26 ± 9.42	.364
CABG	20 (3.7%)	5 (7.46%)	.144	3 (6%)	2 (11.76%)	.595
MI	35 (6.48%)	10 (14.93%)	.018	8 (16%)	2 (11.76%)	.726
Hypertension	306 (56.67%)	42 (62.69%)	.347	32 (64%)	10 (58.82%)	.703
Stroke	36 (6.67%)	1 (1.49%)	.108	1 (2%)	0 (0%)	1.000
Diabetes	116 (21.48%)	24 (35.82%)	.009	17 (34%)	7 (41.18%)	.594
Smoking	281 (52.04%)	45 (67.16%)	.019	33 (66%)	12 (70.59%)	.728
Heart rate	83.29 ± 18.9	98.42 ± 20.67	<.001	97.06 ± 19.73	102.41 ± 23.41	.360
Systolic pressure	131.09 ± 29.95	120.45 ± 27.38	.006	121.16 ± 27.53	118.35 ± 27.65	.718
Killip class						
I	339 (62.78%)	32 (47.76%)	<.001	21 (42%)	11 (64.71%)	.366
II	73 (13.52%)	25 (37.31%)		21 (42%)	4 (23.53%)	
III	83 (15.37%)	3 (4.48%)		3 (6%)	0 (0%)	
IV	45 (8.33%)	7 (10.45%)		5 (10%)	2 (11.76%)	
Top ST elevation>0.3mv	288 (53.33%)	50 (74.63%)	.001	36 (72%)	14 (82.35%)	.527
Sum ST elevation>1.5mv	108 (20%)	24 (35.82%)	.003	18 (36%)	6 (35.29%)	.958
Af/AF	36 (6.67%)	8 (11.94%)	.131	3 (6%)	5 (29.41%)	.021
Serum K^+	4.44 ± 0.99	3.97 ± 0.88	<.001	3.8 (3.1–4.6)	4.2 (3.8–4.7)	.180
Creatinine clearance	73.79 ± 13.92	66.18 ± 12.53	<.001	68.6 (55.3–75)	59.7 (52.5–75.9)	.531
Myocardial location						
Anterior	250 (46.3%)	28 (41.79%)	.485	22 (44%)	6 (35.29%)	0.530
Extensive anterior	110 (20.37%)	10 (14.93%)	.291	6 (12%)	4 (23.53%)	.432
High lateral, anterior-lateral, posterior	54 (10%)	9 (13.43%)	.385	6 (12%)	3 (17.65%)	.682
Inferior	171 (31.67%)	37 (55.22%)	<.001	32 (64%)	5 (29.41%)	.013
Right ventricular	45 (8.33%)	8 (11.94%)	.324	7 (14%)	1 (5.88%)	.448
III°AVB	77 (14.26%)	18 (26.87%)	.007	14 (28%)	4 (23.53%)	.000
CK-MB	285.8 (127.75,438.95)	320.9 (212.4,450.6)	.041	307.3 (197,458.5)	363.9 (203.3–330.5)	.306
LVEF%	46.18 ± 3.71	40.35 ± 3.49	<.001	41.74 (37.96–44.62)	37.71 (36.8–39.06)	.002

CABG = coronary artery bypass grafting, MI = myocardial infarction, III°AVB = three grade atrioventricular block, LVEF = left ventricular ejection fraction, VT/VF = ventricular tachycardia/ventricular fibrillation.

Table 2

Demographic and baseline clinical characteristics of the early-onset group and non-early- onset group, late-onset group and non-late-onset group.

Factors	Non-early onset group (n = 557)	Early onset group (n = 50)	P	Non-late onset group (n = 590)	Late onset group (n = 17)	P
Sex						
Male	428 (76.84%)	39 (78%)	.852	451 (76.44%)	16 (94.12%)	.140
Female	129 (23.16%)	11 (22%)		139 (23.56%)	1 (5.88%)	
Age	62 (54,71)	67.5 (62,72)	.003	63 (54,71)	68 (60,73)	.176
Weight	66 (59,73)	67 (58,73)	.961	66 (58,73)	68 (62,72)	.342
CABG	22 (3.95%)	3 (6%)	.712	23 (3.9%)	2 (11.76%)	.152
MI	37 (6.64%)	8 (16%)	.024	43 (7.29%)	2 (11.76%)	.629
Hypertension	316 (56.73%)	32 (64%)	.320	338 (57.29%)	10 (58.82%)	.900
Stroke	36 (6.46%)	1 (2%)	.244	37 (6.27%)	0 (0%)	.417
Diabetes	123 (22.08%)	17 (34%)	.055	133 (22.54%)	7 (41.18%)	.083
Smoking	293 (52.6%)	33 (66%)	.069	314 (53.22%)	12 (70.59%)	.157
Heart rate	82 (70,94)	96 (83,107)	<.001	82 (70,95)	97 (85,108)	.001
Systolic pressure	130 (105,158)	118 (96,142)	.030	130 (104,158)	115 (98,141)	.102
Killip class						
I	350 (62.84%)	21 (42%)	<.001	360 (61.02%)	11 (64.71%)	.256
II	77 (13.82%)	21 (42%)		94 (15.93%)	4 (23.53%)	
III	83 (14.9%)	3 (6%)		86 (14.58%)	0 (0%)	
IV	47 (8.44%)	5 (10%)		50 (8.47%)	2 (11.76%)	
Top ST elevation >0.3mv	299 (53.68%)	39 (78%)	.001	327 (55.42%)	11 (64.71%)	.448
Sum ST elevation >1.5mv	114 (20.47%)	18 (36%)	.011	126 (21.36%)	6 (35.29%)	.227
Af/AF	41 (7.36%)	3 (96%)	.791	39 (6.61%)	5 (29.41%)	.005
Serum K^+	4.23 (3.73,5.01)	3.8 (3.1,4.6)	<.001	4.2 (3.7,5)	4.2 (3.8,4.7)	.755
Creatinine clearance	73.5 (61.3,85)	68.6 (55.3,75)	.001	73 (61.3,83.9)	59.7 (52.5,75.9)	.016
Myocardial location						
Anterior	256 (45.96%)	22 (44%)	.790	272 (46.1%)	6 (35.29%)	.378
Extensive anterior	115 (20.65%)	11 (22%)	.821	121 (20.51%)	5 (29.41%)	.545
High lateral, anterior-lateral, posterior	55 (9.87%)	9 (18%)	.073	63 (10.68%)	1 (5.88%)	.711
Inferior	176 (31.6%)	25 (50%)	.008	196 (33.22%)	5 (29.41%)	.742
Right ventricular	45 (8.08%)	7 (14%)	.181	52 (8.81%)	0 (0%)	.385
III°AVB	81 (14.54%)	14 (28%)	.012	91 (15.42%)	4 (23.53%)	.494
CK-MB	288.5 (130.9,438.5)	307.3 (197,458.5)	.184	287.85 (141.9,439.4)	363.9 (283.3,388.6)	.096
LVEF%	45.61 (42.63,49.22)	41.74 (37.96,44.62)	<.001	45.42 (42.57,49.07)	37.71 (36.8,39.06)	<.001

CABG = coronary artery bypass grafting, MI = myocardial infarction, III°AVB = three grade atrioventricular block, LVEF = left ventricular ejection fraction, VT/VF = ventricular tachycardia/ventricular fibrillation. Non-early-onset group means no VT/VF group and late-onset group; non-late-onset group means no VT/VF group and early-onset group.

P = .021), LVEF [41.74% (37.96–44.62%) vs 37.71% (36.8–39.06%), P = *.002], and inferior MI (64% vs 29.41%,* P = *.013) showed a statistical difference (Table 1). The LVEF was obtained within 7 days after reperfusion of occluded artery.*

Further demographic and baseline clinical characteristic comparisons between the early-onset-group and non-early-onset group (no VT/VF group and late-onset group), and the late-onset group and non-late-onset group (no VT/VF group and early-onset group) suggested that there was a trend in the early-onset group for patients to be elderly and have pre-MI, a fast heartrate, low systolic pressure, Killip Class > I, inferior MI, low creatinine clearance, and low LVEF etc, while the late-onset group showed a trend of having a fast heartrate, atrial flutter/atrial fibrillation, and low LVEF (Table 2).

3.2. PPCI procedure characteristics

We noted a statistical significance in IRA, left main (LM) lesion, TIMI grade at pre- and post-PPCI, and utilization or not of IABP between the VT/VG group and the no VT/VF group from the PPCI perspective. The IRA in the right coronary artery (RCA), TIMI 0 grade pre-PPCI, TIMI grade post-PPCI of less than 3, and the need for an IABP were more common in the VT/VF group. Compared with the early-onset group, the postoperative TIMI grade < 3 and ST-segment elevation resolution above 50% were less common in the late-onset group (Table 3).

The early-onset group had a higher proportion in of IRA-RCA, LM lesion, TIMI grade at pre- and post-PPCI, and utilization of IABP than the non-early-onset group, while the late-onset group had a larger portion of patients with TIMI grade post-PPCI of less than 3 and ST-segment elevation resolution of less than 50% (Table 4).

3.3. Pharmacotherapy characteristics in hospital

A comparison of each group's pharmacotherapy features suggested that the VT/VF group used β-blockers, angiotensin converting enzyme inhibitor/angiotensin receptor blockers (ACEI/ARBs), and statins less frequently than the no VT/VF group, while there was no difference between the early-onset group and late-onset group (Table 5). In addition, there was less use of β-blockers in the late-onset group than in the non-late-onset group (52.94% vs 76.1%, *P* = .042) (Table 6).

3.4. Risk assessment model building

Logistic multivariate regression analysis for single factors associated with the VT/VF group was used to detect independent

Table 3

Primary percutaneous coronary intervention characteristics.

Factors	Occurrence situation			Occurrence time		
	No VT/VF group (n = 540)	VT/VF group (n = 67)	*P*	Early onset group (n = 50)	Late onset group (n = 17)	*P*
IRA						
LAD	360 (66.67%)	28 (41.79%)	<.001	18 (36%)	10 (58.82%)	.036
LCX	45 (8.33%)	3 (4.48%)		1 (2%)	2 (11.76%)	
RCA	135 (25%)	36 (53.73%)		31 (62%)	5 (29.41%)	
Multi vessel lesion	436 (80.74%)	55 (82.09%)	.791	41 (82%)	14 (82.35%)	1.000
LM lesion	46 (8.52%)	11 (16.42%)	.037	10 (20%)	1 (5.88%)	0.266
TIMI grade before PPCI						
0	411 (76.11%)	62 (92.54%)	.018	44 (88%)	14 (82.35%)	.799
1	46 (8.52%)	3 (4.48%)		3 (6%)	1 (5.88%)	
2	42 (7.78%)	1 (1.49%)		2 (4%)	1 (5.88%)	
3	41 (7.59%)	1 (1.49%)		1 (2%)	1 (5.88%)	
TIMI grade after PPCI						
0	1 (0.19%)	2 (2.99%)	.002	1 (2%)	1 (5.88%)	<.001
1	8 (1.48%)	3 (4.48%)		0 (0%)	3 (17.65%)	
2	38 (7.04%)	8 (11.94%)		1 (2%)	7 (41.18%)	
3	493 (91.3%)	54 (80.6%)		48 (96%)	6 (36.29%)	
Symptom-balloon time	450 (300–630)	420 (300–630)	.883	420 (300–720)	450 (360–570)	.960
Stent	393 (72.78%)	50 (74.63%)	.748	37 (74%)	13 (76.47%)	.716
IABP	105 (19.44%)	20 (29.85%)	.047	16 (32%)	4 (23.53%)	.510
Emerging III°AVB	101 (18.7%)	11 (16.42%)	.649	7 (14%)	4 (23.53%)	.451
ECG recovery >50%	222 (41.11%)	26 (38.81%)	.717	23 (46%)	3 (17.65%)	.038

ECG = electrocardiogram, IABP = intra aorta balloon pump, III°AVB = three grade atrioventricular block, IRA = infarct related artery, LAD = left anterior descending, LCX = left circumflex, LM = left main, PPCI = primary percutaneous coronary intervention, RCA = right coronary artery, TIMI = thrombolysis in myocardial infarction, VT/VF = ventricular tachycardia/ventricular fibrillation.

factors of VT/VF occurrence, such as age, diabetes, heart rate, ST-segment elevation magnitude, LVEF, and IRA (Table 7).

According to the differences and the condition regression tree analysis results, the continuity variable was divided into the classification variable to build the risk assessment model (Table 8). The model of risk classification was based on the regression tree model with full sample training conditions: Class I $\leq$ 4; 4$\leq$ Class II$\leq$ 5.5; 5.5$\leq$ Class III$\leq$ 6.5; and Class IV$\geq$ 6.5. Table 9 demonstrates VT/VF episodes of different risk levels: the higher the level, the higher the risk (Table 9).

Table 4

Primary percutaneous coronary intervention characteristics for the early-onset group and non-early-onset group, and the late-onset group and non-late-onset group.

Factors	Non-early onset group (n = 557)	Early onset group (n = 50)	*P*	Non-late onset group (n = 590)	Late onset group (n = 17)	*P*
IRA						
LAD	372 (66.79%)	24 (48%)		384 (65.08%)	12 (70.59%)	
LCX	47 (8.44%)	1 (2%)	.001	46 (7.8%)	2 (11.76%)	.525
RCA	138 (24.78%)	25 (50%)		160 (27.12%)	3 (17.65%)	
Multi vessel lesion	450 (80.79%)	41 (82%)	.835	477 (80.85%)	14 (82.35%)	1.000
LM lesion	47 (8.44%)	10 (20%)	0.013	56 (9.49%)	1 (5.88%)	.722
TIMI grade before PPCI						
0	426 (76.48%)	47 (94%)		458 (77.63%)	15 (88.24%)	
1	47 (8.44%)	2 (4%)	.028	48 (8.14%)	1 (5.88%)	.875
2	42 (7.54%)	1 (2%)		43 (7.29%)	0 (0%)	
3	42 (7.54%)	0 (0%)		41 (6.95%)	1 (5.88%)	
TIMI grade after PPCI						
0	2 (0.36%)	1 (2%)		2 (0.34%)	1 (5.88%)	
1	11 (1.97%)	0 (0%)	.117	8 (1.36%)	3 (17.65%)	<.001
2	45 (8.08%)	1 (2%)		39 (6.61%)	7 (41.76%)	
3	499 (89.59%)	48 (96%)		541 (91.69%)	6 (35.29%)	
Symptom-balloon time	450 (300,630)	420 (300,720)	.941	450 (300,630)	450 (360,570)	.876
Stent	406 (72.89%)	37 (74%)	.866	430 (72.88%)	13 (76.47%)	.794
IABP	109 (19.57%)	16 (32%)	.037	121 (20.51%)	4 (23.53%)	.762
Emerging III°AVB	105 (18.85%)	7 (14%)	.397	108 (18.31%)	4 (23.53%)	.751
ECG recovery >50%	225 (40.39%)	23 (46%)	.440	244 (41.36%)	3 (17.65%)	.050

IRA = infarct related artery, LAD = left anterior descending, LCX = left circumflex, RCA = right coronary artery, LM = left main, TIMI = thrombolysis in myocardial infarction, PPCI = primary percutaneous coronary intervention, IABP = intra aorta balloon pump, III°AVB = three grade atrioventricular block, ECG = electrocardiogram. Non-early-onset group means no VT/VF group and late-onset group; non-late-onset group means no VT/VF group and early-onset group.

Table 5

Pharmacotherapy characteristics.

Factors	Occurrence situation			Occurrence time		
	No VT/VF group (n = 540)	VT/VF group (n = 67)	*P*	Early onset group (n = 50)	Late onset group (n = 17)	*P*
Aspirin	520 (96.3%)	62 (92.54%)	.144	46 (92%)	16 (94.12%)	1.000
P_2Y_{12} blocker	529 (97.96%)	65 (97.01%)	.645	49 (98%)	16 (94.12%)	.446
β receptor blocker	414 (76.67%)	44 (65.67%)	.049	32 (64%)	12 (70.59%)	.621
ACEI/ARB	415 (76.85%)	44 (65.67%)	.044	33 (66%)	11 (64.71%)	.923
statin	489 (90.56%)	55 (82.09%)	.032	40 (80%)	15 (88.24%)	.716
LMWH	448 (82.96%)	54 (80.6%)	.629	41 (82%)	13 (76.47%)	.725

ACEI = angiotensin converting enzyme inhibitor, ARB = angiotensin receptor blocker, LMWH = low molecular weight heparin, VT/VF = ventricular tachycardia/ventricular fibrillation.

Table 6

Pharmacotherapy characteristics for the early-onset group and non-early-onset group, and late-onset group and non-late-onset group.

Factors	Non-early onset group (n = 557)	Early onset group (n = 50)	*p*	Non-late onset group (n = 590)	Late onset group (n = 17)	*P*
Aspirin	536 (96.23%)	46 (92%)	.253	566 (95.93%)	16 (94.12%)	1.000
P_2Y_{12} blocker	545 (97.85%)	49 (98%)	1.000	578 (97.97%)	16 (94.12%)	.311
β receptor blocker	423 (75.94%)	35 (70%)	.350	449 (76.1%)	9 (52.94%)	.042
ACEI/ARB	426 (76.48%)	33 (66%)	.098	448 (75.93%)	11 (64.71%)	.388
statin	502 (90.13%)	42 (84%)	.174	531 (90%)	13 (76.47%)	.089
LWMH	461 (82.76%)	41 (82%)	.891	489 (82.88%)	13 (76.47%)	.513

ACEI = angiotensin converting enzyme inhibitor, ARB = angiotensin receptor blocker, LMWH = low molecular weight heparin. Non-early-onset group means no VT/VF group and late-onset group; non-late-onset group means no VT/VF group and early-onset group.

The risk grading score and the total sample training were used as predictor variables; 60% of samples were randomly sampled as training sets and 40% of samples were used as test sets for the cross-verification of model prediction. AUC was 0.9 ($P < .001$) when a specific score was a predictor variable and 0.88 ($P < .001$) when the risk class grade for full sample training was a predictor variable (Figs. 2 and 3).

4. Discussion

The study investigated the incidence, episode timing, and risk factors of VT/VF in PPCI patients due to STEMI and built the 1st risk assessment model for predicting the possibility of a VT/VF episode. The incidence of VT/VF in this study was 11%, with approximately 2/3 of cases occurring before the patients were out of the catheter lab, which could be defined as early-onset

Table 7

Logistic regression analysis of risk factors.

Factors	OR	95% confidence interval
Age	1.04	1.001, 1.082
Diabetes	4.804	1.901, 12.654
Heart rate	1.037	1.017, 1.06
Top ST segment elevation (mv)	162.367	8.313, 4075.019
Sum ST segment elevation (mv)	31.705	4.072, 102.933
Serum K^+	0.621	0.394, 0.929
LVEF	0.55	0.456, 0.642
IRA was RCA	1.549	0.997, 2.425
LM lesion	3.624	1.187, 10.95
Killip Class > I	3.255	1.421, 7.849
TIMI grade 0 before PPCI	7.449	2.09, 37.023

IRA = infarct related artery, LM = left main, LVEF = left ventricular ejection fraction, PPCI = primary percutaneous coronary intervention, RCA = right coronary artery, TIMI = thrombolysis in myocardial infarction.

Table 8

Risk assessment score for predicting VT/VF.

Factors	Classification	Risk grade	Score
Diabetes	No	Low	0
	Yes	High	1
TIMI grade 0 before PPCI	No	Low	0
	Yes	High	1
Age	<65 years old	Low	0
	≥65 years old	High	1
Heart rate	≤75 bpm	Low	0
	76–96 bpm	Middle	0.5
	≥97 bpm	High	1
Sum ST segment elevation (mv)	≤1mv	Low	0
	>1mv	High	1
Serum K^+	>3.2mmol/L	Low	0
	≤3.2mmol/L	High	1
Top ST segment elevation (mv)	≤0.2mv	Low	0
	0.3–0.4mv	Middle	0.5
	≥0.5mv	High	1
LVEF	≥42%	Low	0
	<42%	High	1

LVEF = left ventricular ejection fraction, PPCI = primary percutaneous coronary intervention, TIMI = thrombolysis in myocardial infarction, VT/VF = ventricular tachycardia/ventricular fibrillation.

Table 9

VT/VF occurrence situation of different risk grade.

Risk grade	Cases	VT/VF cases	Percentage
I	401	7	1.75%
II	157	30	19.11%
III	31	15	48.39%
IV	18	15	83.33%
Sum	607	67	11.04%

VT/VF = ventricular tachycardia/ventricular fibrillation.

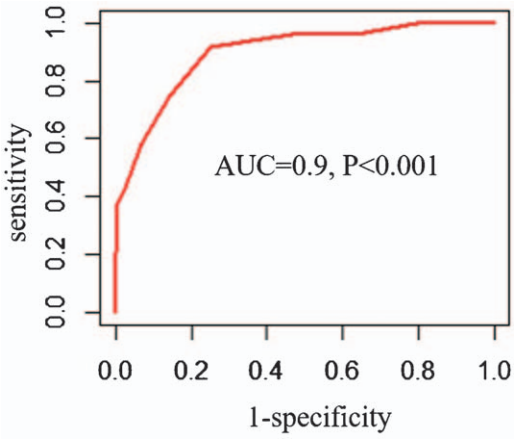

Figure 2. ROC curve when the specific score was the predictor variable. ROC = receiver operating characteristic.

VT/VF.[12] In our study, 91% of patients experienced VT/VF within 48 h, which conforms with other similar studies.[8] Compared with the previous studies of thrombolytic age, the incidence of VT/VF in this study was lower than that of thrombolytic therapy.[4–7] Although the effect of thrombolysis and PCI on VT/VF has not been confirmed by a large study, it is not difficult to understand the differences considering the superiority of percutaneous coronary intervention (PCI) compared with thrombolysis in rescuing near-death myocardium and the predictive significance of the infarct area to VT/VF.[18,19]

4.1. Incidence and timing of VT/VF occurrence

The incidence of VT/VF in this study was 11%, which is a little higher than noted in the APEX-AMI study.[16] However, the previous investigations were not exactly the same, such as the PAMI[8] study, which excluded renal dysfunction and cardiogenic shock, and the APEX-AMI[16] study, which did not enroll inferior MI. We found a majority of VT/VF incidences happened within 48 h after an artery event, which conformed with other studies. The reason for this timing is not very clear, but it may be associated with electric instability and altered ION channel function. The patients in early onset group tend to be "sicker", while the late onset group usually are related to an incomplete reperfusion, a finding that emphasizes the importance of a timely and effective reperfusion.

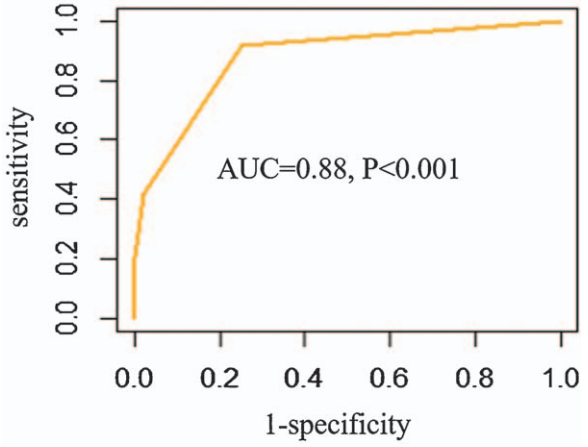

Figure 3. ROC curve when the risk class grade for full sample training was the predictor variable. ROC = receiver operating characteristic.

4.2. Clinical characteristics

This study identified risk factors of VT/VF from clinical characteristics, PPCI data, and pharmacotherapy usage. We found that the VT/VF group had more patients who were elderly and smoked and had pre-MI, diabetes, a faster heart rate, lower blood pressure, worse heart function, low creatinine clearance, low LVEF, and higher CK-MB. The VT/VF group also manifested a high proportion of atrial flutter/atrial fibrillation and top ST-segment elevation magnitude of more than 0.3 mv coupled with sum ST-segment elevation magnitude of more than 1.5 mv. Age, MI history, diabetes, and smoking are high-risk factors of SCD or ventricular arrhythmia,[20] while heart function after MI, CK-MB level, and LVEF can reflect the area of infarction. This shows that the patient's basic health status as well as the ischemic or infarction range may affect the heart's cardiac electrical activity, followed by inducing VT/VF.

Electrolyte disorders, such as low blood potassium and VT/VF, have been widely accepted. In this study, serum potassium of the VT/VF group was lower than the no VT/VF group, which agreed with earlier studies.[14,21] It is noteworthy that the serum potassium of both of the groups was still within the normal range, which would have been associated with the sympathetic nervous system activating the renin-angiotensin-aldosterone-system (RAAS) in the acute period instead of the potassium affecting the process of VT/VF onset. Heart rate is an important hemodynamic parameter, which not only determines oxygen demand, but also affects the blood supply of the coronary arteries. When the heart rate increases rapidly, the myocardial oxygen consumption increases, which can aggravate the ischemic injury and increase the likelihood of VT/VF occurrence.[22] Electrocardiogram (ECG) reveals many predictors of VT/VF, such as J wave, QRS wide, Tp-e, and Tp-e/QT ratio.[23] We compared the ST-segment elevation condition between the groups, and the results suggested that the VT/VF group's ST-segment elevation was higher than the no VT/VF group, which is similar to Demidova's study.[14] The significance of ST-segment elevation is mainly that it could reflect the infarct area in inferior leads, while the number of anterior leads in ST-segment elevation may be more meaningful.[24,25]

The peak of CK-MB was positively correlated with the area of MI: there was a bigger infarct area and worse left ventricular function corresponded to a high CK-MB level.[26] During MI, acidosis rendered by anaerobic glycolysis facilitated Na^+ flow in through the Na^+-H^+ exchanger; free radicals mediate lipid peroxidation, which damaged the cell membrane and decreased Na^+-K^+-ATP enzyme activity, resulting in intracellular Na^+ concentration increase, then the Na^+-Ca^{2+} exchanger in reverse transport mode caused intracellular Ca^{2+} overload, bring about resting potential decline, maximum resting potential, and the threshold potential was approached, automatic rhythmicity was raised, and the likelihood of ventricular arrhythmia is higher.[27] Inferior wall MI, particularly combined with right ventricle infarction, has a greater possibility for the patient to suffer from VT/VF, which may be associated with there being a rich Ito channel in the membrane of the right ventricle.[28] When there is an inferior wall ischemic injury, most of the Ito channels are quickly innactivated, whereas ICa channels are activated,

extending the phase 2 plateau and thus the action potential duration. The voltage gradients between the different myocardial areas induced by such a channel dysfunction give rise to a phase 2 re-entry which is deemed to be the main arrhythmia mechanism..[29] However, there was no difference in the comparison of right ventricular infarction in this study, which may be related to the subjects with ECG in this study who sometimes failed to execute the right ventricular lead in time, capturing ECG changes of right ventricular leads, and underestimating the number of right ventricular infarction patients. In recent years, the potential relationship between atrial fibrillation and malignant arrhythmia has been established, but the specific mechanism is not clear.[30,31] The results showed that there were more patients with atrial fibrillation/atrial flutter in the late-onset VT/VF group, but no difference was found between the VT/VF group and the no VT/VF group, which was in disagreement with previous studies that showed that atrial fibrillation correlated to VF before PPCI;[10] this may be related to a smaller sample size and insufficient patient's arrhythmia data pre-admission. As for Killip class, LVEF could directly reflect the heart function, high Killip class, and low LVEF, suggesting a large infarction area, ischemic condition, and a greater possibility of having VT/VF.

4.3. PPCI characteristics

The TIMI grade 0 before PPCI has a little higher incidence rate of VT/VF than those that have partial flow (TIMI grade ≥ 1), which is consistent with previous studies, suggesting that TIMI 0 grade flow means a more serious ischemic injury. There are some studies that have suggested that the time from symptom onset to balloon $<$ 180–360 min is associated with VT/VF.[8,14] The APEX-AMI study[16] also noted that the ischemia time of the VT/VF group was shorter than in the no VT/VF group. Animal experiments demonstrated that the short coronary artery occlusion time is associated with reperfusion arrhythmia and when the occlusion time is beyond 3 h, it will not increase reperfusion arrhythmia but the incidence of ischemia-induced arrhythmia will be raised.[32] Our data were not consistent with these studies; this may be due to insufficient medical records of the accurate balloon time instead of by processing the ending time, which prolonged the total ischemia time. Thus, the results of the study do not contradict the previous conclusions concerning the correlation between short ischemia time and VT/VF occurrence. The mechanism of arrhythmias following a short ischemia time may mainly be based on an electrical instability due to the rapid time-shift from ischemia to reperfusion because the electro activity may transformation frequently in a relatively short time.

The IRA also has a relationship with malignant arrhythmia. It can be seen that an RCA event has the highest VT/VF incidence. The mechanism of this phenomenon is mainly related to the following aspects: First, when the RCA is opened, the excited vagus nerve could compensate for the activated sympathetic nerve.[33] Second, in almost 60% of cases, the sinus node artery arises from the RCA, so its pacemaker function might be impaired after the vessel's occlusion, making easier for ectopic pacemakers in the ventricular muscle to get activated in a highly sympathetic driven condition such as the myocardial infarction. Third, the RCA occlusion often causes an inferior wall and right ventricular infarction, making more likely to present with ventricular arrhythmias. We also found that the VT/VF group has more patients with LM lesions, but multi-vessel lesions are similar between each of the groups. The LM lesions mean more serious MI and a larger area at risk (AAR) may be an appropriate reason.

Reperfusion efficiency also influences cardiac electro activity. The CLARITY-TIMI 28 study[34] enrolled 3491 STEMI patients to investigate the relationship between impaired myocardial perfusion (TIMI grade 0–2) and VT/VF after fibrinolytic therapy. The results even suggested LVEF $\geq$ 30% or the coronary artery flow rehabilitation impaired myocardial perfusion grade remained associated with an increased incidence of VT/VF. The ST-segment recovery $>$ 50% suggested frequent revascularization. We found that the degree of ST-segment recovery was related to post-procedure VT/VF, and the late-onset ST-segment was more common in recovery in less than 50% of the groups. The late-onset group has a high proportion of TIMI grade $<$ 3 after PPCI, ST-segment recovery of less than 50%, and a low proportion of TIMI grade 3 after PPCI, and ST-segment recovery of more than 50%, suggesting that the reperfusion effect is associated with postoperative VT/VF incidence.

4.4. Pharmacotherapy characteristics

The METOCARD-CNIC study[35] enrolled 270 anterior wall MI cases that were below Killip II; patients were given metoprolol or placebo at random before reperfusion and the infarction size was compared. The results showed that the intravenous infusion of metoprolol before reperfusion could reduce the infarct size and improve LVEF. However, the Early-BAMI study[36] researched 683 STEMI $<$ 12 h, Killip I–II patients who randomly received intravenous metoprolol or placebo, and the results suggested that the infarct size made no difference between the 2 groups, but metoprolol could reduce malignant arrhythmia. It can be seen that although β-receptor blockers have different results in reducing the area impacted by MI, the reduction of VT/VF has been confirmed in many aspects. In the treatment of ventricular arrhythmia in acute myocardial infarction, beta receptor blocker is recommended.[37]

The ACEI/ARBs and statins could reduce the ischemia burden, ameliorate ventricular remodeling, stable plaque, inhibit inflammation, and have an antiarrhythmic effect, and they have been widely accepted in the prevention of ventricular arrhythmia in patients with MI.[38] Our results also support the use of beta blockers, ACEI/ARBs, and statins, which were used less in the VT/VF group than the no VT/VF group; this suggests that beta blockers, ACEI/ARBs, and statins should be used as early as possible to reduce the incidence of VT/VF and significantly improve the patient's prognosis.

4.5. Risk assessment model

The data mentioned above suggests that there are many risk factors related to VT/VF from baseline clinical characteristics to reperfusion therapy and drug treatments, such as blood pressure, heart function, and reperfusion effect. This suggests we should prevent VT/VF from occurring in multiple ways and use β blockers as early as possible to reduce the onset of this type of malignant arrhythmia.

Multivariate regression analysis showed that there were many factors that were independently related to VT/VF occurrence, such as age, diabetes, heart rate, ST-segment elevation magnitude, LVEF, and IRA. We further constructed a risk assessment model and obtained the scoring system for VT/VF risk, from low to high with 4 grades, using the statistical method: the higher the level, the higher the risk of occurrence of VT/VF. Then, the

predictive value was evaluated by cross-validation with the risk classification as the predictor variable based on the specific score and full sample training (AUC was 0.9 or 0.88 respectively, $P < .001$). It can be seen that the possibility of VT/VF occurrence could be specifically predicted using the risk assessment model and scoring system, but the validation method is purely statistical and requires subsequent trials with larger samples and more accurate data collection to demonstrate its accuracy.

4.6. Study limitation

The main limitation of this study is that it is a single-center retrospective study, and the data were not comprehensive. In addition, we only investigated patients who underwent PPCI; patients who had not received PPCI were not included in the study. We are conducting further research through a multicenter prospective study. We also call for further studies to build risk assessment system to predict VT/VF of STEMI patients.

5. Conclusion

Incidence of VT/VF in STEMI patients undergoing PPCI is 11% and it occurs more frequently from the time that symptoms begin to before the end of PPCI, which, in most cases, occurs within 48 h of the event. Our risk assessment model could predict the possible occurrence of VT/VF.

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Author contributions

Conceptualization: Jiabing Huang, Shenghua Zhou.
Data curation: Xiaofan Peng.
Supervision: Zhenfei Fang, Xinqun Hu.
Writing – original draft: Jiabing Huang.
Writing – review & editing: Jiabing Huang.

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