Journal of Electrocardiology 52 (2019) 1–5

Contents lists available at ScienceDirect

Journal of Electrocardiology

journal homepage: www.jecgonline.com

# Prevalence of junctional ST-depression with tall symmetrical T-waves in a pre-hospital field triage system for STEMI patients

Ruben W. de Winter, BSc [a], Rob Adams, MSc [a], Giovanni Amoroso, MD, PhD [b], Yolande Appelman, MD, PhD [c], Lucia ten Brinke, BSc [c], Bart Huybrechts, BSc [d], Pieternel van Exter, MD [d], Robbert J. de Winter, MD, PhD [a,*]

[a] Department of Cardiology, Academic Medical Center - University of Amsterdam, Meibergdreef 9, 1105AZ Amsterdam, the Netherlands
[b] Department of Cardiology, OLVG Oost, Oosterpark 9, Amsterdam Oost, the Netherlands
[c] Department of Cardiology, VU University Medical Center, De Boelelaan 1117, 1081, HV, Amsterdam, the Netherlands
[d] Amsterdam Ambulance Organization, the Netherlands

ARTICLE INFO

*Keywords:*
STEMI equivalence
LAD occlusion
Electrocardiogram
Prevalence

ABSTRACT

*Introduction:* The prevalence of the junctional ST-depression with tall symmetrical T-waves in a field triage system for ST-Elevation Myocardial Infarction (STEMI) is unknown.
*Material and methods:* We prospectively collected all transmitted 12-lead electrocardiograms (ECGs) from the STEMI field triage system in Amsterdam from 2011 to 2013. Electrocardiograms with junctional ST-depression with tall symmetrical T-waves were recognized and angiographic documentation and clinical follow up were collected.
*Results:* A total of 5588 patients with at least 1 transmitted field ECG were identified from the database. ST-elevation infarction was present on the field ECG in 1864 patients (33%) and 701 ECGs (12,5%) showed anterior infarction. In 11 patients, junctional ST-depression with tall symmetrical T-waves was identified (0,2% of total transmitted ECGs and 1,6% of anterior infarctions). The 11 angiograms invariably showed involvement of the proximal Left Anterior Descending (LAD) artery (segment 5,6 and 7). Mortality was 27% within the first week.
*Conclusions:* An ECG with junctional ST-depression with tall symmetrical T-waves is an infrequent finding. Because this pattern of STEMI equivalent is associated with LAD occlusions, it is important to recognize this pattern, so patients can be transported to the catheterization laboratory without delay.


## Introduction

Primary percutaneous coronary intervention (PCI) is the preferred treatment for patients with ST-elevation myocardial infarction (STEMI) (European Society of Cardiology guidelines [1]). A system of prehospital field triage, with 12-lead electrocardiogram (ECG) performed by ambulance personnel in patients presenting with chest pain, has been shown to be able to identify STEMI patients and shorten time to reperfusion [2,3]. ECG manifestations of a STEMI are: new ST-elevation at the J point in two contiguous leads with the cut-points: ≥0.1 mV in all leads other than leads V2–V3 where the following cut points apply: ≥0.2 mV in men ≥40 years; ≥0.25 mV in men <40 years, or ≥0.15 mV in women [4]. More recently, patients are increasingly recognized without ST-elevation on the standard 12-lead electrocardiogram, who do have an acute thrombotic occlusion of a large epicardial coronary artery and qualify for urgent mechanical reperfusion with primary PCI [5,6]. One of such ECG patterns without ST-elevation, so called STEMI equivalents, is junctional ST-depression with tall symmetrical T-waves (called the "de Winter T-wave" by some [7]). This was previously found to be associated with proximal left anterior descending (LAD) occlusion and was present in 2% of the anterior myocardial infarctions in one study [8,9]. The aim of our study is to demonstrate the prevalence of this pattern in a prehospital field triage system in Amsterdam.

## Materials and methods

In 2003, an ECG field triage system was implemented in the larger Amsterdam region for the timely recognition of STEMI patients. Ambulances are alerted by general practitioners or a central emergency dispatch center to patients with chest pain. Ambulance staff records the patients 12 lead ECG and transmits this to 1 of

* Corresponding author at: Dept. of Cardiology, B2-137, Academic Medical Center, Meibergdreef 9, 1105AZ Amsterdam, the Netherlands.
*E-mail address:* r.j.dewinter@amc.uva.nl (R.J. de Winter).

https://doi.org/10.1016/j.jelectrocard.2018.10.092
0022-0736/

**Table 1**
Age, gender and ECG characteristics from patients whose ECG was transmitted within the field triage setting.

| Characteristic | Anterior MI ($n = 701$) | Non anterior MI ($n = 1163$) | Other ($n = 3724$) | Total ($n = 5588$) |
|---|---|---|---|---|
| Age (years) mean ± SD | 62 ± 15 | 63 ± 14 | 64 ± 16 | 64 ± 16 |
| Gender (F, M, missing) | 87, 194, 420 | 154, 306, 703 | 447, 735, 2542 | 688, 1235, 3665 |
| Heart frequency (bpm) mean ± SD | 81 ± 23 | 74 ± 23d | 88 ± 30 | 84 ± 28 |
| Left bundle branch block n(%) | 1 (0,1) | 3 (0,3) | 366 (9,8) | 370 (6,6) |
| Right bundle branch block n(%) | 28 (4,0) | 41 (3,5) | 417 (11,2) | 486 (8,7) |
| Atrial fibrillation n(%) | 28 (4,0) | 59 (5,1) | 324 (8,7) | 411 (7,4) |
| ST-depression without ST elevation n(%) | – | – | 433 (11,6) | 433 (7,7) |
| Lead I ST height (mm) mean ± SD | 0,64 ± 1,18 | −0,46 ± 1,14 | −0,12 ± 0,89 | −0,09 ± 1,03 |
| Lead II ST height (mm) mean ± SD | −0,19 ± 1,42 | 1,95 ± 1,77 | −0,12 ± 1,48 | 0,29 ± 1,75 |
| Lead III ST height (mm) mean ± SD | −0,83 ± 1,53 | 2,41 ± 2,17 | 0,00 ± 1,48 | 0,39 ± 1,96 |
| Lead AVR ST height (mm) mean ± SD | −0,73 ± 12,8 | −0,78 ± 1,50 | 0,10 ± 1,30 | −0,19 ± 4,76 |
| Lead AVL height (mm) mean ± SD | 0,74 ± 1,16 | −1,43 ± 1,50 | −0,06 ± 0,97 | −0,23 ± 1,31 |
| Lead V1 height (mm) mean ± SD | 1,08 ± 1,20 | −0,32 ± 1,26 | 0,53 ± 1,28 | 0,43 ± 1,33 |
| Lead V2 height (mm) mean ± SD | 3,34 ± 1,87 | −0,86 ± 1,97 | 0,83 ± 1,91 | −0.81 ± 2,25 |
| Lead V3 height (mm) mean ± SD | 1,35 ± 2,40 | 0,52 ± 1,52 | 0,51 ± 1,45 | 0.62 ± 1,64 |
| Lead V4 height (mm) mean ± SD | 2,45 ± 2,60 | 0,41 ± 2,04 | 0,25 ± 1,89 | 0,56 ± 2,15 |
| Lead V5 height (mm) mean ± SD | 0,90 ± 1,93 | 0,67 ± 2,62 | −0,22 ± 1,54 | 0,11 ± 1,92 |
| Lead V6 height (mm) mean ± SD | −0,17 ± 2,47 | 0,65 ± 1,42 | −0,34 ± 1,31 | −0,12 ± 1,58 |

The information that was available on the transmitted ECG's is summarized here. By ambulance protocol age, time of onset of symptoms and the time stamp of the ECG was available. Gender was missing in 61%. The presence of left bundle branch block, right bundle branch block, atrial fibrillation and ST-depression without ST elevation was scored by two experienced ECG readers (RWDW, RJDW) Millimeters of ST elevation or ST depression was copied from the automatic ECG reading system (Lifepak 12, Physio-Control, Inc. Redmond WA, USA).

the 3 (high volume) PCI capable hospitals in the region. The decision to transmit ECGs is at the discretion of the ambulance staff but mandated in case of symptoms compatible with acute coronary syndrome and/or ECG abnormalities. Together with the cardiologist of the PCI center, direct transfer is coordinated to the catheterization laboratory for urgent reperfusion therapy. All ambulance staff was trained in recording high quality standard 12 lead ECGs in patients with chest pain which was recorded with the Lifepak 12 system (Lifepak 12, Physio-Control, Inc. Redmond WA, USA). Telephone communication was established between the

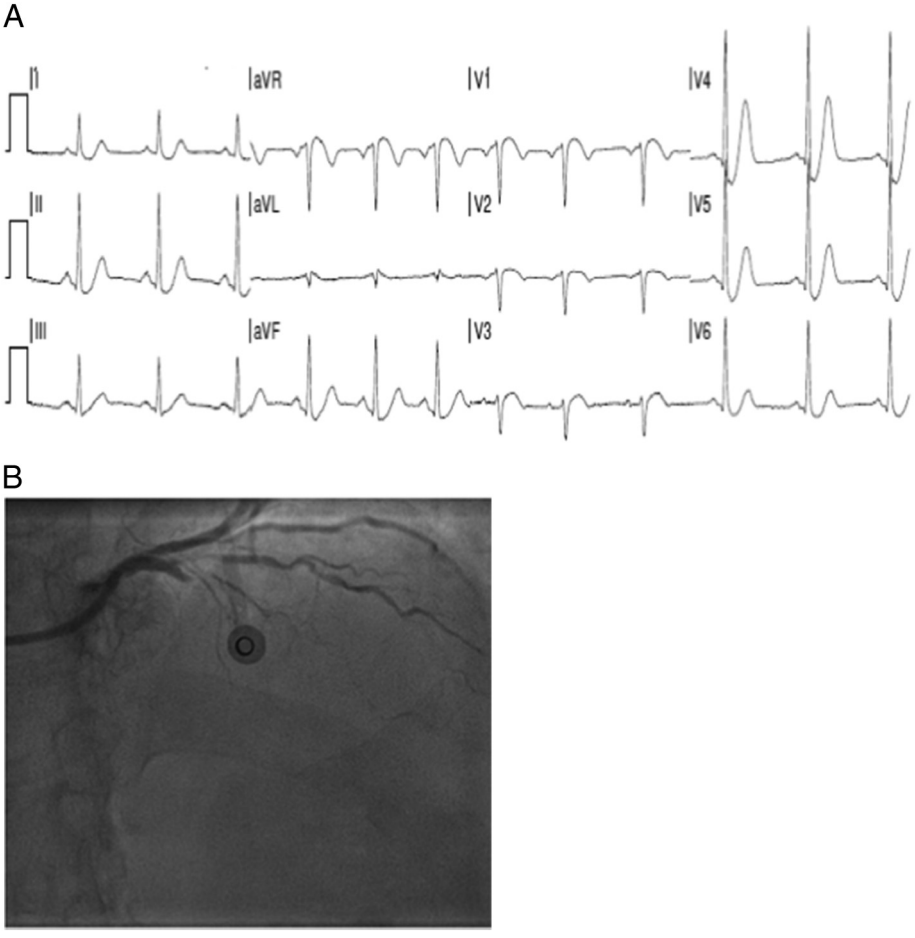


**Fig. 1.** A. 12-lead standard electrocardiogram of patient number 1 showing junctional ST-depression and tall symmetrical T-waves. B. Initial coronary angiogram of patient number 1 showing occluded proximal left anterior descending coronary artery with TIMI 0 flow.

cardiologist at the PCI center and the ambulance personnel and the indication for primary PCI was established. During outside office hours, the cathlab team was alerted while the patient was transported to the PCI center, providing a response time of 30 min. Ambulance staff were encouraged to transmit ECGs with a low threshold of suspicion for acute myocardial infarction. In general, automated computed descriptions of ECG abnormalities from the Lifepak system were ignored. All transmitted ECGs were stored in a central database as a PDF file and the identification of STEMI (anterior or non-anterior STEMI) and STEMI equivalents was prospectively planned. The patients' age and gender are noted on the transmitted ECGs. Experienced ECG readers (RWDW, RJDW) reviewed all ECGs that were transmitted within the system from January 2011 until December 2013. ECGs were classified as showing anterior ST-elevation infarction or non-anterior ST-elevation infarction, other abnormalities suspect for infarction or ischemia and the presence of arrhythmias, conduction defects and/or the presence of bundle branch block. From the patients showing junctional ST-depression with tall symmetrical T-waves [9] on the field ECG, the angiograms were retrospectively collected from the 3 PCI hospitals. Angiograms were reviewed by two interventional cardiologists (RJDW, GA). In September 2017, vital status of patients was checked with the Dutch City council registry and hospital records were checked of the 11 patients showing junctional ST-depression with tall symmetrical T-waves. This project collected data in order to evaluate the quality and performance of clinical practice within the pre-hospital triage system. The medical ethics committee provided a waiver for this study.

*Statistical analysis*

The study was of an exploratory nature. No formal sample size calculation or statistical plan was drawn. All data was analyzed with SPSS (version 24, IBM, Chicago, IL, USA). Means were calculated with available data. For missing values, no data was imputed. Descriptive statistics were used to describe the prevalence of ST elevation on the field ECGs and percentage of ECGs showing junctional ST-depression with symmetrical tall T-waves. Data collection was part of clinical outcome assessment in the 3 participating centers. All data was anonymized prior to analysis. All data was collected and anonymized and considered part of quality control of the pre-hospital triage system by the participating centers.

## Results

A total of 5588 patients with at least 1 transmitted field ECG were identified from the database. The average age of the patients was 64 ± 16 years, 65% were male. A total of 1864 ECGs showed ST-elevation infarction (33%) and 701 patients (12,5%) showed anterior ST-elevation infarctions (Table 1).

In 11 patients, junctional ST-depression with tall symmetrical T-waves was identified (0,2% of total transmitted ECGs and 1,6% of anterior myocardial infarctions). As an example, Fig. 1A shows a 12-lead standard ECG transmitted by the ambulance staff of patient number 1. The initial coronary angiogram showed an occluded proximal left anterior descending coronary artery (Fig. 1B). Fig. 2 shows the ECGs of 11 patients, demonstrating the variation in electrocardiographic appearance.

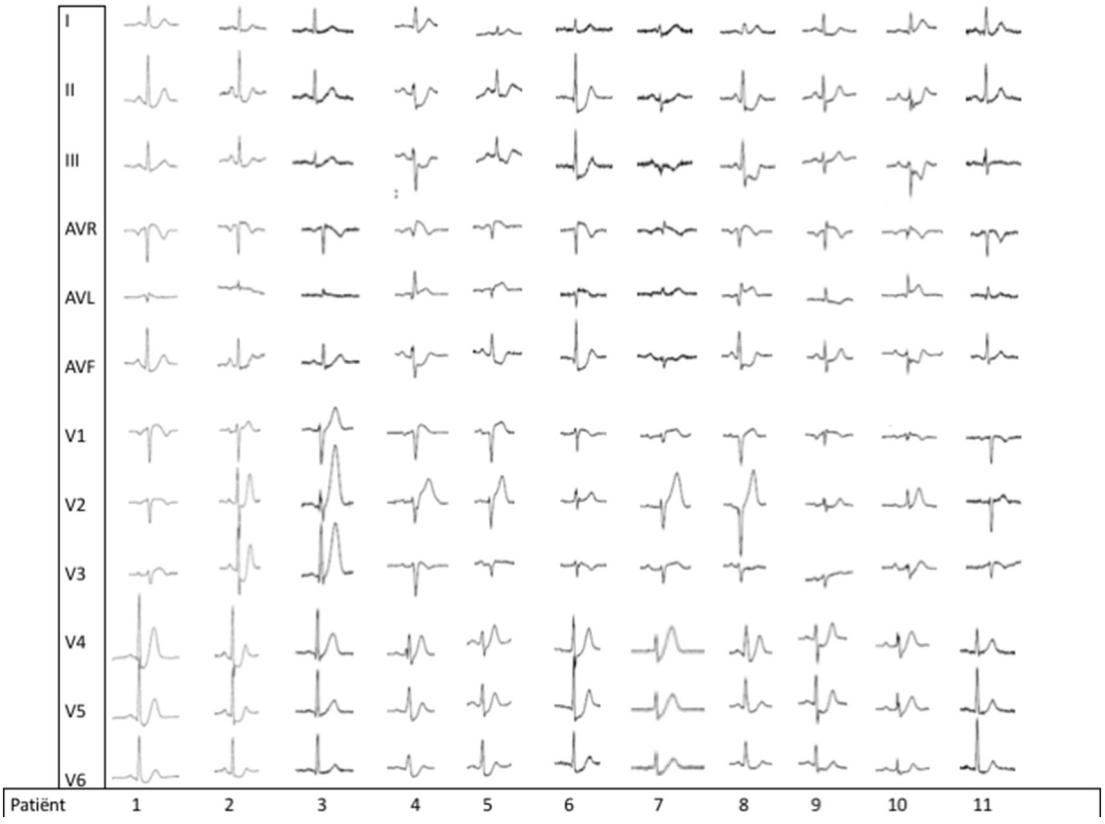


**Fig. 2.** 12 lead electrocardiograms of all 11 patients that were transmitted by the ambulance staff to the PCI centers, showing the variation in electrocardiographic appearance. In the Amsterdam pre-hospital triage system, lead V3 is positioned V3R. In patients 2 and 3, a normal V3 was registered. In all patients, the left anterior descending coronary artery was the infarct related artery. Also note frequent occurrence of ST-depression in leads II, III and AVF (cases 1, 2, 4, 5, 6, 8 and 10) and ST elevation in lead AVR (cases 1, 2, 4, 5, 6, 8, and 9). In patient number 9 and 11, junctional depression in leads V4-V6 and ST elevation in AVR was subtle.

**Table 2**
Age, gender, time to treatment and follow up of the 11 patients with junctional ST-depression and tall symmetrical T-waves.

| N | Age (years) | Gender | Heart frequency (bpm) | Time interval between first medical contact to start PCI procedure | Infarct related segment | Follow up | Time to follow up |
|---|---|---|---|---|---|---|---|
| 1 | 62 | M | 71 | 1 h 39 min | 6 | Alive | 76 months |
| 2 | 66 | M | 90 | 1 day 22 h 59 min | 7 | Alive | 75 months |
| 3 | 48 | M | 66 | 1 h 47 min | 7 | Alive | 64 months |
| 4 | 73 | M | – | 1 h 12 min | 5 | Deceased | Day 6 |
| 5 | 60 | M | 94 | 1 h 11 min | 7 | NA (tourist) | – |
| 6 | 71 | M | 77 | 3 days 9 h 3 min | 7 | NA (tourist) | – |
| 7 | 77 | M | 68 | 1 h 1 min | 6 | Alive | 47 months |
| 8 | 45 | M | 91 | 1 h 12 min | 6 | Deceased | Day 2 |
| 9 | 66 | M | 77 | 2 h 10 min | 5 | Deceased | Day 1 |
| 10 | 88 | F | 80 | 1 h 9 min | 7 | Alive | 71 months |
| 11 | 62 | M | 73 | 56 min | 6 | Alive | 70 months |

In all 11 patients, the proximal or mid LAD was the culprit of the infarct related artery identified at the time of the first coronary angiogram (segment 5, 6 or 7).

Table 2 summarizes the characteristics of all 11 patients. In 2 patients, reperfusion therapy was not administered in a timely fashion. The time from field ECG to first coronary angiogram was >3 days in patient 6 and almost 2 days in patient 2. In the other patients, urgent angiogram was performed within several hours. Of these 11 patients, 3 died on day 1, 2 and 6. Two patients were tourists who survived until hospital discharged but follow up could not be obtained. Supplement Fig. 1 shows the 11 angiograms.

## Discussion

Most patients with an acute myocardial infarction caused by an occlusion in a large epicardial coronary artery show ST elevation on the prehospital field triage ECG. For these patients, direct reperfusion therapy by primary PCI is the first choice of treatment. Immediate transportation to a PCI center and alerting the cathlab staff is essential. In the recent TASTE study, overall 30-day mortality was 2.9%, with the highest mortality in patients with anterior infarctions (infarct related artery LAD 4.0%, LCx 2.4% and RCA 1.8%) [10]. In addition, in a subgroup analysis of the INFUSE-AMI study, Brener et al. reiterate increased 30-day mortality with involvement of the proximal LAD versus the mid LAD (4.2% vs. 0.6%) [11]. However, in approximately 10–20% of patients with an acute myocardial infarction caused by acute occlusion of a large epicardial coronary artery, ST elevation is not present on the standard 12-lead ECG [12]. These are also called the STEMI equivalents [5]. In 2008, we presented an ECG pattern of junctional ST-depression with tall symmetrical T-waves which was associated with proximal LADclusion [9]. Since then several case reports confirmed this observation [13,14]. The prevalence of this particular STEMI equivalent was reported to be 2% in a consecutive cohort of anterior STEMI patients from the primary PCI database of a single center [8].

In the present study, we investigated the prevalence of this ECG pattern in a field triage system for STEMI patients in the larger Amsterdam area. The total number of transmitted ECGs, the number of ECGs with ST elevation that signified acute myocardial infarction and the number of ECGs with junctional ST-depression with tall symmetrical T-waves from a period of 3 years were reported. We identified 11 patients (1,6% of anterior infarctions) with an ECG showing junctional ST-depression with tall symmetrical T-waves. Ten out of eleven patients were male, confirming the findings by Verouden et al. (33 male/2 female) [8]. We confirmed that the LAD was involved in all our patients and that significant delays up to several days occurred in some patients. Because this pattern of STEMI equivalent is associated with LAD occlusions, it is important to recognize this pattern, so patients can be transported to the catheterization laboratory without delay.

Strict criteria for this pattern are not yet fully established. In a recent analysis, Morris et al. described quantitative criteria for the so called “de Winter” pattern. Some degree of upsloping ST depression was found in the precordial leads, most often in lead V3, with a median height of 3 mm (IQR 2–4 mm) and the T-wave height peaked in lead V3 with a median amplitude 0.9 mV (interquartile range: 0.8–1.1 mV) [15]. It may be a challenge to educate ambulance staff, emergency physicians and cardiologists and make them familiar with this infrequent ECG pattern. Every 3 months, approximately 50 anterior MI ECGs will be recorded for every single ECG with J-point depression and tall symmetrical T-waves, within the entire Amsterdam prehospital triage system. Therefore, it may be more effective and practical to maintain a low threshold for ECG transmission to a PCI center in patients with chest pain and invest in ECG-reading skills of the physicians at the PCI center. Alternatively, neural network based self-learning computer systems, with pattern recognition algorithms can better distinguish these specific STEMI equivalent.

Our study has some limitations. Some patients with junctional ST-depression with tall symmetrical T-waves may have been missed if the field ECG was not transmitted within the system. In addition, we only have the transmitted field ECG, no serial ECG or cathlab ECGs were available. Our field triage system services the inner city of Amsterdam and 2 of our patients were tourists in whom follow up after hospital discharge was missing. Furthermore, the combination of junctional ST-depression and tall symmetrical T-waves can be transient or persistent and the exact electrophysiological explanation of the occurrence of this particular ECG pattern is still unknown [6,14]. One possible explanation for the pattern of junctional depression in the precordial leads and tall symmetrical T-Waves was given by Gorgels APM, in 2009 [16]. There may be subendocardial localization of ischemia and resulting behavior of the subendocardial action potentials, compared to the subepicardial action potentials.

## Conclusions

An ECG with junctional ST-depression with tall symmetrical T-waves is an infrequent finding in a field triage STEMI system (1,6% of all anterior infarctions). The association of this pattern with transmural, anterior wall ischemia is strong and the evidence supporting the need for direct reperfusion therapy is accumulating. All professionals involved in the care for patients with acute myocardial infarction should be able to recognize this pattern, so patients will receive optimal and timely treatment. A major goal of research is to prospectively establish the diagnostic accuracy in other large field triage systems.

## Acknowledgement

RWdW and RJdW conceived the study and designed the trial. RWdW, RJdW, RA, GA, YA LtB, BH PvE supervised the conduct of the trial and data collection. RJdW, RA and BH managed the data, including quality control. RJdW and RWdW analyzed the data; RWdW drafted the manuscript, and all authors contributed substantially to its revision. RJdW takes responsibility for the paper as a whole.

Special thanks to the ambulance personnel and the nursing staff of the ECG receiving stations at the coronary care units of the respective hospitals.

## Funding

None.

## Declarations of interest

None.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jelectrocard.2018.10.092.

## References

[1] Ibanez B, James S, Agewall S, Antunes MJ, Bucciarelli-Ducci C, Bueno H, et al. 2017 ESC guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation: The Task Force for the management of acute myocardial infarction in patients presenting with ST-segment elevation of the European Socie. Eur Heart J August 2017. https://doi.org/10.1093/eurheartj/ehx393.

[2] Kalla K, Christ G, Karnik R, Malzer R, Norman G, Prachar H, et al. Implementation of guidelines improves the standard of care: the Viennese registry on reperfusion strategies in ST-elevation myocardial infarction (Vienna STEMI registry). Circulation 2006;113(20):2398–405. https://doi.org/10.1161/CIRCULATIONAHA.105.586198.

[3] Adams R, Appelman Y, Bronzwaer JG, Slagboom T, Amoroso G, Exter van, et al. Implementation of a prehospital triage system for patients with chest pain and logistics for primary percutaneous coronary intervention in the region of Amsterdam, the Netherlands. Am J Cardiol 2010;106(7):931–5. https://doi.org/10.1016/j.amjcard.2010.05.022.

[4] Thygesen K, Alpert JS, Jaffe AS, Simoons ML, Chaitman BR, White HD, et al. Third universal definition of myocardial infarction. Eur Heart J 2012;33(20):2551–67. https://doi.org/10.1093/eurheartj/ehs184.

[5] Amsterdam EA, Wenger NK, Brindis RG, Casey DE, Ganiats TG, Holmes DR, et al. 2014 AHA/ACC Guideline for the management of patients with Non-St-Elevation Acute Coronary Syndromes: A Report of the American College of cardiology/American Heart Association Task Force on Practice Guidelines, Vol 130; 2014. https://doi.org/10.1161/CIR.0000000000000134.

[6] Gorgels APM. ST-elevation and non-ST-elevation acute coronary syndromes: should the guidelines be changed? J Electrocardiol 2013;46(4):318–23. https://doi.org/10.1016/j.jelectrocard.2013.04.005.

[7] Baranchuk A, Bayes-Genis A. Naming and classifying old and new ECG phenomena. CMAJ 2016;188(7):485–6. https://doi.org/10.1503/cmaj.151209.

[8] Verouden NJ, Koch KT, Peters RJ, Henriques JP, Baan J, van der Schaaf RJ, et al. Persistent precordial "hyperacute" T-waves signify proximal left anterior descending artery occlusion. Heart 2009;95(20):1701–6. https://doi.org/10.1136/hrt.2009.174557.

[9] de Winter RJ, Verouden NJW, Wellens HJJ, Wilde AAM. A new ECG sign of proximal LAD occlusion. N Engl J Med 2008;359(19):2071–3. https://doi.org/10.1056/NEJMc0804737.

[10] Fröbert O, Lagerqvist B, Olivecrona GK, et al. Thrombus aspiration during ST-segment elevation myocardial infarction. N Engl J Med 2013;369(17):1587–97. https://doi.org/10.1056/NEJMoa1308789.

[11] Brener SJ, Witzenbichler B, Maehara A, Dizon J, Fahy M, El-Omar M, et al. Infarct size and mortality in patients with proximal versus mid left anterior descending artery occlusion: the intracoronary abciximab and aspiration thrombectomy in patients with large anterior myocardial infarction (INFUSE-AMI) trial. Am Heart J 2013;166(1):64–70. https://doi.org/10.1016/j.ahj.2013.03.029.

[12] Schmitt C, Lehmann G, Schmieder S, Karch M, Neumann FJ, Schomig A. Diagnosis of acute myocardial infarction in angiographically documented occluded infarct vessel: limitations of ST-segment elevation in standard and extended ECG leads. Chest 2001;120(5):1540–6.

[13] de Winter RW, Adams R, Verouden NJW, de Winter RJ. Precordial junctional ST-segment depression with tall symmetric T-waves signifying proximal LAD occlusion, case reports of STEMI equivalence. J Electrocardiol 2016;49(1):76–80. https://doi.org/10.1016/j.jelectrocard.2015.10.005.

[14] Fernandez-Vega A, Martínez-Losas P, Noriega FJ, Fernandez-Ortiz A, Biagioni C, Cruz-Utrilla A, et al. Winter is coming after a cardiac arrest. Circulation 2017;135(20):1977–8. https://doi.org/10.1161/CIRCULATIONAHA.116.026253.

[15] Morris NP, Body R. The De Winter ECG pattern: morphology and accuracy for diagnosing acute coronary occlusion: systematic review. Eur J Emerg Med 2017;24(4):236–42. https://doi.org/10.1097/MEJ.0000000000000463.

[16] Gorgels APM. Explanation for the electrocardiogram in subendocardial ischemia of the anterior wall of the left ventricle. J Electrocardiol 2009;42(3):248–9. https://doi.org/10.1016/j.jelectrocard.2009.01.002.