

REVIEW MANUSCRIPT

Myocardial Infarction Analysis Based on ST-Segment Elevation and Scores

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Abstract

This review focuses on the major issues regarding ST segment abnormalities during acute myocardial infarction (AMI), which may be estimated from electrocardiogram (ECG) tests. Diagnosis, prognosis, treatment and the drawbacks associated to this methodology are discussed. Finally, the major AMI quantitative assessments based on ECG deviations are compared and discussed in the context of telemedicine systems.

Keywords: Electrocardiography; Myocardial infarction; Telemedicine

Introduction

In 2004, cardiovascular diseases accounted for 10.49% of hospitalizations and 285,543 deaths in Brazil, of which 65,482 were caused by acute myocardial infarction (AMI), which represents 22.93% of deaths caused by cardiovascular diseases and 6.39% of the total deaths¹.

Patients with AMI may present typical ischemic symptoms (precordial pain or chest pain) or atypical symptoms^{2,3}. The pain may spread through the upper limbs, jaw, neck, back or abdomen^{4,5}. Among the atypical ischemic symptoms, the main findings are: dyspnea (49.3%), diaphoresis (26.2%), nausea or vomit (24.3%) and presyncope or syncope (19.1%)^{2,3}. Diagnosis of patients with atypical symptoms may be difficult. In 23.8% of the cases, inaccurate diagnosis is given². Moreover, due to the delay in reaching the health services, there are greater chances of mortality under these circumstances².

According to the current recommendations for the diagnosis of AMI, the patient has to present increased

levels of biochemical markers associated with cardiac muscle necrosis and at least one of the following conditions: ischemic symptoms (generally identified by precordial pain) or abnormal ECG findings^{4,5}. Among these conditions, increased levels of biochemical markers is the most important one and is considered necessary for the diagnosis of AMI^{3,4}.

New methods of electronic signal acquisition and recording have allowed the scanning of ECG tests during acquisition or from printed analogical ECG tests^{6,7}. It is also possible to transmit the ECG signal to remote areas to be analyzed by specialists, leading to a more efficient care in cases of chest pain⁸. Both situations have allowed the establishment of telemedicine centers for data interchange and case discussion among specialists in the field, greater accessibility to health records and the feasibility of performing digital analysis. The availability of these resources made it possible to implement automatic methods for a better understanding of the AMI physiopathology and its clinical evolution, helping and assessing the therapeutic procedures⁹⁻¹¹.

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The purpose of this article is to review the literature related to abnormal ECG findings caused by AMI, especially focusing on ST segment abnormalities, scores and the methods that increase the clinical value of the ECG, considering the technological improvements in the field.

ECG in AMI

AMI can be classified according to the presence of ST-segment elevation following AMI (STEMI) or non-ST-segment elevation following AMI (NSTEMI) in ECG. STEMI is the most severe event among the ischemic syndromes, affecting, in general, the entire wall of the heart¹².

The ECG remains the main tool for early diagnosis of AMI and the main avenue for choosing the treatment to be adopted³, due to the long time delay required after myocardial necrosis for the detection of biochemical markers elevation in the plasma³, due to the presence² or even the absence of atypical symptoms^{2,13}. Because it is simple to handle and inexpensive, the ECG is the test most conducted in the first hours after the patient arrival and during the monitoring of the AMI clinical evolution.

When a patient presents STEMI, there is a well-known evolution of the ECG signal⁵. Some minutes after arterial occlusion, the J point rises and the T-wave increases in amplitude and develops spikes; immediately after that, there is an elevation of the ST segment in the leads associated with AMI, and ST segment depression in the opposite leads, making up a mirrored image or reciprocal effect¹⁴. Abnormal Q waves usually appear on the first day of AMI. Later, the ST segment returns to its original amplitude and there is an inversion of the T wave, which may take hours or even days after the first event.

ST-segment in STEMI

The ST segment starts from the J point, where the QRS-complex ends, presenting its concavity upwards in normal conditions. The offset of the ST segment is not well defined, since it is difficult to be distinguished from the onset of the T wave¹⁴. When there is an ST-segment elevation in AMI, several criteria can be adopted to perform the analysis. The amplitude of J, J+20 ms, J+40 ms, J+60 ms or J+80 ms points can be observed.

Under normal conditions, the ST segment is isoelectric. Therefore, for the ST-segment elevation to be measured, it is necessary to determine a baseline. The baseline is determined by drawing a straight line between two

points of the ECG. The baseline varies from study to study. The PR segment^{15,16}, the TP segment^{15,17-22} and the PQ segment²³ are used.

Once the baseline is determined, the distance from the baseline to the end of complex QRS must be measured to determine the J point amplitude. The same is done for the points located 20 ms, 40 ms, 60 ms and 80 ms from the J point, as required in the study.

ST-segment elevation can be used to evaluate the clinical evolution of the infarcted patient. Its main applications, discussed in the literature, are described below:

Assessment of patient prognosis –

Patients with greater ST-segment elevation during the first 24 hours after onset of symptoms are more likely to present atrial fibrillation, first- and second-degree atrioventricular block, ventricular extrasystole, ventricular tachycardia, ventricular fibrillation, cardiogenic shock and death¹⁷. These pathologies are more correlated to the ST-segment elevation amplitude than to the number of leads presenting this change.

Schröder et al.²⁴ studied two ECG scans per patient, wherein the first one was taken six hours after the onset of AMI symptoms, and the second one was taken from 2-4 hours after thrombolytic treatment. Reduction of ST-segment elevation to its original amplitude was noticed and it was found that when that reduction occurs within 3 hours after thrombolytic treatment, it is the best variable to predict early death. Patients with a smaller ST segment reduction presented more incidence of tachyarrhythmia, cardiogenic shock and heart failure.

Recovery of myocardial function –

Lancellotti et al.²⁵ found a strong correlation between the existence of ST-segment elevation during exercise or dobutamine stress tests in patients with 6.0±2.0 days after their admission to health services and better recovery of myocardial function one month after the test. The findings also pointed out proportionality between the sum of ST-segment elevation considering several leads under a dobutamine stress test and the magnitude of myocardial recovery evaluated through the ECG. ST-segment elevation in those cases probably represents a region with residual metabolic activity and possible recovery.

ABBREVIATIONS AND ACRONYMS

- ACC – American College of Cardiology
- AMI – acute myocardial infarction
- ECG – electrocardiogram
- ESC – European Society of Cardiology
- LVEF – left ventricular ejection fraction
- NSTEMI – non-ST-segment elevation myocardial infarction
- STEMI – ST-segment elevation acute myocardial infarction

Myocardial Dysfunction – Elhendy et al.²³ compared MIBI SPECT and echocardiogram with ECG and found, in patients with recent AMI (<1 month), a correlation between the ST-segment elevation during dobutamine stress test and reduced right ventricle function.

Lancellotti et al.²⁵ also found a correlation between ST-segment elevation and reduced regional myocardial function. However, in such study, the conclusion was obtained from the ECG and echocardiogram results, both at rest.

Coronary occlusion – In the study of Elhendy et al.²³, it was also possible to find a correlation between ST-segment elevation during dobutamine stress test in patients with AMI and total occlusion of one or more coronary arteries on angiography.

Diagnosis of AMI – Diagnosis of AMI in ECG is only possible by observing the ST-segment elevation in more than 80% of the cases^{18,26}. The Joint Committee of the European Society of Cardiology (ESC)⁴ and the American College of Cardiology (ACC)⁴, in a consensus document redefining myocardial infarction, reaffirmed that ST-segment elevation is the consequence of ischemic myocardial changes and allows diagnosing AMI³⁻⁵. In order to be considered in such diagnosis, ST-segment elevation must be presumably recent and appear in two or more adjacent leads, showing an amplitude of ≥ 2 mm from V_1 to V_3 or ≥ 1 mm in the other leads, always measured from the J point³⁻⁵.

AMI Treatment – In the medical literature, there is evidence on the ST-segment elevation reduction after AMI treatment^{4,15,24,26}. Many studies report fast ST-segment elevation reduction after an efficient coronary reperfusion^{24,26}. Persistent ST-segment elevation may indicate intermittent coronary reocclusion²⁶. Many treatments with hyaluronidase, nitroglycerine, propranolol, aortic balloon pump and oxygen administration have been confirmed to be able to reduce the sum of ST-segment elevation amplitude in many leads, as well as the number of leads presenting this change, probably indicating the beneficial results of these treatments.¹⁵

Other studies have found a correlation between greater ST-segment elevation amplitude and increased effectiveness of thrombolytic treatments²⁶.

Location of AMI – Blanke et al.¹⁸ pointed out ST-segment elevation as the most frequent event in patients with occlusion in any of the coronary arteries related to AMI.

When any of the coronary arteries is blocked, it produces ST-segment elevation more frequently in some specific leads, namely: left anterior descending artery (LAD) – V_2 , right coronary artery (RCA) – D3 and circumflex artery (ACX) – V_6 .

The sum of the ST-segment elevation on all leads is reported in some studies as a result of the ischemic acuteness in the cardiac tissue, while the number of leads with ST-segment elevation is related to the ischemic extension^{15,17}.

Drawbacks in the clinical use of ST-segment elevation – The occurrence of ST-segment elevation and its analysis have some limitations, as well as all other resources employed in AMI diagnosis. There are some phenomena causing changes in the ECG signal and making its interpretation very hard, like bundle branch blocks, pacemakers¹⁵ and heart rate changes²⁶. Technical limitations during ECG acquisition may result in signal changes, due to skin resistance changes, the distance between the electrodes and the ischemic region, variations in the anatomic position of the heart in the chest and the variable projection of the infarcted region with regard to the chest wall¹⁵.

Some patients may also present delayed ECG changes, unspecific changes or AMI with ECG remaining normal or with very little changes²⁶.

Other diseases may also cause ST-segment elevation: right or left bundle branch block, left ventricular hypertrophy, acute myocarditis, aortic dissection, acute pulmonary thromboembolism, abnormalities of the central and autonomic nervous system, tricyclic antidepressant overdose, Duchenne muscular dystrophy, Friedreich ataxia, thiamine deficiency, hypercalcemia, hyperkalemia, acute cocaine intoxication, mediastinal tumor compressing the right ventricle outflow, dysplasia or arrhythmogenic right ventricle cardiomyopathy, long QT syndrome, early repolarization syndrome, Brugada syndrome²⁷, arterial pressure reduction and pericarditis¹⁵.

Nevertheless, ST-segment elevation is an important tool for diagnosing and following up patients with AMI and, despite many factors that make it hard to use, its study is still of great clinical importance.

Due to the problems mentioned above and others related to the ST segment, other ECG changes from an infarcted patient are widely investigated and employed as a support to the limitations related the use of the ST-segment analysis alone. Based on the comparisons of

ECG scans and anatomopathologic and epidemiologic findings, it was possible to conceive several scores and methods allowing a better assessment of the myocardial ischemia evolution.

Elaborating on ECG information

ECG is of paramount relevance to evaluate and diagnose the etiology of acute precordialgia. Thanks to its applicability in clinical practice, several studies have elaborated on its ability of estimating the ischemic region, ischemic severity, the area at risk, the amount of necrosed myocardium, the presence and the quality of the reperfusion obtained²⁸.

In order to perform the estimations above, it is important to analyze the initial portion of the QRS-complex (Q and R waves), ST segment and the T wave in the ECG signal. In such studies, each of these variables is evaluated alone or combined with other clinical, laboratorial and imaging information using covariance or logistic regression analyses²⁸. Some of these studies are described below.

Selvester score – In 1972, Selvester et al.¹⁶ created a score system based on QRS complex analysis using standard 12-lead ECG. It is composed of 57 criteria and 32 points. Each point represents 3% necrosis of the left ventricle, allowing to estimate the final AMI size. This first study is based on a computer simulation of the human cardiac activity and after it was applied, an improved version of this score was proposed using 54 criteria and 32 points¹⁶. A simplified version of this score was developed in 1982 by Wagner et al.^{29,32}, including 37 criteria and 29 points, resulting in a widely validated, high-specificity tool. During the chronic phase of the AMI, this score correlates with left ventricular ejection fraction (LVEF) and infarction size in patients without reperfusion therapy²⁸.

Aldrich score – The Aldrich score was developed in 1988¹⁹ for the purpose of estimating myocardial area under potential risk of necrosis, based on ECG scans taken no later than eight hours after the onset of AMI symptoms. This score is calculated using the variables related to ST-segment elevation, such as the number of leads associated with this change and the sum of ST-segment elevation amplitudes (considering the J point for such measurement) in some specific leads. This score has two equations that are used according to the AMI

location (anterior or inferior). It is important to obtain the magnitude of the ST-segment elevation in the D2, D3 and aVF leads to inferior AMI and the number of leads with ST-segment elevation in the previous AMI¹⁹⁻²¹. Some studies included tests to modify the original equations of Aldrich et al.^{20,21} including other parameters. The Aldrich score presents low correlation in patients undergoing thrombolytic therapy²⁸.

Anderson-Wilkins score (AW acuteness score) – It is a computational algorithm that evaluates the time delay between coronary occlusion and the patient care²⁸. It is important to point out that the ischemic time may indicate the infarction acuteness as well as the percentage of the myocardial tissue that may be recovered using reperfusion therapy. However, patient-reported onset of AMI symptoms may be, in many cases, inaccurate, since there are atypical and painless AMIs^{2,13,33} and the pain tolerance also depends on each person³³. The Anderson-Wilkins score classifies the QRS complex morphology in phases 1A, 1B, 2A, 2B, meaning: 1A – high T wave and normal Q wave; 1B – positive T wave and normal Q wave; 2A – high T wave and abnormal Q wave; 2B – positive T wave and abnormal Q wave^{9,22,28,33,34}. In this score, the points were distributed through the phases identified in each of the 11 leads, except for aVR, as follows: 1A=4 points, 1B=3 points, 2A=2 points and 2B=1 point. AMI phases more advanced than 2B did not receive a score^{33,34}. The points of phases in each lead were added up to make up the Anderson Phasing Score. Later, Wilkins et al.³⁴ divided this sum by the number of leads with phases 1A, 1B, 2A and 2B to evaluate the anatomic extension involved in the AMI, hence producing the Anderson-Wilkins ECG acuteness score. That score is restricted to the leads with positive T wave and ST-segment elevation^{28,33}. This score has been tested both manually and automatically for several applications that may be coupled to digital ECG systems. A new upgrade has been recently suggested to the abnormal Q wave, aiming at achieving similar results either for anterior or inferior AMI, since this problem has been found in the application of the original formula²².

Perfusion recovery after AMI and ECG changes – Kalinauskiene et al.³⁵ classified ECG changes of patients with AMI over time, through stages I, II, III, IV, defined as follows: I – ST-segment elevation with positive T wave and without Q waves; II – ST-segment elevation with abnormal Q wave; III – ST-segment elevation with

negative T wave; IV – isoelectric ST-segment with negative T wave. That study concluded that patients presenting two or more stages during the first 48 hours after the unblocking of the artery responsible for the infarction (either using thrombolytic therapy, percutaneous angioplasty or spontaneously), achieved a smaller Selvester score and suffered less perfusion deficits over three months than those who did not undergo those stages. Such study employed the simplified version of the Selvester score as well as scintillography, which allowed classifying these patients into four groups according to their perfusion conditions: 0 – normal; 1 – slightly reduced; 2 – moderately reduced e 3 – highly reduced^{28,35}.

Heart rate after AMI as an indicator of prognosis – Mauss et al.³⁶ affirmed that heart rate after AMI under sinus rhythm is an independent predictor of AMI survival even in patients using beta-blocker. It is also a good prognosis indicator when combined with age and LVEF (left ventricular ejection fraction). This study did not include some clinical information, such as blood pressure, Killip classification, diabetes and AMI history²⁸. Heart rate was measured using 24-hour Holter monitoring and standard 12-lead ECG, presenting, in both cases, similar results³⁶.

Note that heart rate at rest indicates autonomic tonus and, if it is >100 bpm, indicates sympathetic influence with more probability to develop arrhythmia (fibrillation and ventricular tachycardia) and sudden death after AMI. On the other hand, patients with post-infarction heart rate ≤ 70 bpm would have a better prognosis. When, combined with LVEF, it ranges between 35-40%, it becomes a strong predictor of mortality³⁶.

Conclusion

ST segment elevation is a parameter of great relevance in AMI, as its easy assessment combined with many clinical meanings make it possible to be applied in electronic tools for an automatic analysis of ECG scans.

The scores are interesting, not only for automatic application, which could be very fast, practical and accurate, but also for manual application, mainly in places where other technologies for following up patients

with AMI are not available. These scores can also be combined with digital equipment used in telemedicine systems.

As opposed to the analysis of biochemical markers associated with cardiac muscle necrosis, which may cause delays in clinical practice and may be often considered expensive, determination of ST-segment elevation and scores may be automatically estimated through computer methods. As consequence, these methods may be considered low cost tools operating in real time, which is a condition absolutely necessary for the successful treatment of patients with severe AMI.

Among the scores detailed in this study, the best established one used in comparisons is the Selvester score. Although all these scores are widely applied in studies and research, they are not commonly used in medical practice. Most of them are under consolidation and validation. Among the scores described in this study, one of the most interesting ones is the Aldrich score, as it can be easily applied and employs ST-segment elevation, which is typical in the acute phase of infarction, in which the estimate of the area at risk is of greater value in the choice of therapy and analysis of the patient's prognosis.

The continued use of ECG in medical practice around the world and the growing use of automatic methods to help interpreting it require a revision of concepts as to the interpretation of ECG signals and greater knowledge of the sensitivity and specificity of diagnosis criteria available at the medical centers. New techniques to extract and categorize as much information as possible about this reputable and valuable method should be developed.

Potential Conflicts of Interest

This study has no relevant conflicts of interest.

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Academic Association

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