POINT OF VIEW

Significance of initial ST segment elevation in acute coronary occlusion

Ioan Tiberiu Nanea[1]

INTRODUCTION

Notwithstanding the multimodality myocardial imaging age, the information obtained by analyzing the electrocardiographic changes that occur during the acute coronary occlusion is underestimated.

The dynamics of ST segment elevation is essential for diagnosis, therapeutic approach and efficiency, and also for risk stratification of the patient with acute myocardial infarction. Many studies have tried to estimate the myocardial area at risk and eventually the established myocardial infarction, by ascertaining a score of the ST segment magnitude and of the number of electrocardiographic leads where it happens.

Thus, in case of anterior myocardial infarction the number of leads with ST segment elevation has been strong correlated with the infarcted myocardium, and in case of inferior one the magnitude of ST segment elevation has been related to the final size of the infarction.

The size and extension of the ST segment elevation is also correlated with the presence of an effective collateral circulation and with a residual flow through the involved coronary artery which is adequate to the viability of the subjacent tissue.

In patiets who benefited from efficient coronary angioplasty there is a poorer correlation between these electrocardiographic scores and the myocardium at risk identified by studies with radionuclides or by magnetic resonance imaging. However, the assessment of the myocardium at risk using the cuantification of the magnitude and extension of ST segment elevation is an independent method which is different from other technics performed with the same purpose. Therefore, the analysis of the ST elevation particularities stands up-to-date in establishing the myocardial at risk and in evaluation of the prognosis to the patient with acute coronary occlusion.

THEORIES EXPLAINING THE ST SEGMENT ELEVATION

Information regarding therapeutic efficacy, prognosis and risk stratification in the patients with acute myocardial infarction, obtained by analysing the electrocardiographic changes is underestimated.

The dynamic ST segment elevation represents the essential change in the matter of diagnosis (STEMI), complications, therapeutic approach, therapeutic efficacy and risk stratification in patients with acute coronary occlusion[1].

The myocardial lesion, expressed through ST segment elevation or depression, denotes an advanced stage of myocardial ischemia, signifying transmural lesion with a subepicardial prevailing pattern.

There are two theories that explain the ST segment elevation: diastolic and systolic current of injury.

During the electric diastole (TQ interval), the injured myocardium remains depolarized, in contrast to the normal adjacent myocardium which becomes repolarized. Thus, a potential difference appears between these zones, a diastolic current of injury whose vector is oriented from the injured zone towards the normal electropositive myocardium, determining a TQ segment depression. The superficial electrocardiogram records the TQ segment depression as ST

[1] Department of Cardiology and Internal Medicine, „Prof. Dr. Theodor Burghele" Clinical Hospital, „Carol Davila" University of Medicine and Pharmacy, Bucharest, Romania

Contact address:
Ioan Tiberiu Nanea, MD, PhD, Department of Cardiology and Internal Medicine, „Prof. Dr. Theodor Burghele" Clinical Hospital, Bucharest, Romania.
E-mail: tiberiu.nanea@yahoo.com

segment elevation, as electrocardiographs use an amplified current which adjustes in a proportional mode every TQ segment depression.

During the electric systole (QT interval) a potential difference (systolic current of injury) appears between the injured zone which is early repolarized and the normal adjacent depolarized zone. The vector of the systolic current of injury is oriented towards the electropositive injured zone. The superficial electrocardiogram records a ST segment elevation. The leads which are oriented to the injured zones will record a ST segment elevation, and the opposed ones a ST segment depression.

The magnitude of the ST elevation is measured at J point (the junction between the end of the QRS and the beginning of the ST segment), having as orientation mark the TP segment which is isoelectric.

The morphological aspects, the dinamics, the size and the number of electrocardiographic leads where there is recorded the ST segment elevation offer information regarding:

1. Diagnosis and myocardial area at risk of developing subsequent myocardial necrosis (analysing the ST segment magnitude and the number of the involved leads).
2. Risk stratification in patients with acute myocardial infarction (analysing the morphology and the leads with ST segment elevation).
3. Efficacy of reperfusion therapy (analysing the ST segment dinamics).
4. Identification of the reperfusion injury (noticing the ST segment dinamics).
5. Localization of the myocardial necrosis (analysing the ST segment location in the electrocardiographic leads).
6. Identification of the coronary artery responsible of occlusion (measuring the magnitude and localizing the ST segment elevation on electrocardiogram).
7. Evaluation of the residual flow (measuring the size of ST segment elevation).
8. Identification of ventricular aneurysm (analysing the electrocardiographic signs of necrosis and lesion).
9. Prediction of left ventricular function (existence of ST segment elevation in more leads is associated with reduced ejection fraction).
10. Diagnosis and myocardial area at risk of developing subsequent myocardial necrosis

The dinamics of the ST segment elevation after coronary occlusion is influenced by:

a. Duration of the occlusion;
b. Antegrade residual flow through the coronary artery responsible for infarction;
c. Myocardium at risk of developing an established myocardial infarction;
d. Flow level through the coronary vessels which are collateral to the injured area;
e. Ischemic preconditioning;
f. Myocardial oxygen consumption;
g. Physiological fibrinolysis;
h. Moment of performing the reperfusion therapy;
i. Quality of reperfusion.

Many studies suggested[1] that the level of initial magnitude of the ST segment elevation (at the beginning of the coronary syndrome) and its extension in more leads can anticipate the area of myocardial necrosis (the final risk of necrosis). It is considered that if the injured myocardial area increases, the transmural electrical potential differences between the ischemic area and the normal myocardium will be augmented, causing ST segment elevation[2,3]. According to this theory, the magnitude of the ST segment elevation reflects the extension of myocardium at risk that will necrosed afterwards. The initial ST segment elevation at the admission has predective value for the estimation of the myocardial infarction size later established.

Many studies tried to estimate the myocardial area at risk, the size of myocardial infarction, developing a score using the value of the ST segment magnitude and the number of electrocardiographic leads where it occured. Aldrich has established formulas for evaluation of the final myocardial infarction size taking into account the anterior and inferior localization[4].

Formula for anterior myocardial infarction = 3(1.5 [number of leads with ST elevation – 0.4])

Formula for inferior myocardial infarction = 3(0.6 [ΣST elevation in leads II, III, aVF] + 2.0).

The final size of myocardial infarction was estimated through QRS score described by Selvester, which was calculated at discharge[5]. Selvester score for evaluation of the myocardial infarction size consists of 57 criteria based on the duration of Q or R waves, the amplitude of the R or S waves and the amplitude of the R/Q or R/S ratio. Each point in the Selvester score corresponds to 3% of the myocardial infarction size. The Selvester QRS Score for evaluation of the myocardial infarction size was validated by morphopathological studies (by measuring of the myocardial infarction quantity during autopsy) and by radionuclide studies[5,6] (Figure 1).

In a study performed by Aldrich on 148 patients (without reperfusion treatment), the number of leads with ST segment elevation that signifies the myocardial infarction at risk was correlated with the size of the established anterior myocardial infarction (r = 0.72). In contrast, in case of inferior infarction, the sum of ST elevations magnitude was strongly correlated to the size of the established myocardial infarction (r = 0.61)[4].

In his study which included 67 patients with coronary angioplasty, Thymothy estimated the size of the myocadial infarction at risk electrocardiographically assessed, by comparison with radionuclide and angiographic measurements. For the calculus of the area at risk, it was used a different formula compared to the one described by Aldrich. So, for the anterior myocardial infarction, the formula becomes:

4.5 x (number of leads with ST elevation ≥ 1 mm) – 1.2;

and for the inferior myocardial infarction:

1.8 x (ΣST elevations in mm in leads II, III, aVF) + 6.6.

The myocardial area at risk and the collateral circulation were evaluated by radionuclide studies quantifying the perfusion defects, and by coronary angiography. The collateral coronary circulation was evaluated, using Rentrop score.[7] The authors conclude that the ST segment elevation score is correlated to the radionuclide or to the coronary angiographic evaluation of the flow through the collateral coronary circulation. The magnitude of the ST elevation (myocardium at risk) has a poor correlation to the established myocardial infarction detected by perfusion defects.[4] However, in many cases we obtained a good correlation between the magnitude of the ST segment eleveation and the size of established myocardial infarction detected by perfusion defects (Figure 2).

In patients who received coronary reperfusion therapy, there is a weaker correlation between these scores based on the magnitude and the number of leads with ST segment elevation and the size of esta-

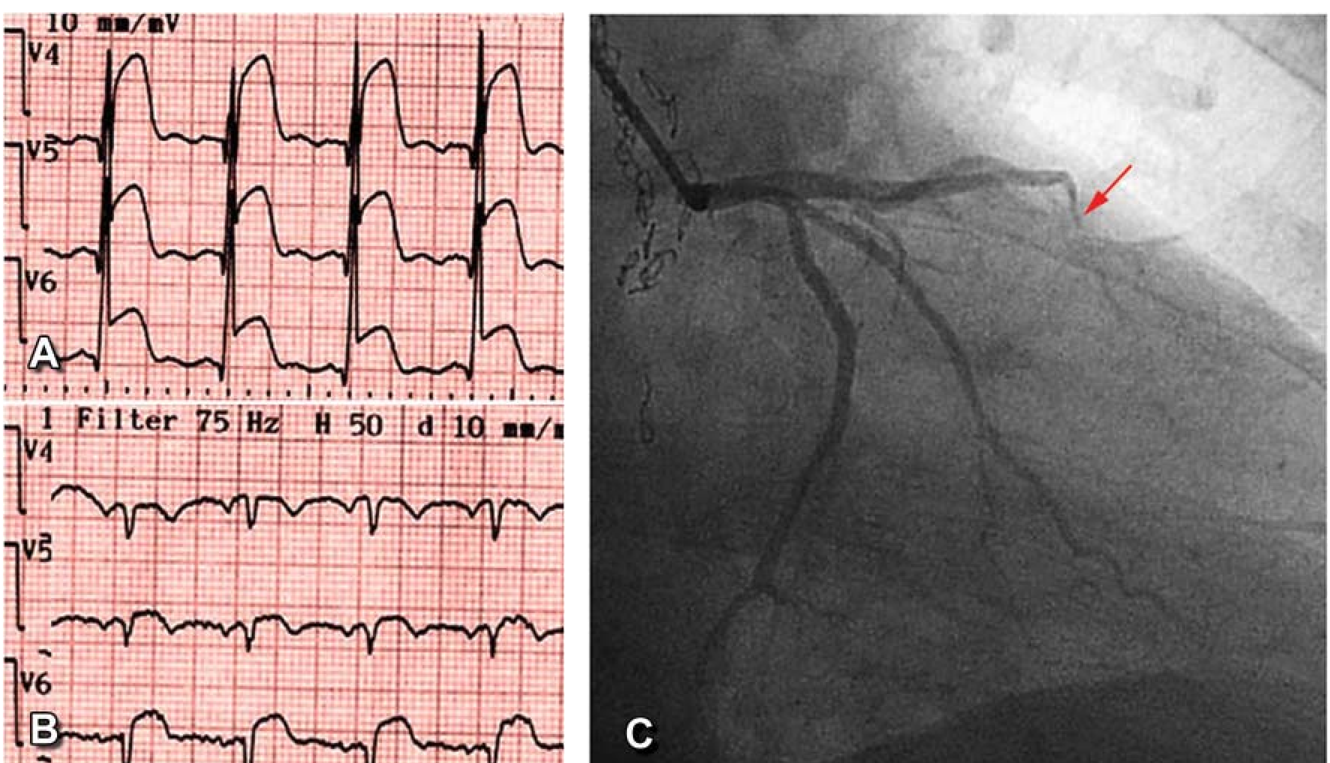


Figure 1A. ST segment elevation with increased magnitude (9 mm) in V4-V6 which reflects the myocardium at risk. **Figure 1B.** Transformation of the myocardium at risk in established infarction, Q wave V4-V5 aspect with the resolution of the R wave. **Figure 1C.** Occlusion of anterior descending artery in the medial segment (arrow).
Personal case.

blished myocardial infarction. One of the explanations is the rapid reperfusion after angiography through the occluded artery[8,9]. In addition, the electrocardiographic leads do not represent equally all the myocardial areas. The inferior and the anterior walls are well represented, while the lateral and posterior walls, along with the apical regions are not. Moreover, ischemia in the myocardial regions opposed to the direct areas of electrocardiographic elevation can reduce or can increase the ST elevation[8].

GISSI study[8] which analises the prognostic significance of the extension of the myocardial injury in acute infarction on 8731 patients who received Streptokinase therapy, reports, also, a high mortality in patients who had an increased magnitude of the ST segment elevation at admission. The authors stratify the mortality risk in relation with the size of the myocardial infarction as follows:

Mortality rate in small infarct (ST elevation present in 2 to 3 leads): 6.5%.

Mortality rate in modest infarct (ST elevation present in 4 to 5 leads): 9.6%.

Mortality rate in large infarct (ST elevation present in 6 to 7 leads): 14.3%.

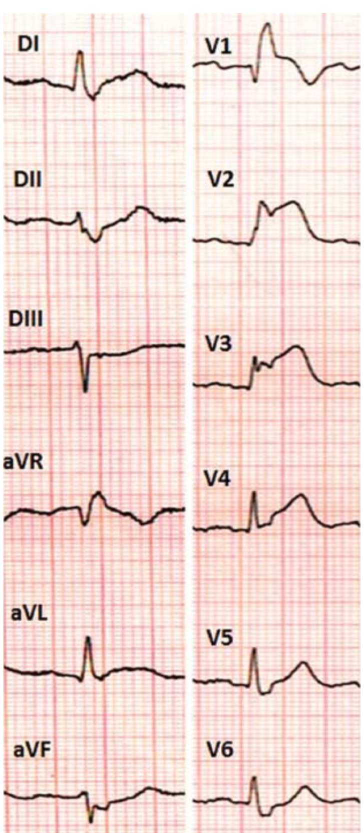
Mortality rate in extensive infarct (ST elevation present in 8 to 9 leads): 21.7%8.

ST elevation in presence of left bundle branch block is used to identify an associated acute myocardial infarction (Sgarbossa criteria). Thus, concordant ST elevation ≥1 mm in leads with a positive QRS complex and discordant ST elevation ≥5 mm in leads with a negative QRS complex indicate the development of an acute myocardial infarction (Figure 4).

A recent study (TRANSIENT trial, 2019) describes a new class of acute coronary syndrome: acute coronary infarction (demonstrated by coronary occlusion) with transient ST segment elevation. In this case, 5.6% of 142 patients suffered reinfarction. I conclude that the dynamic of ST segment elevation is very important concerning this new coronary syndrome[9].

1. Risk stratification in patients with acute myocardial infarction

There were described some patterns of ST segment elevation morphology which were associated with a



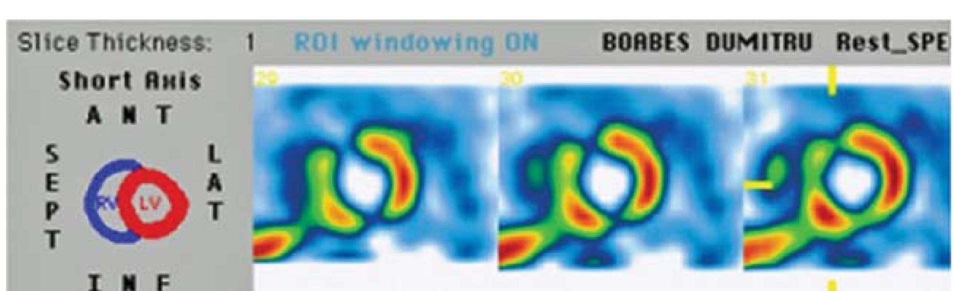


Figure 2A. The magnitude of the ST segment elevation higher than the R wave amplitude in V2,V3 leads. **Figure 2B.** The scintigraphy demonstrates the occurance of myocardial infarction with antero-septal location.
Personal case.

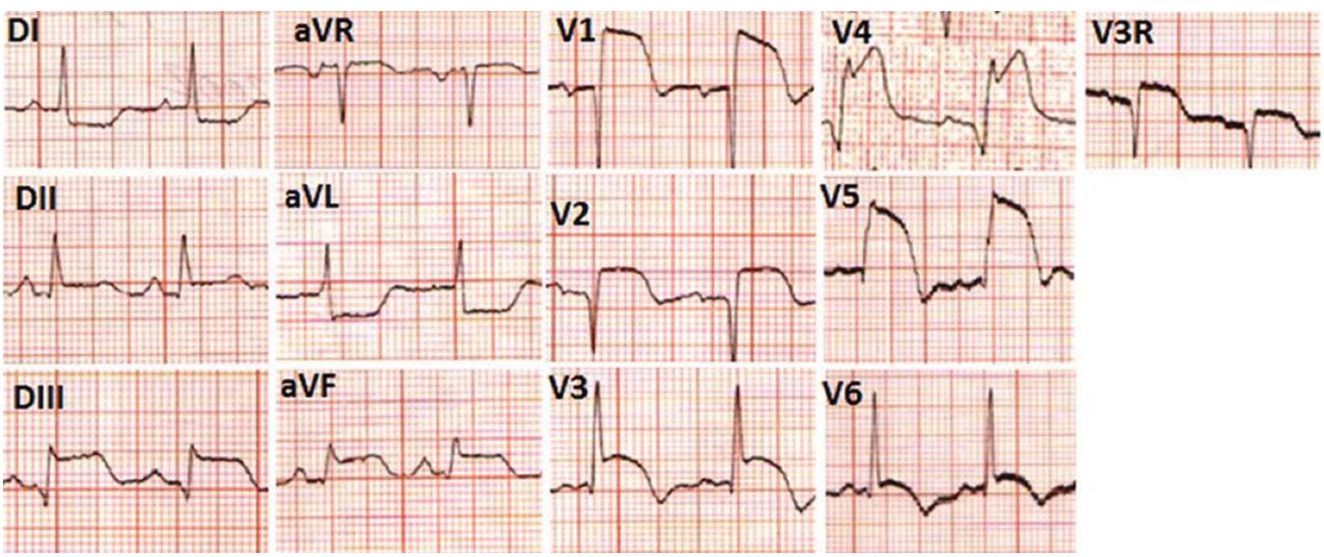
poorer prognosis of the acute myocardial infarction. It was described a tombstoning ST segment elevation which has as an essential particularity. This consists in an upward convexity of the ST segment elevation which peak is higher than the R wave. The tombstoning pattern is related to an extensive myocardial infarction, a reduced left ventricle function, complications in the acute phase and a very poor prognosis. Tombstoning ST elevation happens to the patients with poor collateral circulation, sudden occlusion and lack of ischemic preconditioning. The electrophysiological mechanism consists in a myocardial conduction defect10 (Figure 3).

2. Efficacy of reperfusion therapy

The resolution of the ST segment[9] after the initiation of reperfusion therapy is an excellent predictor of the prognosis and improvement of the left ventricle contractile function, of the cardiac metabolism and also of the normal electric activity in the irrigated areas. ESC Guidelines for acute myocardial infarction asserts that a resolution with more than 50% of the ST segment elevation at 60-90 minutes after reperfusion therapy is associated with coronary repermeabilization[11].

3. Identification of the reperfusion injury

In some patients with STEMI, the restoration of coronary flow after the interventional therapy may cause



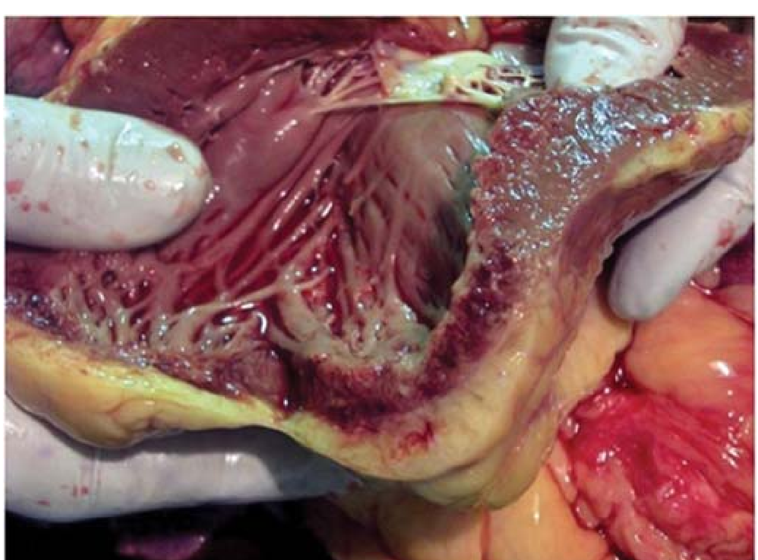


Figure 3A. Antero-lateral, inferior and right ventricle myocardial infarction. Tombstone ST segment elevation in V4, V5 leads (ST nadir > R wave amplitude). **Figure 3B.** Anatomopathological examination of the patients mentioned above. There can be remarked hemorrhagic necrosis lesions of the inferior, anterior and right ventricle walls.
Personal case.

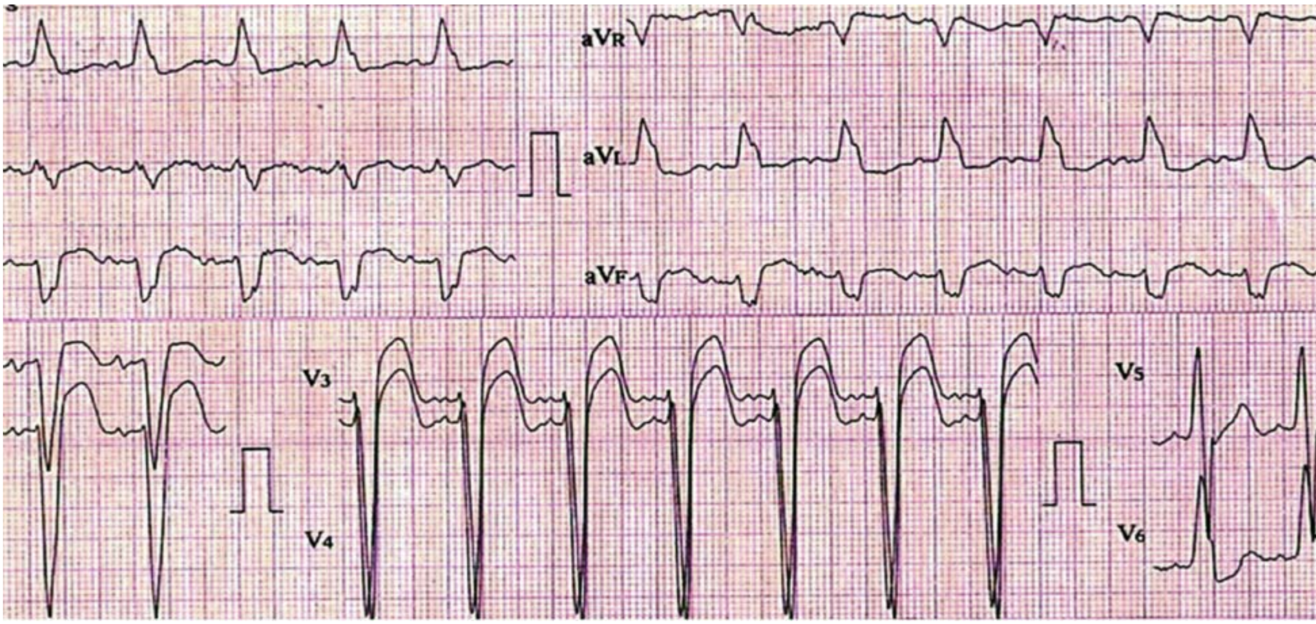


Figure 4. Left bundle branch block. ST segment elevation > 5 mm in V3,V4 leads suggesting associated myocardial infarction.
Personal case.

a new ST segment elevation. A new ST elevation after recanalisation is defined as an additional increase of ST segment with at least 0.5 mV in the leads with STEMI during the first 15 minutes after the therapeutic recananalisation. The additional augmentation of the ST segment after coronary recanalisation is associated with an extended myocardial infaction, with left ventricular disfunction and reduced contractile reserve.

4. Localization of the myocardial necrosis

The ST elevation is useful in establishing the location of the myocardial infarction. In addition to the classical localization of the infarct, using the 12 standard electrocardiographical leads – anterior, septal, lateral, inferior necrosis and combinations of them – supplementary leads are required for the identification of the myocardial necrosis where classical electrocardiography can not distinguish the myocardial walls[12].

5. Identification of the coronary artery responsible of occlusion

ST segment elevation in DIII lead which exceeds in magnitude the ST elevation in DII lead, associated to the ST elevation in V1, signifies proximal occlusion of the right coronary. ST elevation in DII that is equal or greater than the one in DIII, associated to the ST depression in V1-V2 or to the ST elevation in D1, aVL, suggests the circumflex artery occlusion or the distal occlusion of the right coronary artery (which is dominant). The ST segment elevation in V1-V3 leads indicates the proximal occlusion of the right coronary artery (can simulate an anterior myocardial infarction). The ST segment elevation in V1R, V2R or the ST depression in V1-V2 could be also helpful.

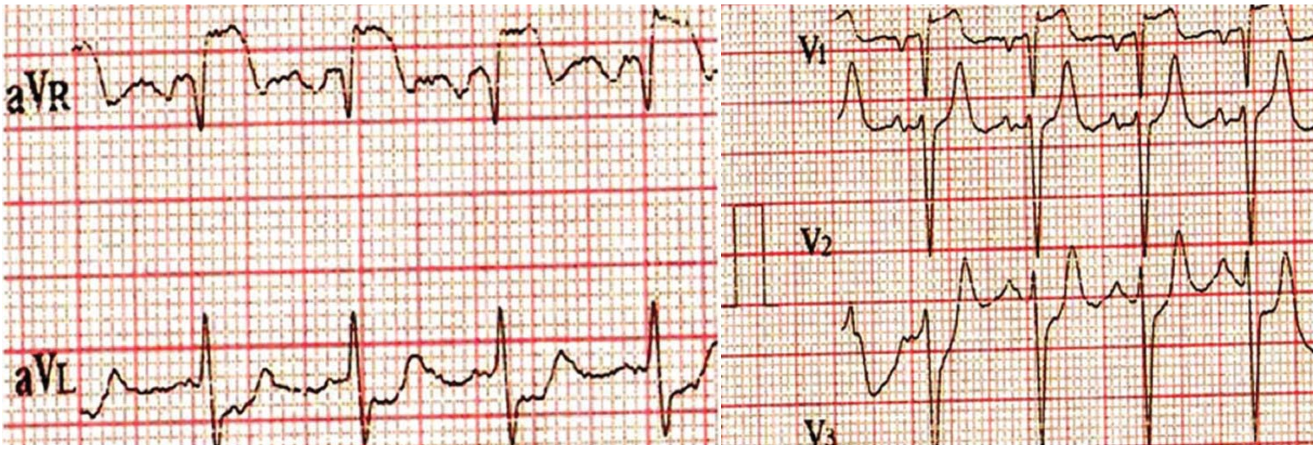
The aVR lead has a unique position, because the positive pole is directed to the right part of the heart and the vector of injury current points towards the right shoulder. The ST segment elevation in aVR, associated to ST segment depressions in other leads, in case of clinical conditions, suggests acute myocardial infarction, by left coronary occlusion (Figure 5).

6. Evaluation of the residual flow

European Cooperative Study Group who analised a large number of patients with myocardial infarction – 721 patients who were administred thrombolytic therapy – reports a high mortality rate in patients with augmented ST segment elevation[12]. It was noticed that patients with ST segment elevation > 20 mm suffered an extensive myocardial infarction. The extension of the myocardial infarction was ascertained using enzyme assays. The results suggested that the magnitude of the ST segment elevation reflects the dimension of residual flow to the infarct zone either through collateral and antegrade flow[13].

7. Identification of ventricular aneurysm

It is noticed a ST segment resolution to baseline after STEMI, while necrotic Q waves are usually persistent. However, 60% of patients with anterior STEMI and 5%



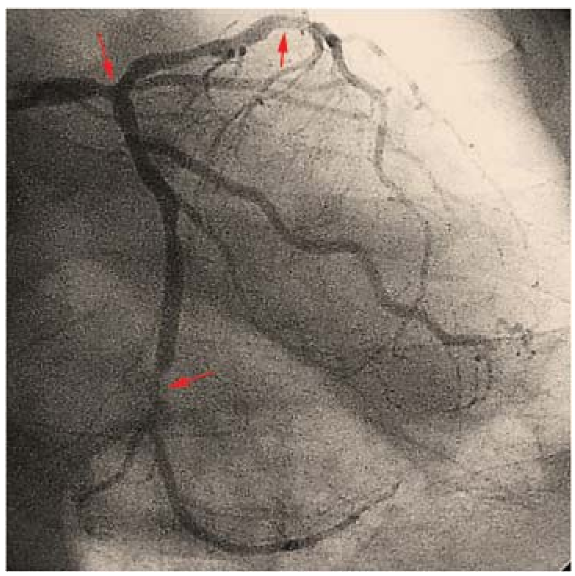


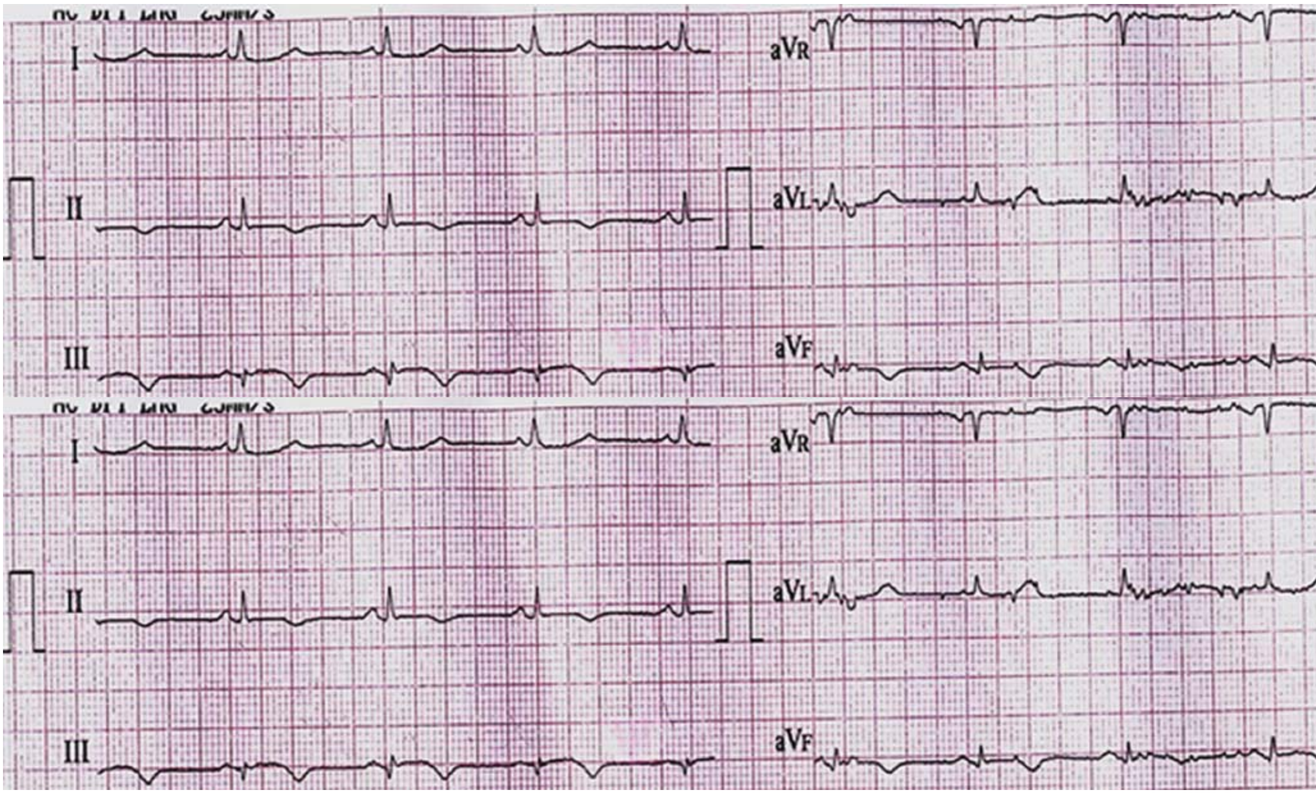
Figure 5A. ST segment elevation in aVR and V1 leads with ST depression in aVL, V3 leads, aspect that suggests an acute myocardial infarction determined by left coronary artery occlusion. **Figure 5B.** Significant stenosis of the left coronary artery, anterior descending artery and circumflex artery (arrows) – the same pacient described above.
Personal case.

of those with inferior STEMI maintain a level of ST segment elevation. The ST segment persistent elevation over 2 weeks after STEMI occurence, associated with Q wave and low amplitude T waves suggests a left ventricle aneurysm. These changes are equivalent of the imagistic methods which indicate a wider systolic silhouette of the left ventricle segment in comparison with the diastolic one (Figure 6)[14].

8. Prediction of left ventricle function

In a study that included 50 patients with anterior acute myocardial infarction who were thrombolysed with streptokinase, there was ascertained a comparison between patients with hyperacute upright T wave, patients with hyperacute T wave and ST segment elevation and patients with tombstone ST segment elevation. In patients with tombstone ST elevation, the left ventricular ejection fraction was the most reduced (31%) compared to the other types[10].

A more recently study demonstrated the correlation between the sum of the ST elevations and the left ventricular ejection fraction. There was calculated the sum of the ST elevations measured in DI, aVL and V1-V6 leads for the 239 patients included with total coronary occlusion and angioplasty. The sum of ST elevation ≥10 mm was well correlated to a significantly reduced ejection fraction compared to patients with ST elevation <10 mm (51 ± 14% versus 57 ± 14%, $p < 0.01$)[16].



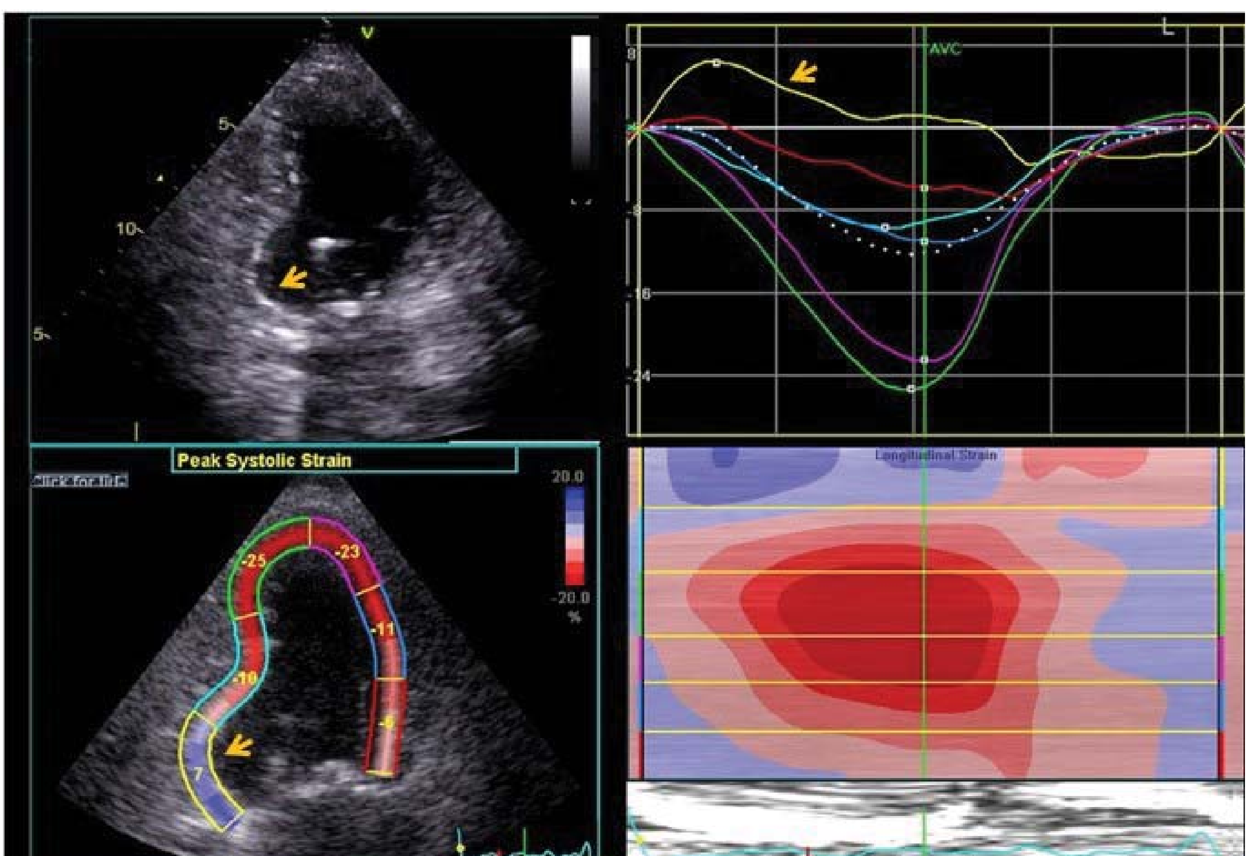


Figure 6A. Necrosis Q waves noticeable in DII, DIII, aVF leads associated with ST segment elevations and negative T waves. This aspect is suggestiv for inferior wall aneurysm of the left ventricle. *Figure 6B.* It can be distinguished the aneurysmal aspect of the inferior wall (thin arrow) in the patient above. The strain value of the inferior wall of left ventricle during the systolic period is positive suggesting an aneurysm (big arrow).
Personal case.

CONCLUSIONS

1. Electrocardiographic assessment has to be initial and it is essential in diagnosis of acute coronary occlusion, at the same time underlying the therapeutic approach.
2. Evaluation regarding magnitude and extension of the ST segment represents a total different assay in comparison to radionuclidic techniques or nuclear magnetic resonance used for the evaluation of the myocardium at risk of necrosis.
3. Information about morphopathologic features of ST segment elevation in case of acute myocardial infarction provides additional details to the anatomic and metabolic changes.
4. In my opinion, the presence of a „momentum" which identifies a major amplitude of ST segment elevation constiutes, however, a reference point in establishing the severity of the myocardial injury and in adopting a quick decision regarding proper therapeutic approach.

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