Review Article

High-Risk Electrocardiographic Patterns in Patients with Acute Coronary Syndrome

Diego Alejandro Echeverri-Marín1, a, Cristhian F. Ramírez-Ramos2, b, Andrés Felipe Miranda-Arboleda1, a, Gustavo Adolfo Castilla-Agudelo3, c, Clara Inés Saldarriaga-Giraldo4,

Acute myocardial infarction is the leading cause of death in the world, and the electrocardiogram remains the diagnostic tool for determining an acute myocardial infarction with ST-segment elevation. Nonetheless, only half of the patients present classic electrocardiogram findings compatible with the ST-elevation infarction criteria. There is a spectrum of electrocardiographic findings that may reflect a phenomenon of acute coronary occlusion, which should be promptly recognized by the clinician to offer early reperfusion therapy.

Keywords. Myocardial infarction; Electrocardiography; ST elevation myocardial infarction.

Patrones Electrocardiográficos de Alto Riesgo en Pacientes con Síndrome Coronario Agudo

El infarto agudo del miocardio es la principal causa de muerte en el mundo, y el electrocardiograma sigue siendo la herramienta diagnóstica para determinar un infarto agudo del miocardio con elevación del segmento ST. A pesar de ello, solo la mitad de los pacientes presentan hallazgos clásicos en el electrocardiograma compatibles con los criterios de infarto con elevación del ST. Existe un espectro de hallazgos electrocardiográficos que pueden reflejar el fenómeno de oclusión coronaria aguda, el cual debe ser prontamente reconocido por el clínico para ofrecer una terapia de reperfusión temprana.

Palabras clave. Infarto del miocardio; Electrocardiografía; Infarto del miocardio con elevación del ST.
The correct interpretation of the electrocardiographic findings in acute coronary syndromes (ACS) is a diagnostic challenge for all clinicians; and is especially important in the emergency room, where an early diagnosis of acute coronary occlusion and early reperfusion therapy reduces morbidity and mortality in patients with ST-segment elevation myocardial infarction (STEMI) [1].

Classically the elevation of the ST segment (STE) in the electrocardiogram has been recognized as the electrical interpretation of an acute phenomenon of an epicardial coronary artery occlusion [2]. STEMI is defined, in an appropriate clinical context, as the STE (measured at the J point level), in at least 2 contiguous leads > 2.5 mm in men <40 years, 2 mm in men ≥40 years, or 1.5mm in women in leads V2 and V3 and/or 1 mm in the other leads in absence of left bundle branch block (LBBB) or left ventricular hypertrophy [3]. Despite this, at least half of the patients with an acute myocardial infarction do not present electrocardiographic changes [4].

In turn, some electrocardiographic patterns have been recognized as equivalent to STEMI or acute myocardial infarction with high-risk electrical findings, which are caused by the occlusion of an epicardial artery with an important irrigated myocardial territory [5].

These high-risk electrocardiographic patterns are described below, in order to provide the clinician with an additional tool to identify and recognize them early and provide the appropriate treatment.

**Occlusion of the first diagonal**

The occlusion of the first diagonal branch of the left anterior descending (LAD) artery, appears electrocardiographically, as a significant elevation of the STE in aVL and V2 (Figure 1). See previously described values for STE; it can be accompanied by hyperacute T waves in these two leads, and occasionally negative T waves on the lower leads [3]. This electrocardiographic characteristic has been called “non-anatomical electrocardiographic presentation” since it does not meet the traditional criteria for STE in acute myocardial infarction [5].

The importance of early diagnosis of this entity lies in the fact that the diagonal branch of the LAD artery supplies the entire anterolateral wall of the left ventricle which is a large percentage of the myocardial mass of the left ventricle [6].

**De Winter´s pattern**

It was described in 2008 by Robert de Winter et al. [7]. This pattern is characterized by an ascending depression of the ST segment from the J point of 1-3 mm in leads V1-V6 with symmetrical positive T waves and eventually, a subtle 1-2 mm STE in aVR (Figure 2). This rare electrocardiographic pattern is commonly associated with single-vessel coronary artery disease and is static without progression to a STEMI pattern (disappears only after revascularization). It has been documented in 2% of

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**Figure 1.** 12-lead electrocardiogram. The typical abnormalities of ST-segment changes are shown in aVL and V2. In addition, there is an ST-segment depression in DIII and aVF, and also ST-segment elevation in DI.
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Figure 2. 12-lead electrocardiogram. A depression with an ascending terminal part of the ST-segment is shown with positive and symmetrical T waves in V3-V4-V5-V6. In addition, there is a horizontal depression in DII and aVF. An STE is found in aVR.

anterior wall infarcts. One year after the initial publication, the same group reported an observational study where this finding was found in 2% of proximal occlusions of the LAD artery (positive predictive value 100%). It is more frequently seen in young people with dyslipidemia. The same observation was confirmed in Amsterdam, with a 1.6% in anterior infarcts and invariably with proximal or middle occlusion of the LAD artery predominantly in men.

Wellen’s pattern

This electrocardiographic finding is characterized by a T wave inversion in leads V2-V3 (usually in the pain-free period) in patients with a history of intermittent symptoms on the spectrum of coronary heart disease. It is considered an alarm sign since represents a critical proximal lesion of the LAD artery that has been associated with a poor prognosis in patients who do not undergo angiography or revascularization. Findings are characterized by a deep inversion of the T wave (type B pattern; Figure 3) or a positive-negative biphasic wave (type A pattern; Figure 4), in which the second component of the T wave is inverted. 76% of the patients present with the type B pattern and 24% with the type A pattern. In 1982, De Zwaan et al. reported a study of 145 patients who presented to the hospital without symptoms, but with angina at often in crescendo, worsening of angina, or postinfarction angina, characteristically having little or no elevation of cardiac enzymes. 18% (n= 26) had an inversion of the T wave in V2-V3 on admission or in the first 24 hours. The prognostic value of these findings was unknown for 9 of the 26 patients; however, 8 patients developed a myocardial infarction despite the fact that the symptoms were resolved with medical management. Of the remaining population, 13 underwent angiography, finding the coronary disease in 12 cases. All had a 90% or greater stenosis of the LAD artery. In a later study with 1260 patients who presented with unstable angina, 14% had similar findings on the T wave like the original work. Angiography of these patients revealed 50% or more stenosis of the LAD artery in all patients and the lesion was proximal to the second anterior septal perforating artery in 83%. The degree of obstruction was 79-85% and total occlusion in 18%.

ST elevation in aVR and diffuse ST depression > 6 leads

The clinical presentation of most patients with an ACS with this electrocardiographic pattern is with cardiogenic
shock, pulmonary edema, life-threatening arrhythmias and/or sudden death \cite{12}. This is because this electrocardiographic pattern may represent the occlusion of the left main stem coronary artery (LMS), which supplies 75% of the left ventricular mass \cite{13}. It can also be found in patients with multivessel coronary disease or proximal compromise of the LAD artery \cite{14}.

The electrocardiographic findings of this pattern consist of STE in aVR and ST depression > 1 mm in more than 6 leads of the electrocardiogram (Figure 5). Given these findings, one should not wait for the taking of biomarkers of myocardial injury to urgently carry out invasive stratification \cite{13}.

**Inferobasal myocardial infarction**

Since 2008, Dr. Antony Bayés de Luna proposed a dogmatic change and, thanks to cardiac magnetic resonance studies, he was able to show that the heart lacks a posterior wall and that what was previously called “posterior” corresponds to the inferobasal segment, which it is the continuation of the lower wall of the left ventricle below the atrioventricular groove and resting on the diaphragm \cite{15}.

The fourth universal definition of myocardial infarction supports this change and replaces the term posterior with inferobasal myocardial infarction \cite{16}.

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**Figure 3.** 12-lead surface electrocardiogram. Characteristic findings of a type B Wellens pattern with deep and symmetric inversion of the T wave in leads V2-V3; there is extension up to V4 and V5.

**Figure 4.** 12-lead surface electrocardiogram. Wellens type A pattern shows a biphasic T wave with a negative terminal portion in V2-V3-V4.
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Figure 5. ST depression > 1 mm in all derivatives and STE in aVR > 1 mm.

It is believed that up to 20% of acute myocardial infarction (AMI) may present inferobasal involvement, mainly accompanying inferior and lateral infarcts. True inferobasal involvement is less common and only occurs in 3.3% of all infarcts. The majority of patients who present with this type of infarction have involvement of the circumflex artery (CX), followed by the right coronary artery (RCA) (17).

The inferobasal segment is not represented in the conventional 12-lead electrocardiogram, for its diagnosis it is necessary to use 15 leads that include posterior leads V7, V8, and V9 (Figure 6); any STE > 0.5 mm in these will be positive for infarction Inferobasal. This is explained because in this case there is a loss of the electrical forces that go posteriorly, and therefore the typical STE changes will only be seen in these leads. The key point in detecting this type of infarction is that when a 12-lead ECG identifies an ST depression in V1, V2, or V3, which corresponds to the mirror image, subsequent leads are always taken immediately (Figure 7a). The QRS should also

Figure 6. Location of the posterior leads. V7 would go in the fifth intercostal space with the posterior axillary line, V8 fifth intercostal space with the middle scapular line at the level of the angle of the scapula, and V9 in the fifth intercostal space with the left paravertebral line. To take these leads in conventional electrocardiographs, other precordial leads must be disconnected from v4 to v6 and put them in this place. Taken from: https://liffl.com/posterior-myocardial-infarction-ecg-library/
be evaluated where an R / S ratio > 1 is seen in V1 and V2 as a mirror of a possible Q in progress in V7 to V9 (Figure 7b). Depending on the moment of the presentation there may be hyperacute T waves in the precordial leads. 

**Right bundle branch block (RBBB)**

The presence of bundle branch blocks in the context of acute infarction varies between 1.6% and 10.9% (19), without a significant predominance of left or right bundle branch blocks. This finding is an important factor in the approach to patients who present in the context of infarction, as this can interfere with the interpretation of repolarization changes and delay therapeutic interventions.

The right bundle branch block (RBBB) does not affect the interpretation of the repolarization alterations that usually affect the left ventricle. However, its presence in the acute infarction scenario is a poor prognostic factor that has been gaining strength in recent years; patients with AMI and RBBB have a 2-fold higher risk of death at 30 days (20).

The results of a recent meta-analysis show that the presence of new-onset RBBB is associated with extensive infarctions, and a greater tendency to have complications
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Figure 8. Elevation of the ST segment from V2 to V6 (extensive anterior infarction) is observed, in addition to the morphology of RBBB by rSR in V1 and qR in V6.

Figure 9. Schematic representation of different electrocardiographic criteria for the diagnosis of infarction in the presence of LBBB. 

A) Sgarbossa criteria, B) Smith criteria, C) Cabrera - Friedland criteria, the red arrows show notching >50 milliseconds in the upslope of the S wave in lead V3 and V4 

D) Chapman - Pearce criteria, the red arrows show a notch in the upslope of the R wave in lead I, aVL or V6

such as cardiogenic shock, ventricular arrhythmias, and AV blocks \textsuperscript{(21)}. This could be explained because the right branch of the bundle of His is supplied by the LAD or its proximal septal branches, therefore, the presence of this block indicates proximal occlusion of the LAD artery.

Electrocardiographic characteristics of this pattern will include STE in anterior wall V2 to V6 and QRS morphology compatible with RBBB due to the presence of rSR in V1 and qRs in V5 or V6 (Figure 8).

\section*{Left bundle branch block}

Approximately 7\% of AMI present with left bundle branch block (LBBB). Different studies have shown that patients with AMI and LBBB at the time of presentation have a worse prognosis due to an increase in mortality 2 to 3 times greater than those who do not have LBBB. Some explanations for this lie in the fact that patients with this electrocardiographic pattern are often older, suffer from heart failure, have more comorbidities and multivessel disease; furthermore, when LBBB occurs in the context of AMI, it is correlated with occlusion of the proximal LAD, affecting a large area. Another factor related to a worse prognosis in this population is that the presence of LBBB makes it difficult to interpret the repolarization alterations typical of AMI, causing a delay in diagnosis and the implementation of therapeutic measures \textsuperscript{(22)}. However, it has also been noted that in patients with chest pain and LBBB, an inadequate diagnosis of infarction is frequently made and in up to half of the cases they have been treated as infarction, even receiving thrombolysis, but without having any evidence of it in retrospective analyzes \textsuperscript{(23)}.

Different criteria and scores have been proposed for the diagnosis of AMI in the presence of LBBB. The most frequent are:

\begin{itemize}
  \item \textbf{Sgarbossa criteria}
\end{itemize}

In 1996, Dr. Elena Sgarbossa et al. published the criteria for the diagnosis of infarction in the presence of LBBB based on the

\begin{figure}[h]
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\includegraphics[width=\textwidth]{figure10.png}
\caption{Diagnostic algorithm in patients with LBBB and suspected AMI.}
\end{figure}
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Information collected in a controlled clinical study called Global Utilization of Streptokinase and Tissue Plasminogen Activator for Occluded Coronary Arteries (GUSTO-I) (24). From this publication, the following was proposed as diagnostic criteria (see figure 9a):

1. ST-segment elevation ≥1mm and concordant with the QRS (5 points).
2. ST-segment depression ≥1mm in V1, V2, or V3 (3 points).
3. ST-segment elevation ≥5mm and discordant with the QRS complex (2 points).

The diagnosis of infarction is made with the presence of 3 points or more, the most powerful predictor of infarction being the criterion of discordant elevation of the ST with a specificity of 98% but a sensitivity of 20%, that is, they are very useful when they are present but their absence does not rule out AMI. The criterion of discordant ST elevation ≥5mm was found to have the lowest diagnostic yield (25).

• Modified Smith or Sgarbossa criteria

In 2012, Smith published what has been considered the modified Smith or Sgarbossa criterion, this was done to improve the diagnostic performance of the last Sgarbossa criterion of discordant ST elevation ≥5mm and introduced the concept of proportionality of STE in relation to the size of the QRS. The Smith criterion proposes a relationship between the STE divided by the size of the S, both measured from point J; it is considered positive if this result is < - 0.25 (Figure 9b). In the context of infarction, the presence of this criterion was associated in 58% of the cases with occlusion of the proximal LAD artery vs 8% in those who did not comply with it. This change increased sensitivity to 91% and specificity to 90%, compared previously to 41% and 85% respectively (26).

• Cabrera - Friedland criterion

Prominent notch > 50 ms duration in the ascending limb of the S wave from V3 to V4 (Figure 9c).

• Chapman-Pearce sign

Prominent nick in the ascending limb of the R wave in DI, aVL, or v6 (Figure 9d).

Figure 10 summarizes a diagnostic algorithm for patients with left bundle branch block and suspected infarction; the electrocardiographic pattern of the patient with AMI and LBBB is exemplified in Figure 11.

Conclusion

Knowing the spectrum of electrocardiographic findings compatible with an acute coronary occlusion in the context of an acute coronary event is essential for early diagnosis and prompt coronary reperfusion, which leads to a reduction in complications and mortality of patients with these findings.

Author’s contributions:

DAEM: Bibliografic search, review, structure, writing; CJS: Bibliografic search, review, structure, writing; CFRR: Bibliografic search, review, structure, writing; GACA: Bibliografic search, review, structure, writing; AFMA: Bibliografic search, review, structure, writing.
Bibliographic References


