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The Quantitative Measurement of ST-Segment Deviation and Pathological Q Wave for Predicting in-Hospital Mortality in Patient with ST-Elevation Myocardial Infarction

Muhammad Surya Tiyantara[1], Yustye[2], Djoen Herdianto[3], Swandari Paramita[4]

Abstract

Background: The appearance of ST-segment elevation (STE) and pathological Q wave were signs of worse myocardial damage and function, the quantitative measurement of the waves have a potential prognosis role. This study assesses the performance of the quantitative measurement of the waves in predicting in-hospital mortality and compares it with the Global Registry of Acute Coronary Events (GRACE) score as the standard recommended risk score.

Methods: This was a cross-sectional study included patients with ST-elevation myocardial infarction (STEMI) that hospitalized in Abdul Wahab Sjahranie General Hospital Samarinda during January to December 2016. Standard 12-lead electrocardiograms (ECG) were assessed at patient admission as well as other data for GRACE score. The subjects were grouped into non-survivor and survivor group based on hospitalization survival state, and six quantitative ECG characteristics performance will be assessed. The performances were assessed using receiver operating characteristics (ROC) curve and area under the curve (AUC).

Results: There were 57 subjects consisting of 9 non-survivor subjects. The AUC of the four ECG characteristics highest STE amplitude, deepest Q amplitude, total Q amplitude, and total STE amplitude did not significantly different with GRACE score ($p>0.05$). Highest STE amplitude has the best performance than the other ECG characteristics (AUC=0.81, 95% CI:0.65 to 0.97), and cut off point 4.5mm provides 56% sensitivity and 94% specificity.

Conclusion: The quantitative measurement of ST-segment deviation and pathological Q wave have the prognosis role for predicting in-hospital mortality.

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Keywords: pathological Q wave, ST-segment deviation, ST-elevation myocardial infarction, prognosis

[1]Faculty of Medicine, Mulawarman University, Samarinda, Indonesia
[2]General Practitioner, Abdul Wahab Sjahranie Hospital, Samarinda, Indonesia
[3]department of Cardiology and Vascular Medicine, Abdul Wahab Sjahranie Hospital, Samarinda, Indonesia
[4]Laboratory of Public Health, Faculty of Medicine, Mulawarman University, Samarinda, Indonesia

Correspondence:
Muhammad Surya Tiyantara, MD
Faculty of Medicine Mulawarman University, Samarinda, Indonesia
E-mail: suryatiyantara@gmail.com

Introduction

ST-elevation myocardial infarction (STEMI) is one of the acute coronary syndrome (ACS) spectrum identified by the presence of the myocardial ischemia symptom, and persistent ST-segment elevation (STE).[1] The mortality of this ACS type is higher than the other type.[2,3] Most of this type will be evolved into Q wave myocardial infarction by the presence of pathological Q wave.[2,4]

Ischemic risk assessment is recommended for a patient with acute myocardial infarction (AMI), not only

for prognosis assessment but also help to determine the treatment strategy.[1,5] Global Registry of Acute Coronary Events (GRACE) score is one of risk stratification score that can estimate mortality in hospital, at 6 months, 1 year, and 3 years, European Society of Cardiology (ESC) recommends the use of this risk score for the patient with AMI, include STEMI patient.[1,5]

The appearance of STE and pathological Q wave were signs of worse myocardial damage and function. On electrophysiological perspective, STE is a sign of the electrical shift of ST-segment because of abnormality of K+ channel result from transmural myocardial ischemia, while the pathological Q waves are signs of the electrical window, an area that severely electrically impaired, ranging from hibernating, stunning, and necrosis of myocardium.[6-9]

Our hypotheses are the characteristics and magnitude of the STE and pathological Q wave have prognostic a role. In this study, we determine the quantitative measurement of STE and pathological Q wave and its performance in predicting the in-hospital mortality and compare it with GRACE score as the standard risk score for STEMI.

Methods

The subjects were STEMI patients who were treated in period January to December 2016 in the Abdul Wahab Sjahranie General Hospital in Samarinda, East Kalimantan. ESC criteria for STEMI were used to define the STEMI diagnosis. STEMI was defined by the presence of symptom consistent with myocardial ischemia (eg. persistent chest pain) and ECG sign that meets the STEMI criteria, ST-segment elevation (measured using J-point, and two consecutive PR interval as a baseline), at two or more contiguous leads with elevation ≥2.5mm in men <40 years, ≥2.0mm in men >40 years, or ≥1.5mm in the woman in leads V_2-V_3 and/or ≥1mm in other leads. Standard 12-lead ECG calibration 10mm/mV and 25mm/s were used in this study. Standard treatment such as thrombolytic, anticoagulant, antiplatelet, and other medications are used as indicated.

The subjects were grouped into a non-survivor and survivor group based on the survival state during hospitalization. The ECG characteristics and GRACE score are compared between the group, and the performance of these variables to predict mortality will also be analyzed. Exclusion criteria are subject with a history of AMI, poor quality ECG and/or with QRS confounders (e.g. left bundle branch block).

There are six ECG characteristics included as variables in this study. The definitions of the variables are shown in table 1. Pathological Q waves are defined as Q-wave with a duration of ≥40 ms and/or a depth ≥25% of the R-wave in the same lead, that present in two or more contiguous leads. The ECG characteristics were measured by a physician manually based on the ECG criteria. GRACE score is obtained by calculating the characteristics of the subject that include the age, heart rate, systolic blood pressure, creatinine level, Killip class, cardiac arrest at admission, ST-segment deviation, and cardiac enzymes. All of the ECG characteristics and data to determine the GRACE score are obtained from the medical record at the time of patient admission.

Kolmogorov-Smirnov test was used to asses the normality distribution of the data. Variables with continuous type were presented as mean and standard deviations for data that normally distributed, or median (25th percentile, 75th percentile) for data that not normally distributed. Variables with categorical type were presented as an absolute number with a percentage. Independent T-test or Mann-Whitney test was used to compare the continuous variables that depend on the distribution of the data, while the Chi-Square test or Fisher exact test was used to compare noncontinuous variables. The performance of the diagnostic value of ECG characteristics and GRACE score to predict in-hospital mortality were assessed using receiver operating characteristic (ROC) curve and area under the curve (AUC). Statistical significance is obtained when $P<0.05$. All analyses were done using IBM SPSS statistics version 19, except for comparison (c-statistic) of the ROC curve and AUC (DeLong method) that using Medcalc statistical software version 18.6.

Results

A total of 57 subjects were included in this study. There were 9 non-survivor subjects during hospitalization, they had higher Killip class and troponin-T value on admission than survivor subjects. The characteristics of the subject are shown in table 2.

ST-segment deviation

Table 3 shows the result of Mann-Whitney test of the ST-segment deviation characteristics. The maximum value of highest STE amplitude of the non-survivor and survivor group were 9mm and 6mm respectively, while maximum number involved lead with STE and maximum total STE amplitude in the non-survivor group were 8 leads and 28mm, and 6 leads and 27mm in the survivor group.

Pathological Q wave

The non-survivor group had the maximum value of deepest Q amplitude and the maximum value of number involved lead 4mm and 5 leads, respectively, as well as survivor group. The maximum value of the total Q amplitude in the non-survivor group was 13mm, and 10mm in the survivor group. The results of the Mann-Whitney test of the pathological Q wave characteristics are shown in table 3.

GRACE score

The median of GRACE score in this study was 138. The non-survivor group had higher GRACE score than the survivor group (207(150, 227) and 133(113, 150), p=0.001) using the Mann-Whitney test. The highest and lowest GRACE score in the non-survivor group were 257 and 155, and in the survivor group 200 and 89, respectively.

ECG characteristics and GRACE score performance

The performance of the ECG characteristics and GRACE score in predicting the in-hospital mortality are shown in figure 1. Highest STE amplitude had the best performance than the other ECG characteristics (AUC=0.81, 95% CI:0.65 to 0.97), cut off point of highest STE amplitude 3.5mm had 78% sensitivity and 65% specificity, and cut off point 4.5mm had 56% sensitivity and 94% specificity. Highest STE amplitude, deepest Q amplitude, total Q amplitude, and total STE amplitude were not significantly different with GRACE score in predicting in-hospital mortality using DeLong method for AUC and standard error comparison (table4).

Table 1. Operational definitions of the Electrocardiogram (ECG) characteristics

	Definition
Number lead with STE	The number of lead in standard 12-lead ECG that contains the ST-segment elevation.
Highest STE amplitude	The highest/maximum deviation of the ST-segment elevation in standard 12-lead ECG. The degree of elevation is measured at J-point of the highest ST-elevation and presented as mm.
Total STE amplitude	The sum of all ST-segment elevation amplitude in all lead that contains ST-segment elevation in standard 12-lead ECG. The degree of elevation is measured at J-point in all lead that contains ST-segment elevation and presented as mm.
Number lead with Q	The number of lead in standard 12-lead ECG that contains the pathological Q wave.
Deepest Q amplitude	The deepest/maximum amplitude of the Q wave in standard 12-lead ECG. The degree of amplitude is presented as mm.
Total Q amplitude	The sum of all Q wave amplitude in all lead that contains pathological Q wave in standard 12-lead ECG. The degree of amplitude is presented as mm.

STE=ST-segment elevation

Discussion

The ECG characteristics have the prognostic information in STEMI patients and help identification of group who will have benefit with more aggressive intervention.[10,11] In this study we found that ECG characteristics had comparable performance to GRACE score. The performance of the four ECG characteristics highest STE amplitude, deepest Q amplitude, total Q amplitude, and total STE amplitude had similar performance with GRACE score in predicting the in-hospital mortality. The highest STE amplitude had the best performance than the other ECG characteristics. Different from the previous studies, in this study, we focused on the quantitative measurement of the wave, that is using a numeric scale for the amplitude of the waves, and we compare the performance of the multiple

ECG parameter (ST-deviation and pathological Q wave characteristics), also comparing with the standard ischemic risk score, GRACE score.

During the progression of the STEMI, there are changes in the characteristic of ECG, the high-grade ischemia (grade 3 from three classifications of the ischemia) has STE with distortion of the QRS terminal (no S wave in leads with usual Rs configuration or J point/R wave ratio ≥ 0.5 in leads with usual qR configuration) reflecting the higher STE the higher grade of ischemia.[12] The terminal QRS distortion in high-grade ischemia reflects the prolongation of Purkinje fibers in the ischemic region and reflects the worse ischemia and prognosis.[12]

A study from De Luca et al. using residual STE after primary percutaneous coronary intervention (PCI) shows that cumulative ST-segment deviation was an independent predictor of 1-year mortality (RR=1.31, 95% CI: 1.06 to 1.63, p=0.014).[13] Cumulative STE has better performance (AUC=0.733) than STE resolution (AUC=0.636) or ST-segment deviation resolution (AUC=0.660) in predicting 1-year mortality.[13] In another study using ST-segment deviation in the ECG lead that contains maximum STE after thrombolysis, the performances were AUC=0.761 for 90 minutes after thrombolysis, and AUC=0.755 after 180 minutes after thrombolysis for predicting 30-day mortality, these performances were better than the performance of sum of STE resolution and STE resolution in only the one lead showing the maximal deviation.[14]

The maximum STE also has better performance than the sum of STE resolution for predicting 180-day mortality (AUC 0.680 vs 0.622).[15] Our study using the ECG that immediately measured when the patient on admission, the maximum magnitude of the STE also shows the best performance than the sum/total STE amplitude, and with better performance than the previous studies, and comparable with GRACE score.

Maximum residual STE magnitude provides prognostic information about another adverse event such as heart failure and shock but still better predicting the 90-day mortality (AUC=0.802 vs AUC=0.832).[16] A study shows that a higher magnitude of STE associated with more total occlusion, less collateral circulation, lower left ventricular ejection fraction (LVEF) and higher infarct size.[17] These parameters are known as the predictor of prognosis in patient with AMI.

Table 2. Subject characteristics

Characteristics	Non-survivor (n=9)	Survivor (n=48)
Age, years*	57±9	56±10
Men, n(%)	7(78)	41(85)
History, n(%)		
Diabetes mellitus	5(55)	13(27)
Hypertension	4(44)	20(42)
Heart rate, bpm†	102(71, 117)	80(66, 89)
Systolic blood pressure, mmHg†	120(80, 130)	130(120, 140)
Diastolic blood pressure, mmHg†	70(U, 80)	80(76, 90)
Respiration rate, bpm†	26(24, 30)	22(20, 26)
Killip class†	3(1, 4)	1(1, 1)
Ureum, mg/dl†	38(31, 42)	35(28, 45)
Creatinine, mg/dl†	1.2(0.9, 1.5)	1(0.8, 1.4)
Troponin-T on admission, ng/L †	882(298, 1950)	138(75,1198)

U=Undetected; *mean±standard deviation; †median(25th percentile, 75th percentile)

Prognostic role of the appearance pathological Q wave was known since years ago, but quantitative measurement and its relation to the degree of adverse event and cardiac performance still challenging. The sum of pathological amplitude is correlated with infarct size and cardiac function in the animal model.[18] The appearance of the wave also reflects the worst ventricular function in the human subject.[19] Another study shows that state of hibernation, stunning and/or necrosis are the conditions that responsible in the formation of the wave.[6-9] A study found that the width of the baseline Q-wave in STEMI has a prognostic role in predicting 90-day mortality, congestive heart failure, or cardiogenic shock, the prognosis was worsened as the width increased.[11]

Another study shows that subjects with pathological Q wave on presentation were more frequently male, had higher heart rates, more advanced Killip class and had a longer time from the onset of symptoms to PCI. Subject with pathological Q wave had higher 1-year all-cause mortality than subjects without the wave (baseline Q waves: 4.9%; no baseline Q waves: 2.8%; hazard ratio=1.78, 95% CI:1.29 to 2.45, p<0.001).[20] The presence of Q waves on baseline ECG was associated with higher 90-day mortality in men (hazard ratio=1.7,

Table 3. Electrocardiogram characteristics between the non-survivor and survivor group

	Non-survivor (n=9)	Survivor (n=48)	p-value
Number lead with STE, lead	3(3, 5)	4(3, 4)	0.925
Highest STE amplitude, mm	5(3, 5)	3(3, 4)	0.002
Total STE amplitude, mm	13(8, 20)	10(7, 12)	0.030
Number lead with Q, lead	3(1, 3)	2(0, 3)	0.044
Deepest Q amplitude, mm	4(1, 4)	2(0, 2)	0.003
Total Q amplitude, mm	9(3, 10)	4(0, 6)	0.005

STE=ST-segment elevation; all characteristics are presented as median(25th percentile, 75th percentile) and compared using Mann-Whitney test

95% CI:1.0 to 2.7) and women (hazard ratio=2.3, 95% CI:1.2 to 4.2), the pathological Q wave was a better marker of risk than symptom onset to PCI.[21]

GRACE score is a risk stratification score that has good performance for prognosis stratification for ACS patient, ESC recommends the use of this score for ACS include STEMI patients.1,5 A study from Myocardial Infarction National Audit Project (MINAP) database shows that the performances of GRACE score are AUC=0.80 (95% CI:0.80 to 0.81) for in-hospital mortality, and AUC=0.80 (95% CI:0.79 to 0.80) for 6-month mortality.[22] In relation to hospital death, one study shows the performance of the GRACE score was AUC=0.87 (95% CI:0.75 to 0.99).[23] GRACE score performance in another study was similar to our study with AUC=0.83 (95% CI:0.79 to 0.87), the endpoints of the study were cardiac death, AMI and unstable angina within 30-day.[24]

GRACE score has several components to measure, include the ST-deviation. The score only has dichotomous value for the ST-deviation not the quantitative measurement of deviation. This study found that the degree of deviation has comparable performance. Highest STE amplitude has the best performance than the other ECG characteristics and comparable with GRACE score, with high specificity in cut off point 4.5mm whom acceptable for "rule in" criteria for clinical practice.

Limitations

For the purpose of better generalization to the population, we use only "immediate ECG measurement on admission" and not restricting with symptom onset, delay of treatment may confound the prognosis of the patient, but the variability in the onset may be the one that responsible in the variability of ECG characteristics. Also, this study was single-center study and the subjects were relatively small, the variability of the center protocol may affect the patient prognosis.

Conclusions

In conclusion, quantitative ECG characteristics have comparable prognostic value with GRACE score and good performance as mortality predictor, especially highest STE amplitude. Quantitative measurement of the waves may add the performance of the novel risk stratification scoring. Future study will be needed to including the quantitative measurement of ECG to prognosis scoring system.

Ethical Clearance

Ethical clearance number for this research is: 154 KEPK-AWS/IX/2018

Conflict of Interest

None

Publication Agreement

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List of Abbreviations

ACS=acute coronary syndrome
AMI=acute myocardial infarction

AUC=area under the curve
CI=confidence interval
ECG=electrocardiogram
ESC=European Society of Cardiology
GRACE=Global Registry of Acute Coronary Events
LVEF=left ventricular ejection fraction
MINAP=Myocardial Infarction National Audit Project
PCI=percutaneous coronary intervention
ROC=receiver operating characteristic
STE=ST-segment elevation
STEMI=ST-elevation myocardial infarction

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