Acute chest pain and ECG – need for immediate coronary angiography?

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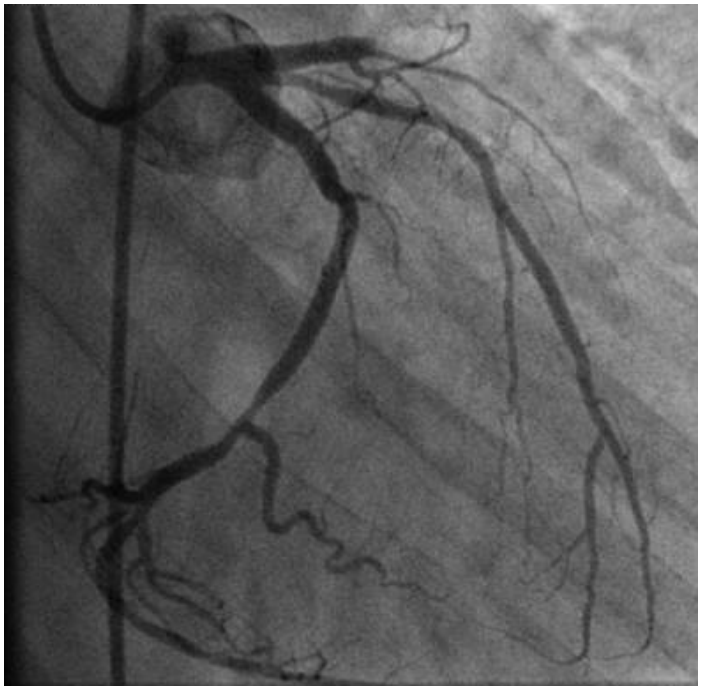
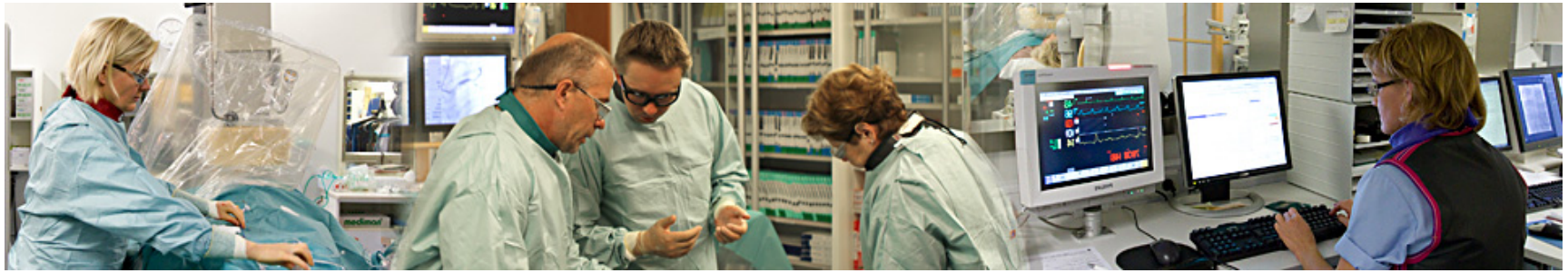
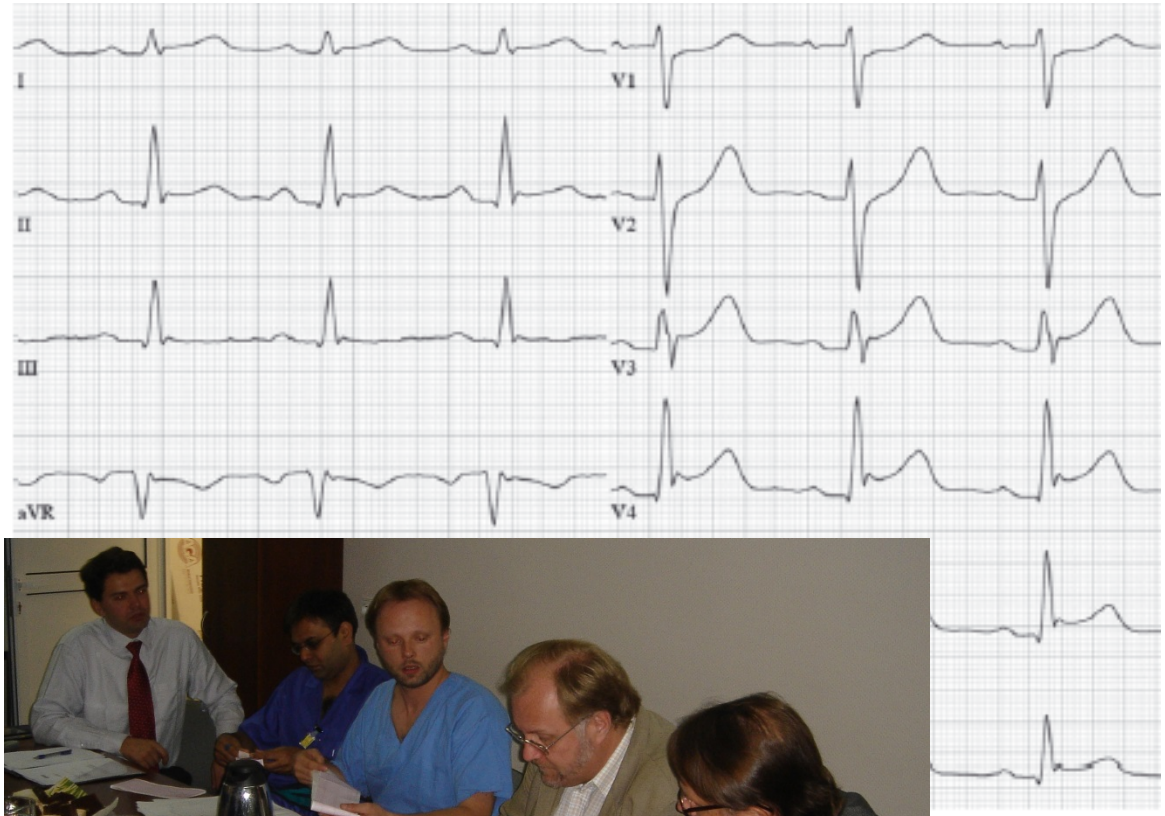
There are clear cases…





But also more challenging ones…

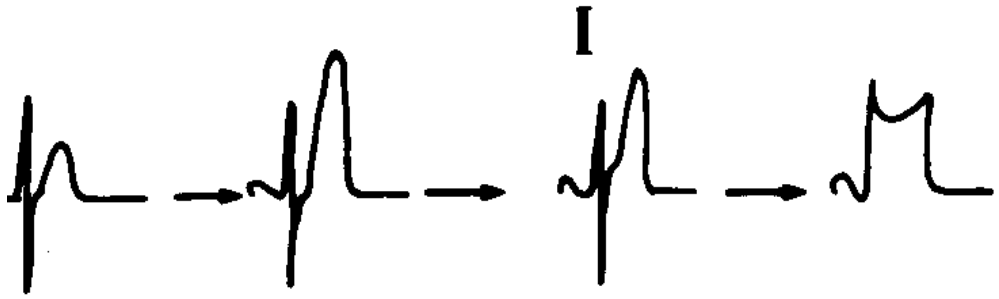


FACTORS AFFECTING ISCHEMIC ECG/ EGM CHANGES

- Pathophysiologic mechanism
  - Supply vs. demand ischemia
  - Total occlusion, stenosis, spasm
- Duration of ischemia
- Transmural vs. subendocardial ischemia
- Severity of ischemia
  - Myocardial protection (collateral flow, preconditioning, second artery)
- Localization vs. electrode(s) – properties of volume conductor (distance etc.), vector direction
- Baseline ECG changes → Importance of comparison
  - (BBB, PM, LVH, WPW, rotation, horizontal vs. vertical heart)
- Variation in coronary anatomy

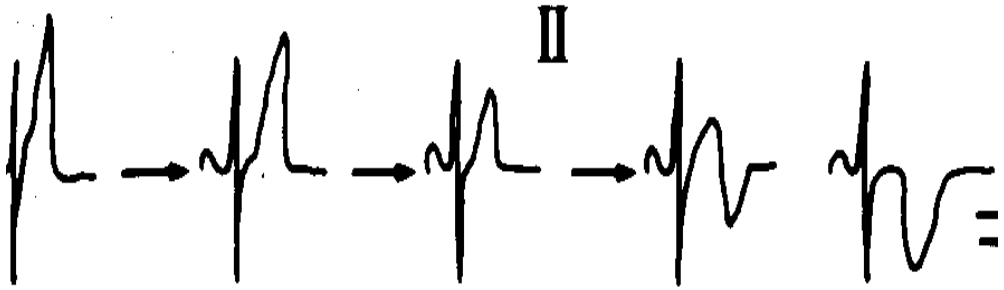
Timing of ECG changes in coronary occlusion

Stage I
Acute occlusion

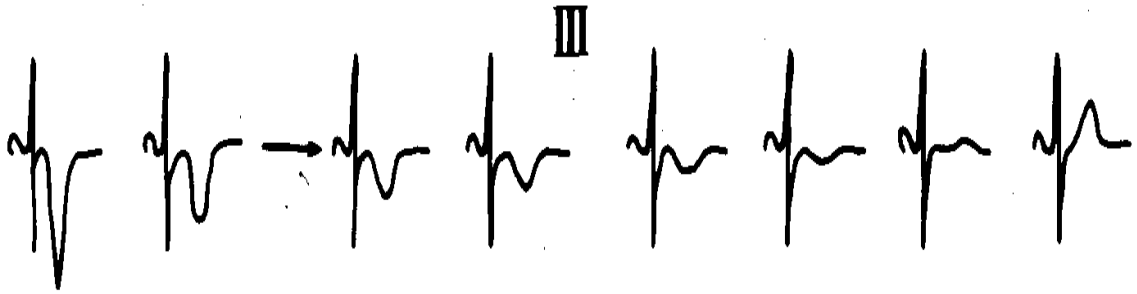


The presenting ECG may be recorded at any of these stages !

Stage II
Reperfusion



Stage III
Restoration of cell metabolism



European Heart Journal (2012) **33**, 2551–2567
doi:10.1093/eurheartj/ehs184

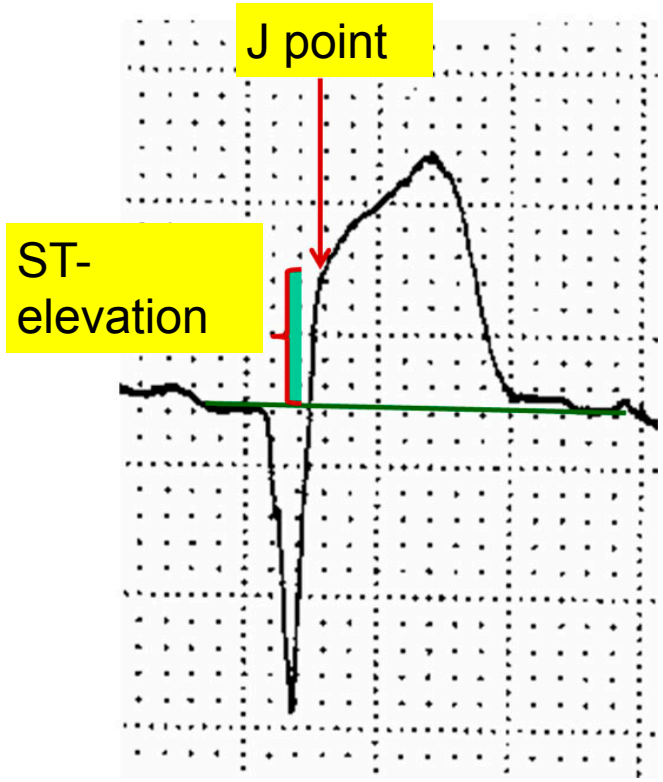
EXPERT CONSENSUS DOCUMENT

Third universal definition of myocardial infarction

Kristian Thygesen, Joseph S. Alpert, Allan S. Jaffe, Maarten L. Simoons, Bernard R. Chaitman and Harvey D. White: the Writing Group on behalf of the Joint ESC/ACCF/AHA/WHF Task Force for the Universal Definition of Myocardial Infarction

Table 3 ECG manifestations of acute myocardial ischaemia (in absence of LVH and LBBB)

ST elevation
New ST elevation at the J point in two contiguous leads with the cut-points: ≥0.1 mV in all leads other than leads V_2–V_3 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.
ST depression and T wave changes
New horizontal or down-sloping ST depression ≥0.05 mV in two contiguous leads and/or T inversion ≥0.1 mV in two contiguous leads with prominent R wave or R/S ratio >1.



The definition of ST elevation is clear, but…
not all ST elevation is STEMI
and on the other hand, acute coronary artery occlusion may be present without ST elevations fulfilling the criteria defined in the guidelines

”NISTE” (non-ischemic ST–elevation)

Table 1
Common patterns of NISTE

STE secondary to LVH
STE secondary to conduction defect (LBBB) and nonspecific IVCD
Early repolarization pattern (notched J-point mainly in anterolateral leads)
Normal variant of STE (nonischemic STE mainly V2-V3)
Concave STE
Old myocardial infarction/ aneurysm
Spontaneously reperfused myocardial infarction
Pericarditis
Brugada syndrome
Wolf-Parkinson-White syndrome (pre-excitation)
Takotsubo syndrome (apical ballooning syndrome)
Hypercalcemia
Hyperkalemia

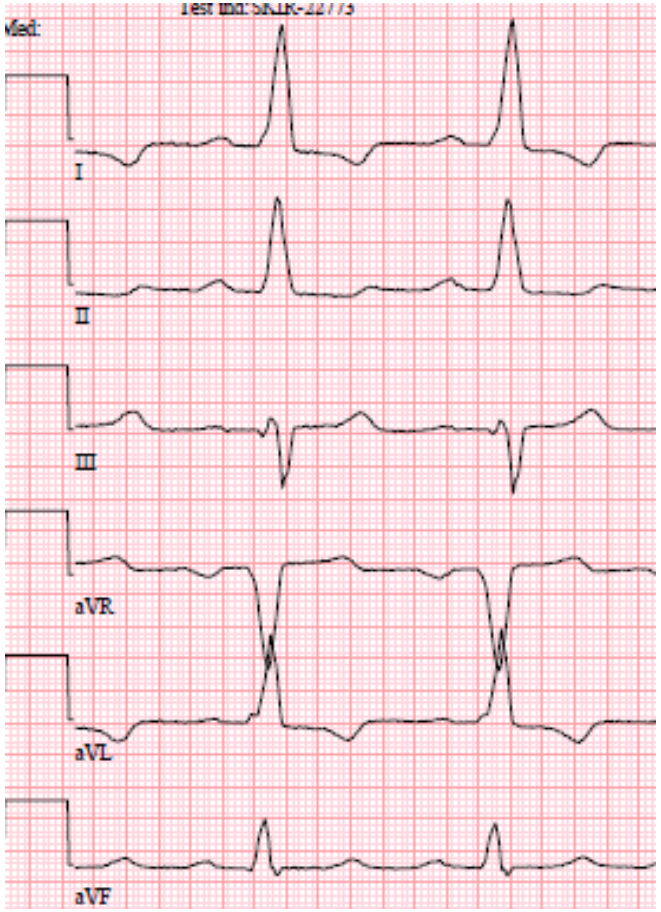
Huang HD et al JECG 2011

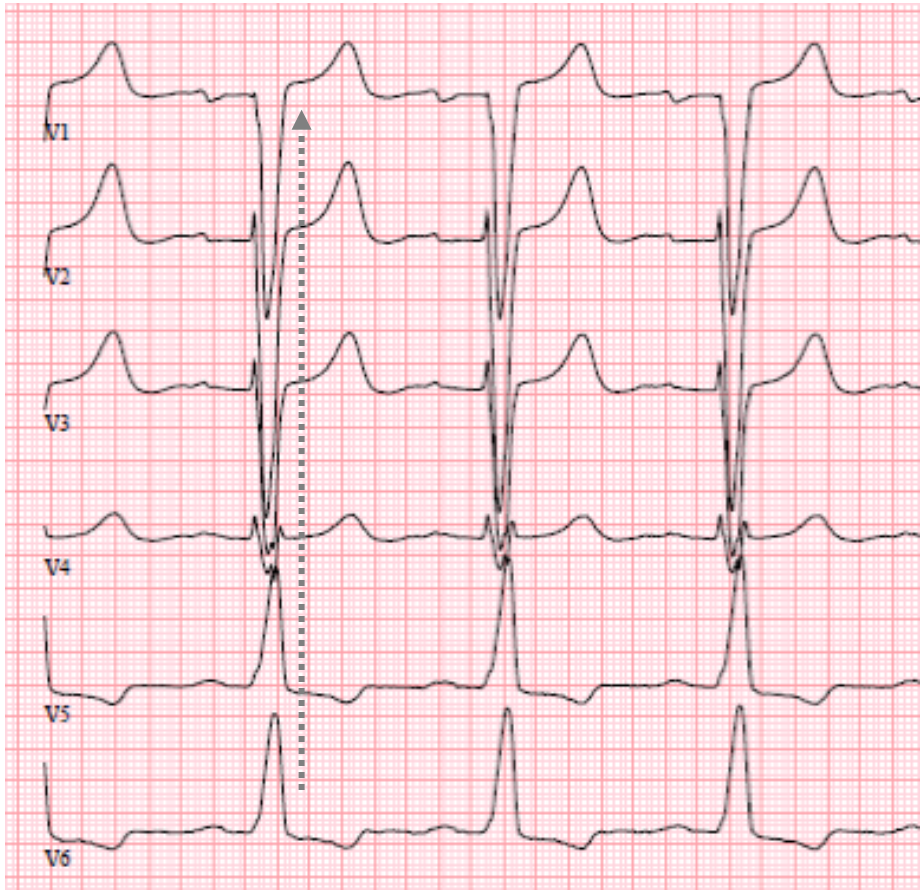
Etiologies for false-positive STEMI

Etiologies	n
Total false-positive STEMI patients (n = 31)	
Coronary spasm (including 2 patients with myocardial bridge)	11
Ventricular tachyarrhythmia status post-CPR	4
Previous MI	4
Acute perimyocarditis	4
Left ventricular hypertrophy	3
Takotsubo cardiomyopathy	3
Aortic dissection	1
Tachycardia related	1
Positive ED biomarker results (n = 13)	
Coronary spasm	4
Ventricular tachyarrhythmia status post-CPR	1
Previous MI	2
Acute perimyocarditis	2
Left ventricular hypertrophy	2
Takotsubo cardiomyopathy	1
Tachycardia related	1

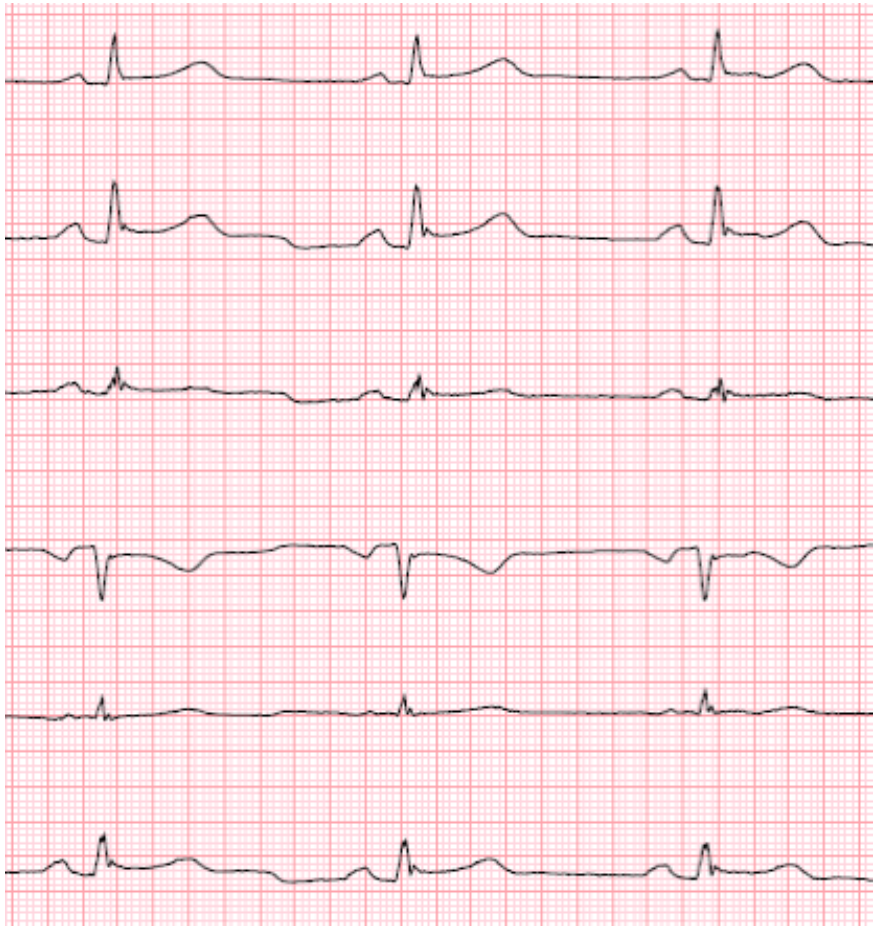
Chung S-L et al. Am J Emerg Med 2013

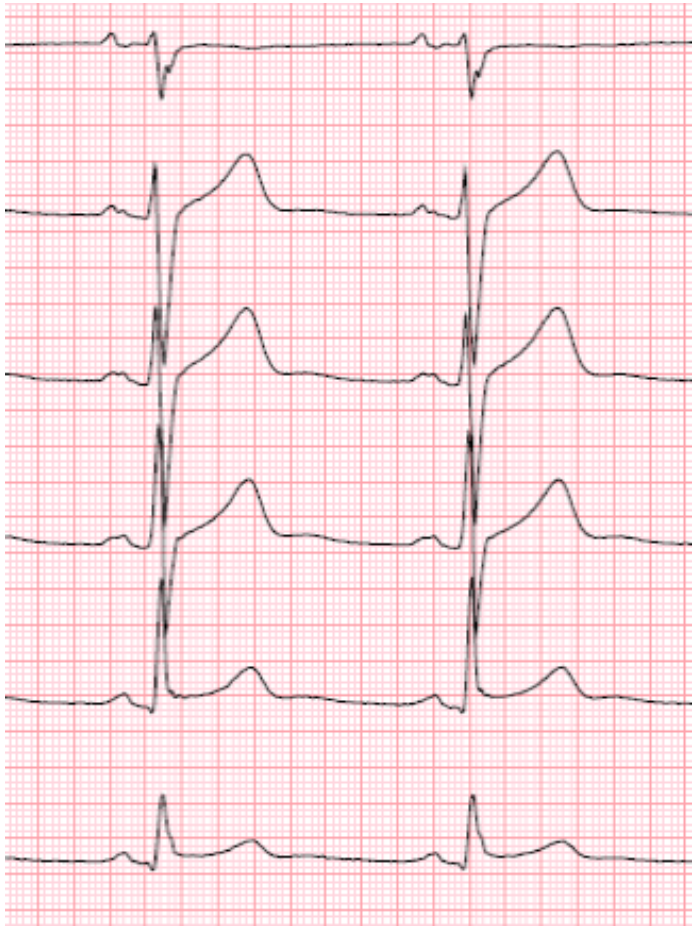
Chronic remodeling, for example in aortic stenosis: primary change ST depression V5-V6, reciprocal ST-elevations in V1-V2





Male 71 y. Chest pain, elevated CRP
No fever or obvious infection





PR Depression Is Useful in the Differential Diagnosis of Myopericarditis and ST Elevation Myocardial Infarction

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Background: Deviation of the PR segment is a common but often ignored ECG finding in acute myopericarditis, but seems to be rare in the acute phase of ST elevation myocardial infarction (STEMI). Since rapid bedside differential diagnosis of acute myopericarditis and STEMI is essential, we decided to assess the diagnostic power of PR depressions in patients presenting with ST elevations in the emergency room.

Methods: Thirty-four consecutive patients with acute myopericarditis and 46 STEMI patients presenting with ST elevations fulfilling the criteria for STEMI were included. The first ECG recorded in the emergency room was analyzed with a focus on the PR segment. The diagnoses of myopericarditis and STEMI were ascertained with clinical follow-up together with rise in troponin levels, and in the STEMI patients also with coronary angiography.

Results: In myopericarditis, the most common location for PR depression was lead II (55.9%), while this ECG finding least likely appeared in lead aVL (2.9%). PR depression in any lead had a high sensitivity (88.2%), but fairly low specificity (78.3%) for myopericarditis. The combination of PR depressions in both precordial and limb leads had the most favorable predictive power to differentiate myopericarditis from STEMI (positive 96.7% and negative power 90%).

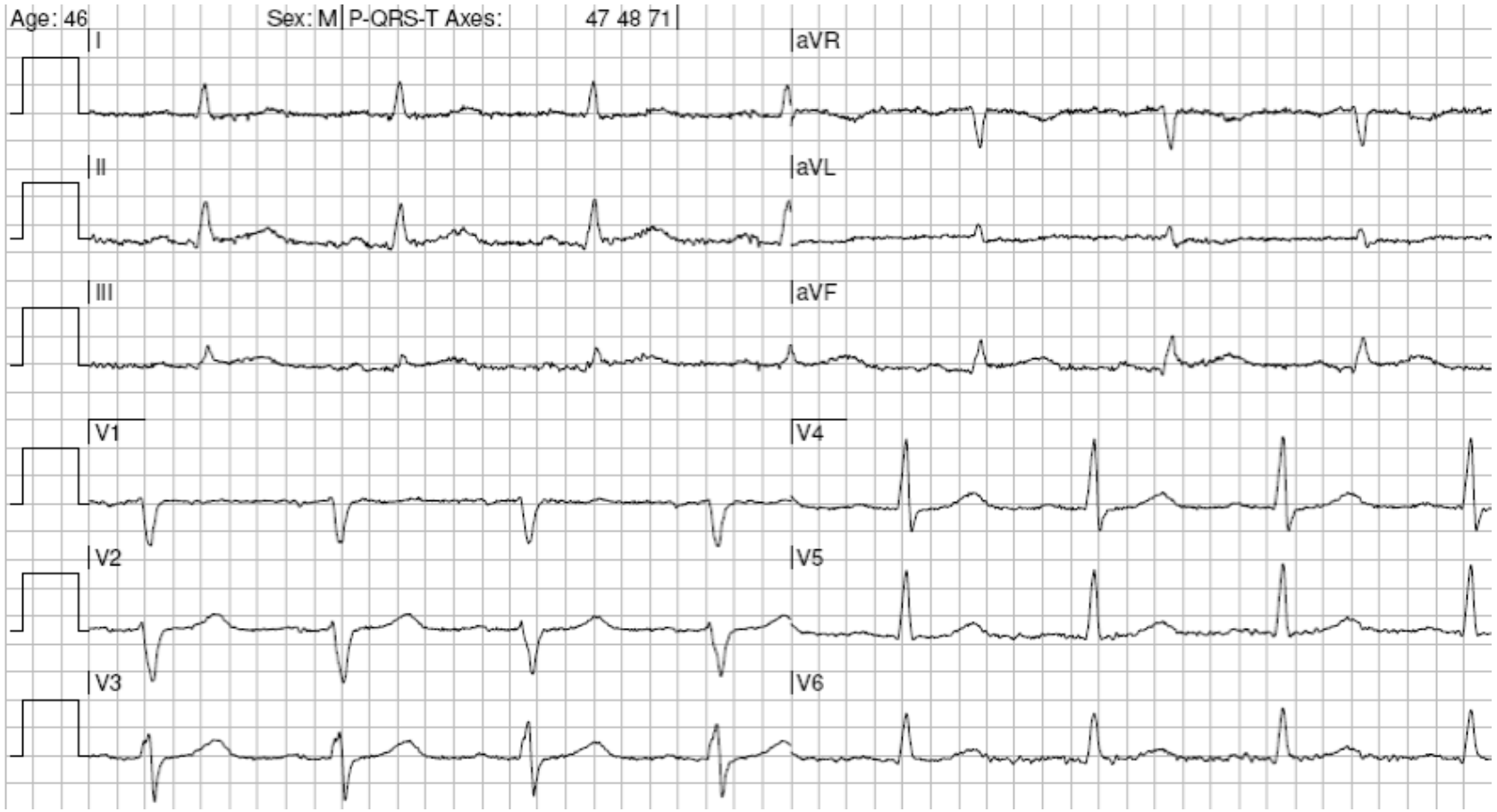
Conclusions: Our present observations show that PR segment analysis is a powerful tool in the differential diagnosis of myopericarditis and STEMI. This simple information should be added to the diagnostic workup of patients presenting with ST elevations.

Ann Noninvasive Electrocardiol 2012;17(2):141–145

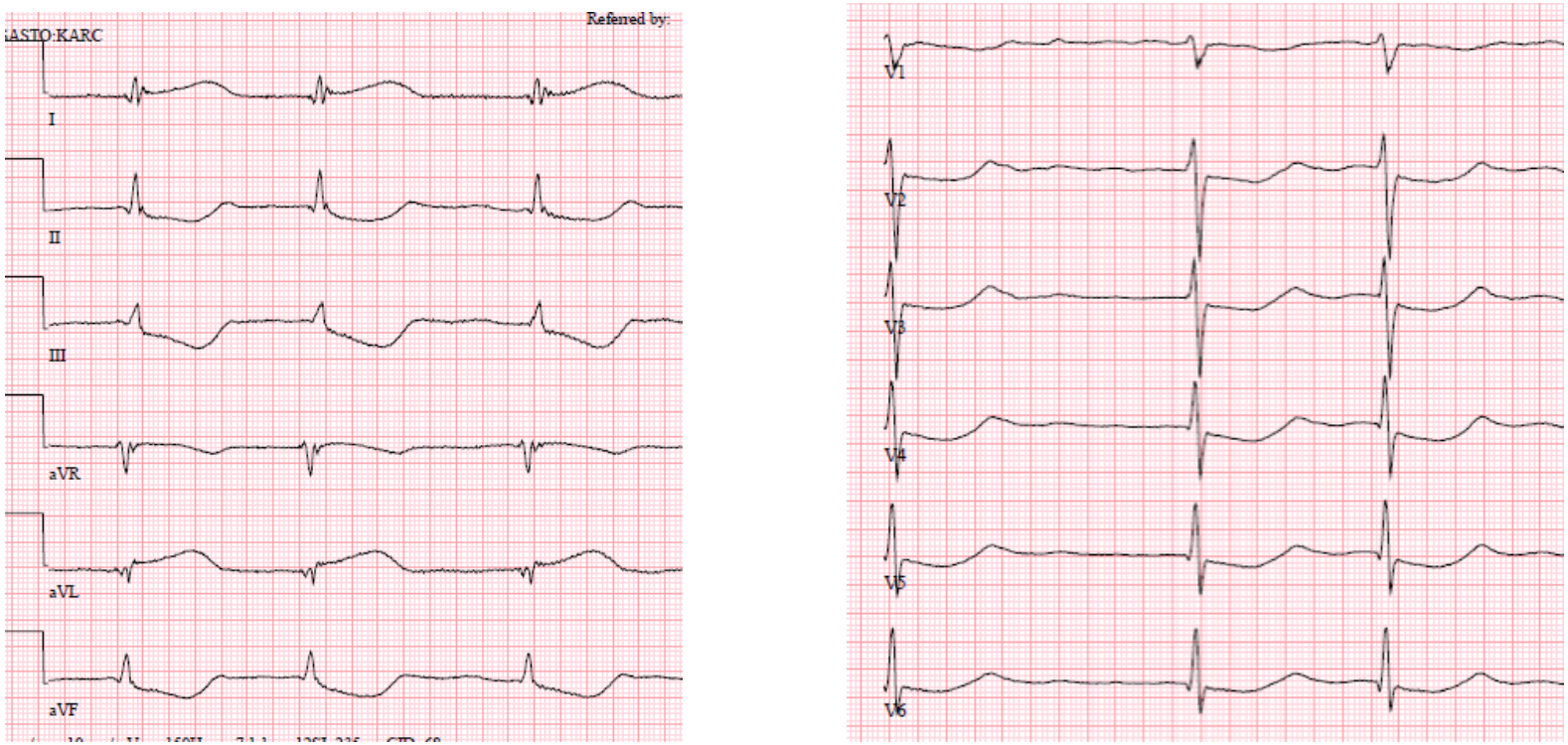
Some causes for STEMIs not recognized in the emergency department

- Sometimes the primary ischemic change (=ST-elevation) may be less evident than the secondary (reciprocal) ST depressions
- ST-elevations may be mild and appear in only 1 lead *(Birnbaum Y et al. Eur Heart J 1993)*
- Old Q-wave MI

Borderline ST-elevations in the leads II, III and aVF
Note reciprocal ST changes in aVL



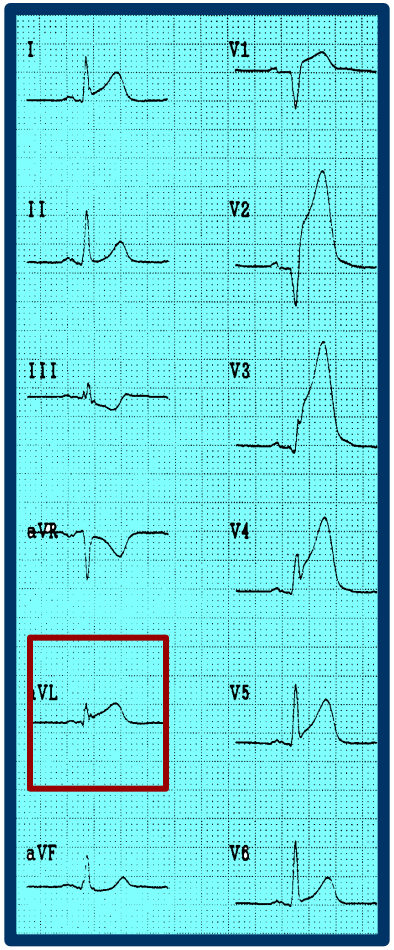
STEMI that could be misdiagnosed as NSTEMI (diagonal branch occlusion)
Eight leads with ST depression
Primary change is ST-elevation in I, aVL

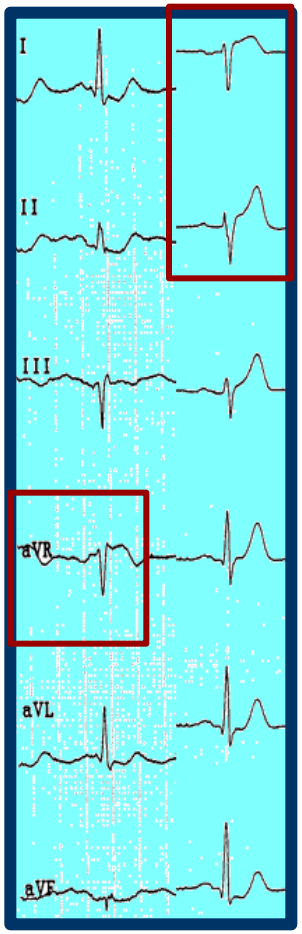


50 mm/sec

Very proximal LAD occlusions may have ST elevations only in V1-V2 (and aVR)

”aVL pattern” ~3/4





”aVR/V1 pattern” ~1/4

Eskola MJ et al. Int J Cardiol 2009

A working group proposed a pathophysiologic classification of ACS instead of categorical classification based strictly on the ECG presentations

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ScienceDirect
Journal of Electrocardiology 43 (2010) 91 – 103
JOURNAL OF Electrocardiology
www.jecgonline.com

Electrocardiographic classification of acute coronary syndromes: a review by a committee of the International Society for Holter and Non-Invasive Electrocardiology ☆

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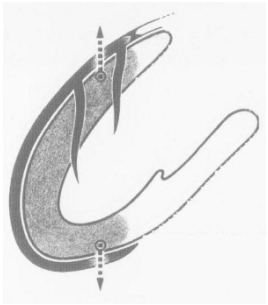
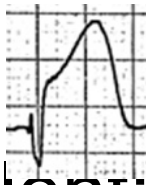
[l] *Cardiovascular Research Institute Maastricht, Maastricht, The Netherlands*
[m] *Cardiology Division of the Department of Medicine, University of Rochester Medical Center, Rochester, New York, USA*

A. Transmural ischemia

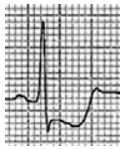


<u>ST elevation</u>

- Typical

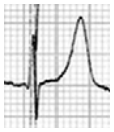


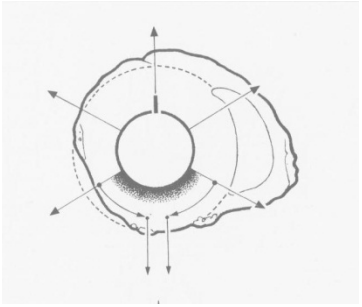
- STEMI-equivalent: ”mirror-image”



<u>T-wave change</u>

- Prominent T waves
- T-wave inversion (post-ischemic “finger prints”)





B. Subendocardial ischemia

ST/T changes

- Circumferential ischemia
- Regional ischemia

Normal ECG

Confounding factors

The most recent international STEMI guidelines point out the importance of recognizing ”atypical ECG presentations”

ESC STEMI guidelines 2012

Table 5 Atypical ECG presentations that deserve prompt management in patients with signs and symptoms of ongoing myocardial ischaemia

• LBBB
• Ventricular paced rhythm
• Patients without diagnostic ST-segment elevation but with persistent ischaemic symptoms
• Isolated posterior myocardial infarction
• ST-segment elevation in lead aVR

ECG = electrocardiogram; LBBB = left bundle branch block.

Non-ST elevation acute coronary syndrome – indications for immediate angiography?

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Journal of Electrocardiology 45 (2012) 463–475

JOURNAL OF Electrocardiology

www.jecgonline.com

Common pitfalls in the interpretation of electrocardiograms from patients with acute coronary syndromes with narrow QRS: a consensus report ☆

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Table 1
More common pitfalls in the ECG interpretation: see ECG pattern, type of ACS and involved artery, zone involved, and recommended management

	ECG patterns	Type of ACS and involved artery	Zone and characteristics of involvement	Management
A	ST depression in V_1-V_4: in the acute phase, prominent ST depression inV_1 without significant terminal positive T wave in V_1-V_2 See Figs. 1A, 3, and 4.	Probably, it is true STE-ACS (STE-ACS equivalent) due to LCX occlusion (rarely distal RCA). Patients have ongoing active symptoms.	Transmural lateral involvement	Emergent PCI
B	Leads V_1-V_4: isoelectric ST segment with tall, wide, positive T wave. Often a transient pattern See Fig. 1B1	Hyperacute phase of STE-ACS. Patient with angina Repeat ECG in few minutes Evolving to LAD total occlusion. Patients usually have ongoing active symptoms.	Anterior subendocardial involvement evolving to transmural involvement	Probably emergent PCI
C	Leads V_1-V_4: ST↓ plus tall positive T wave that evolves to Q wave MI. The change occurs in hours. See Figs. 1B3, 5 (right), 6, and 9B	NSTE-ACS evolving to STE-ACS usually in hours Usually LAD subocclusion evolving to total occlusion Patients usually have ongoing symptom.	Nontransmural involved wall evolving to transmural involvement.	Emergent PCI
D.	Leads V_1-V_3: isoelectric ST segment with mild negative T wave in V_1-V_3 See Fig. 8.	Resolution phase of NSTE-ACS. LAD subocclusion Patients usually have resolution of symptoms.	No transmural involvement	Most probably urgent PCI

1. ”Mirror-image” STEMI

Left circumflex occlusion

- Sensitivity of the ECG to detect acute coronary occlusion:
  - LAD 85-90%
  - RCA 70-90%
  - **LCx 32-50%**

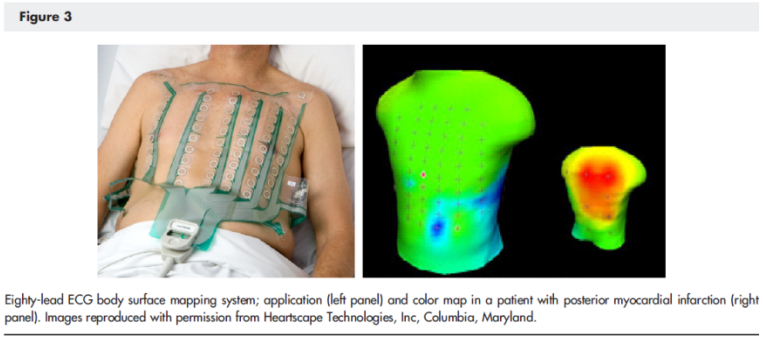
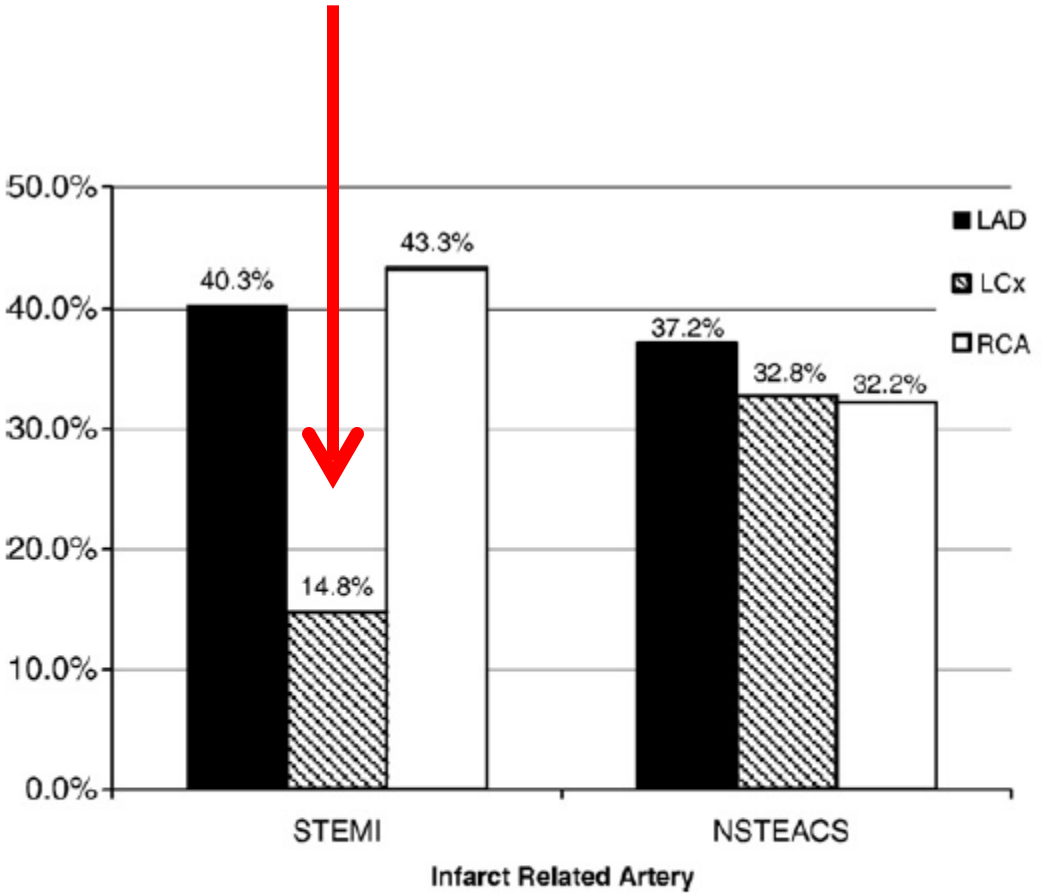


Figure 3

Eighty-lead ECG body surface mapping system; application (left panel) and color map in a patient with posterior myocardial infarction (right panel). Images reproduced with permission from Heartscape Technologies, Inc, Columbia, Maryland.

Role of additional leads
Neill J et al. Coron Art Dis 2010
Krishnaswamy et al. Am Heart J 2009

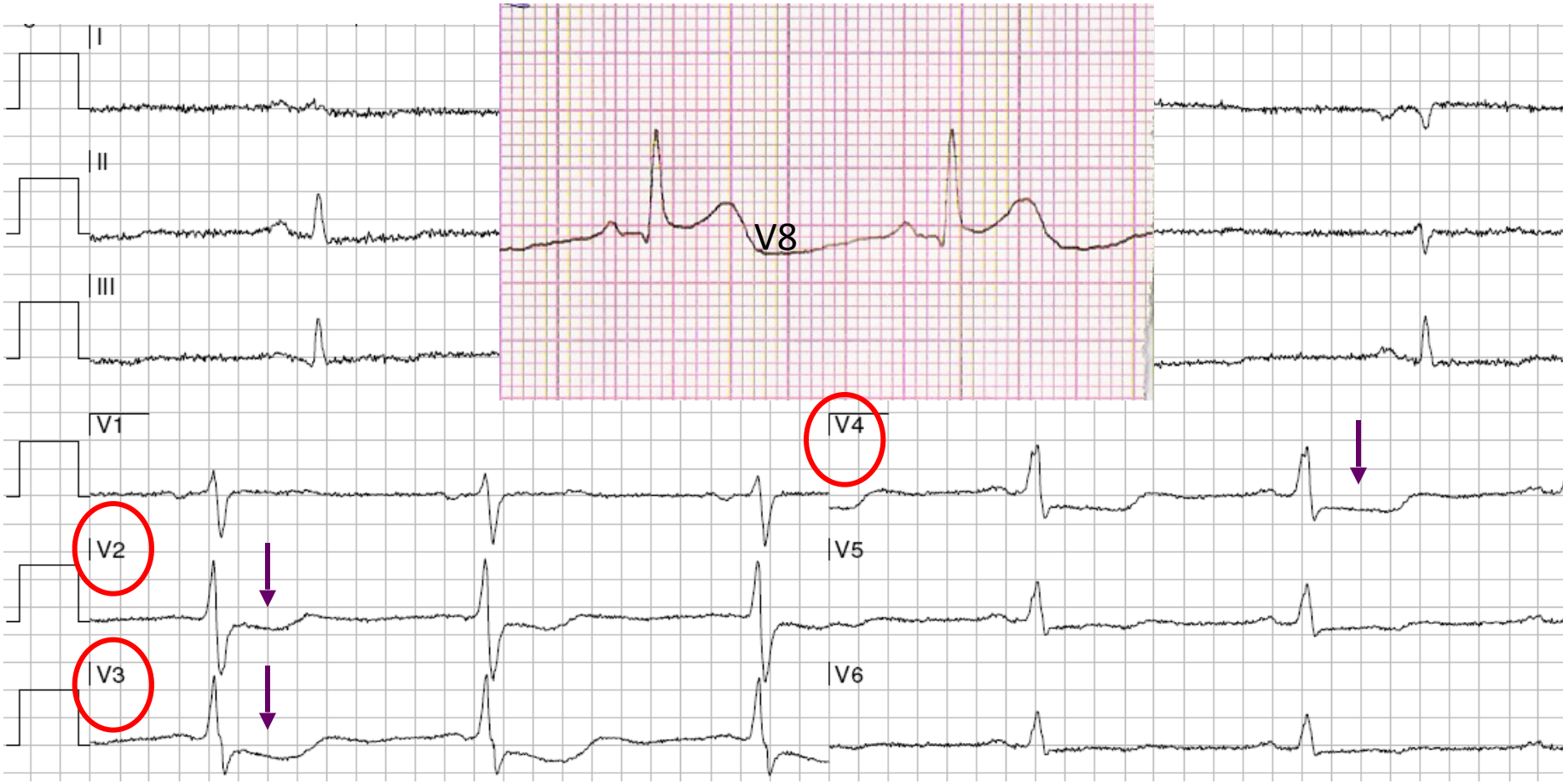
n=11.250
3 randomized studies



Identification of the culprit vessel in major trials of STEMI and NSTEACS.[6-8,20]

Krishnaswamy et al. Am Heart J 2009

ST-depression V2-V4 – posterior leads may help in detecting STEMI



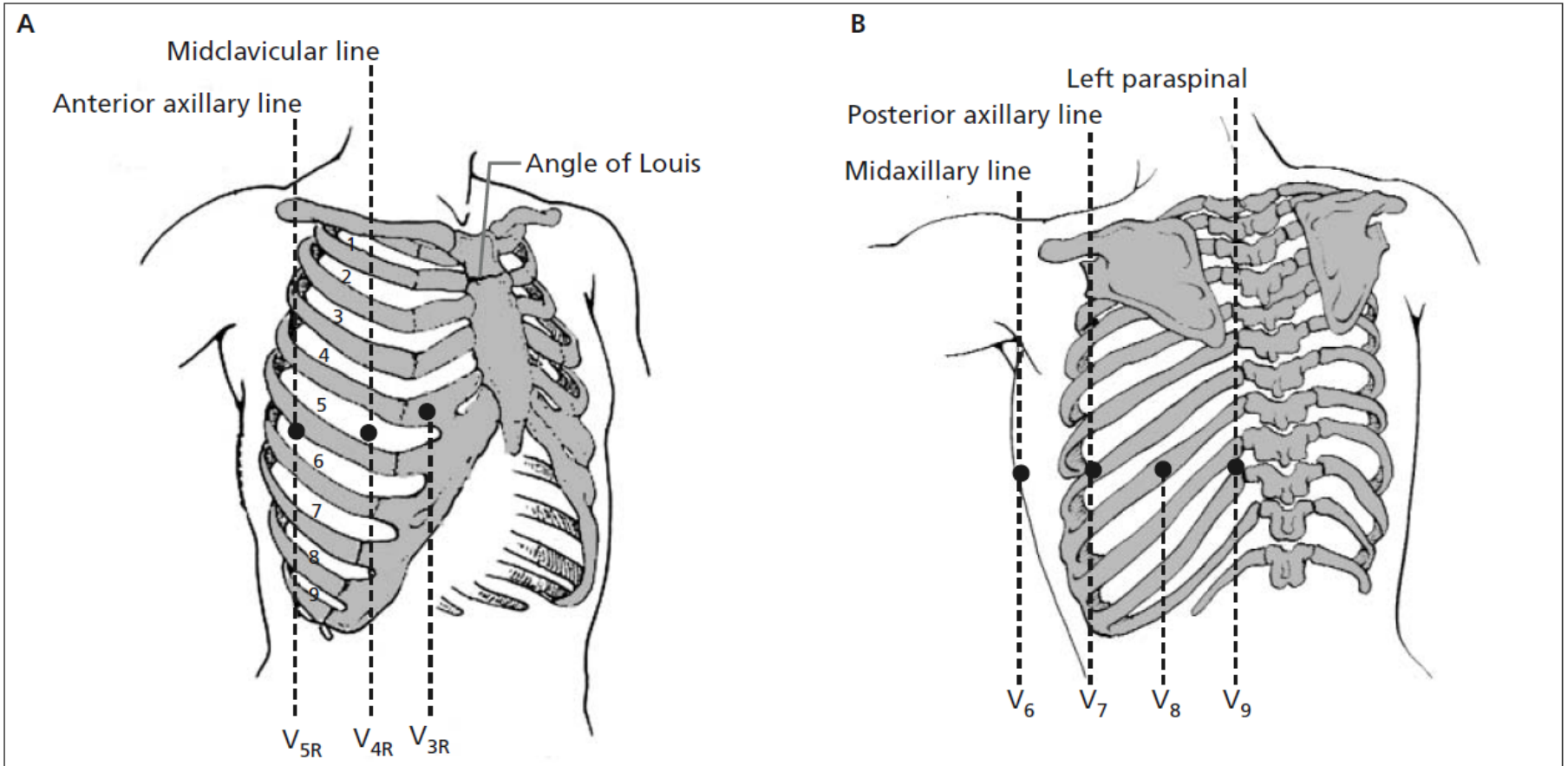


Figure 1 Locations of electrodes for the posterior and right ventricular leads. (A) Locations for right ventricular leads V_{3R} through V_{5R}: V_{3R} is located halfway between V_{2R} (or V_1) and V_{4R}, V_{4R} is located at the right midclavicular line in the fifth intercostal space, V_{5R} is located at the right anterior axillary line at the same horizontal level as V_{4R}. (Modified from Drew and Ide.[12]) (B) Location for posterior leads: V_7 is located at the posterior axillary line at the same level as V_4 through V_6, V_8 is located halfway between V_7 and V_9, and V_9 is at the left paraspinal line at the same level as V_4 through V_6.

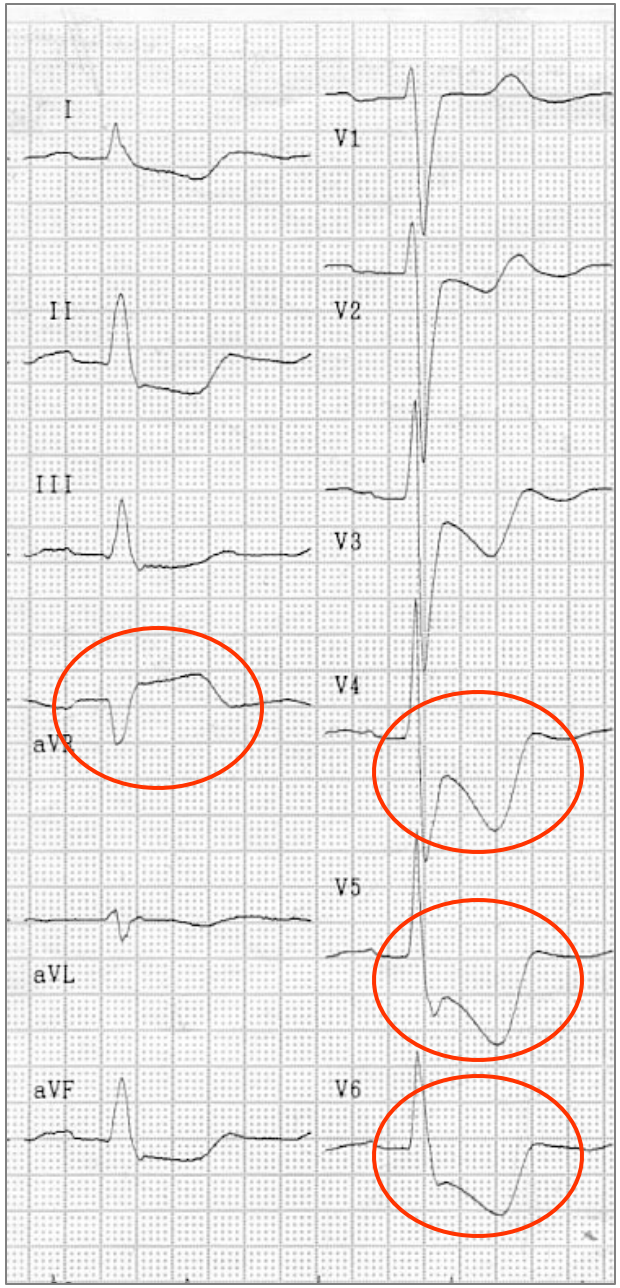
Wung S-F. Am J Crit Care 2007

ESC STEMI guidelines 2012

Table 4 Recommendations for initial diagnosis

Recommendations	Class [a]	Level [b]	Ref [c]
A 12-lead ECG must be obtained as soon as possible at the point of FMC, with a target delay of ≤10 min.	I	B	17, 19
ECG monitoring must be initiated as soon as possible in all patients with suspected STEMI.	I	B	20, 21
Blood sampling for serum markers is recommended routinely in the acute phase but one should not wait for the results before initiating reperfusion treatment.	I	C	-
The use of additional posterior chest wall leads (V_7–V_9 ≥0.05 mV) in patients with high suspicion of infero-basal myocardial infarction (circumflex occlusion) should be considered.	IIa	C	-

2. Circumferential (global) subendocardial ischemia



ECG 50 mm/sec

1. Clinical picture indicating acute coronary syndrome
2. Widespread ST-depressions (≥6 leads)
3. Maximal ST-depression V4-V5
4. Negative T V4-V5
5. ST-elevation ≥0.5 mm aVR
6. Transient changes

Less specific in case of tachycardia or LVH

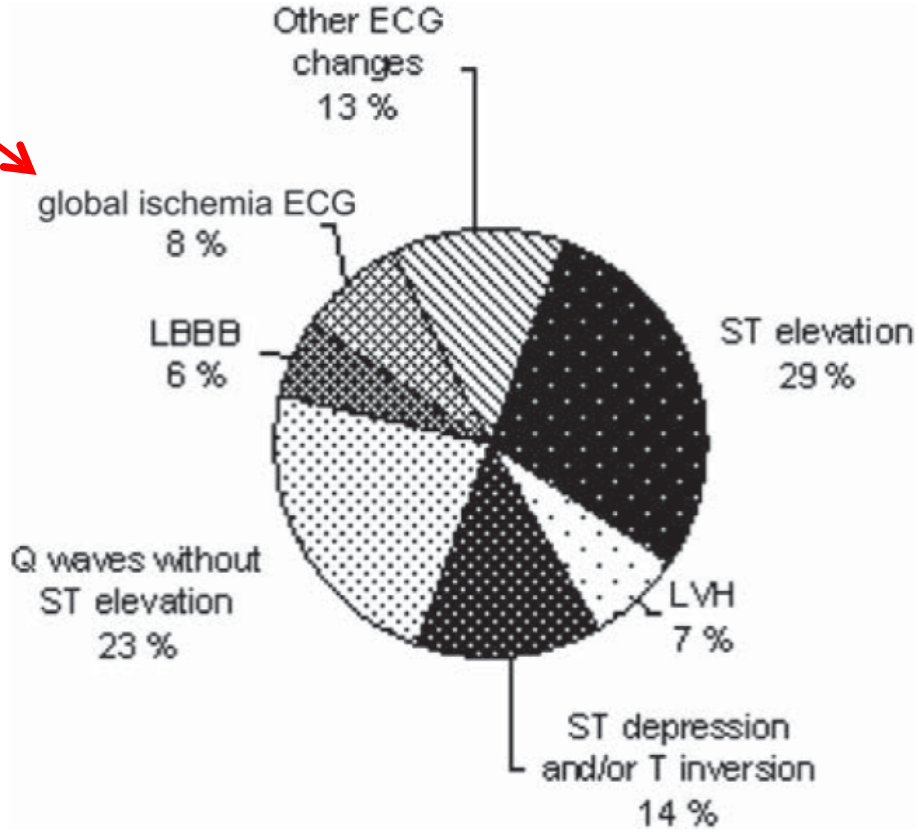
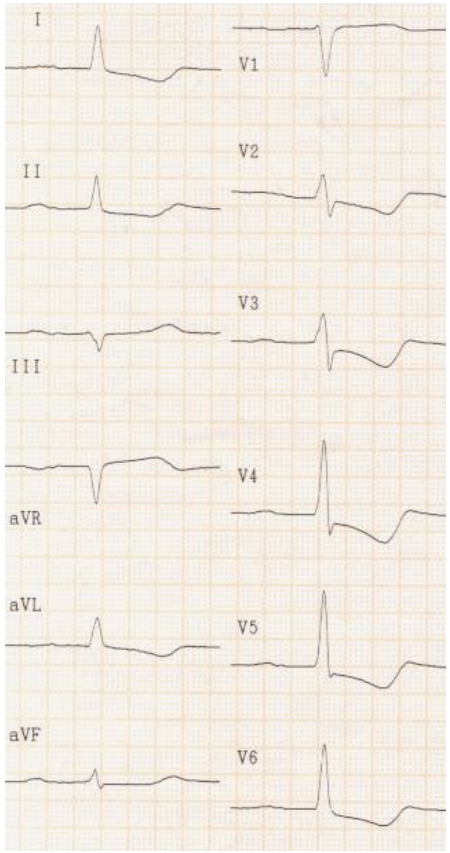


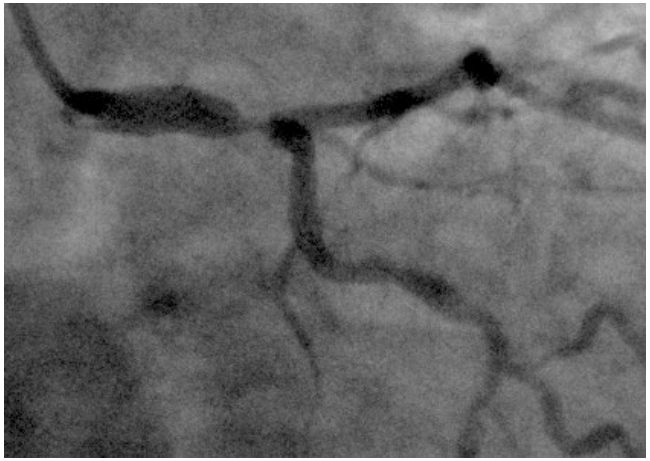
Figure 2. Distribution of ECG changes of all consecutive patients admitted with acute coronary syndrome. Rates are based on the TACOS study, $n = 1{,}188$.

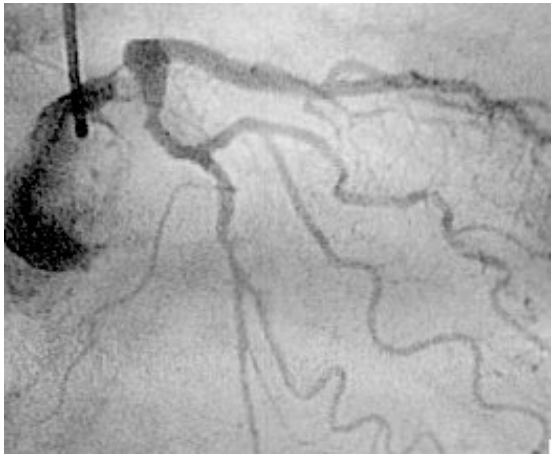
Nikus K ym. Ann Med. 2012



- *Left main coronary obstruction—lead aVR ST elevation and infero-lateral ST depression*: The presence of ST-depression >0.1 mV in eight or more surface leads, coupled with ST elevation in aVR and/or V1 but an otherwise unremarkable ECG, suggests ischaemia due to multivessel or left main coronary artery obstruction, particularly if the patient presents with haemodynamic compromise.[28]

ESC STEMI guidelines 2012





ST DEPRESSION AND INVERTED ASYMMETRIC T WAVES IN PATIENTS WITHOUT TACHYCARDIA

- Extensive ischemia causes global reduction in coronary blood flow *
- This results in impaired relaxation of the left ventricle* *
- The resulting increase in LVEDP induces severe subendocardial ischemia†
- Resulting in a distinct ECG pattern‡

- **Palacios I, Morvell SB, Powel WJ. Circulation 1976; 39:744*
- ** * Baim DS, Grossman W. Grossman´s cardiac catheterisation, angiography, and intervention. Lippincott Williams & Wilkins, 2001; 382.*
- *† Visner MS, Arentzen CE, Parrish DG et al. Circulation 1985; 71: 610-9.*
- *‡ Sclarovsky S. Electrocardiography of acute myocardial ischaemic syndromes. London: Martin Dunitz, 1999:10*

ST DEPRESSION WITH POSITIVE T WAVE

Regional, non-extensive, subendocardial ischemia may manifest as ST depression*

Tall and peaked T waves * *

Probably caused by high extracellular potassium†, related to hyperpolarization of myocytes

Due to an opening of the K-ATP-channel‡

**Guyton R, McClenathan JH, Newman G et al. Am J Cardiol 1977;40:373*

** *Sclarovsky S, Birnbaum Y, Solodky Y et al. Int J Cardiol 1994;46:37-47*

†Katz AM. Physiology of the heart. 3rd ed. Lippincott Williams & Wilkins, 2001: 644

‡Kondo T, Kubota I, Tachibana H et al. Cardiovasc Res 1996; 31: 683-87

- **Levine and Ford described for the first time circumferential subendocardial infarction: the clinical picture, ECG, myocardial and coronary anatomy.** *(Levine H ; Ford R. Circulation 1950;1:246-62)*

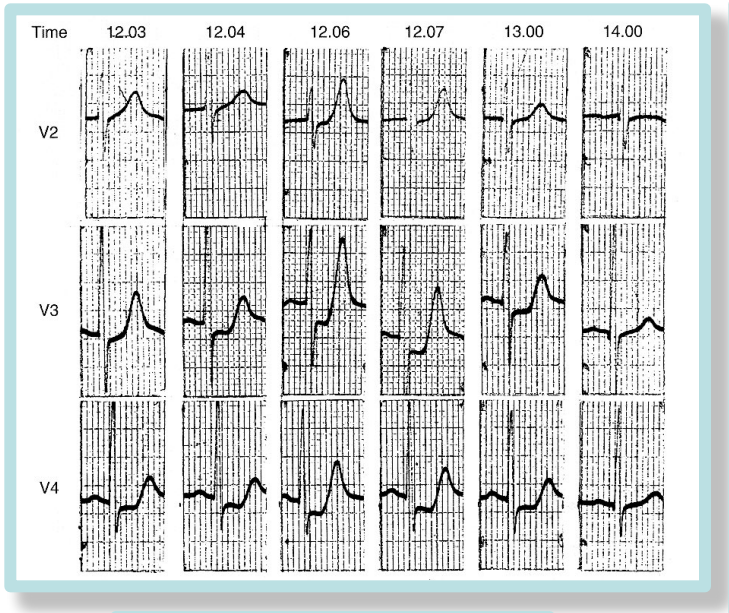
- **5 out of 6 cases were due to mechanical or atherosclerotic obstruction of the left main coronary artery, one had severe 3-vessel disease.**

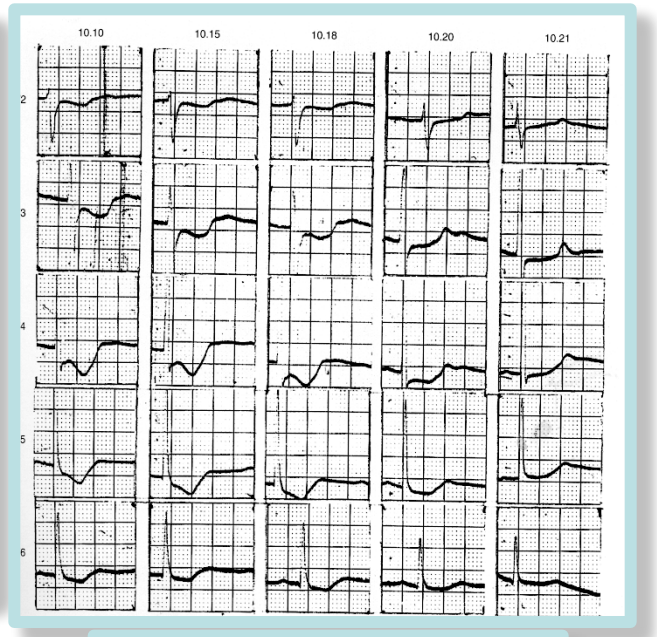
- **No one could reproduce this type of MI in animal experiments**

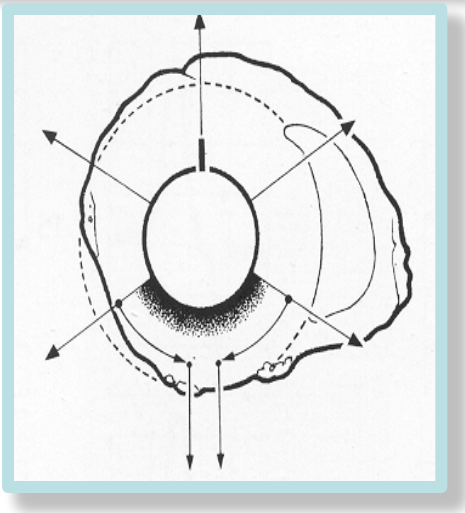
- **Levine was so convinced of his findings that he said: "Nature, it seems, can fulfill the conditions of the experiment much more readily than can a physiologist"**

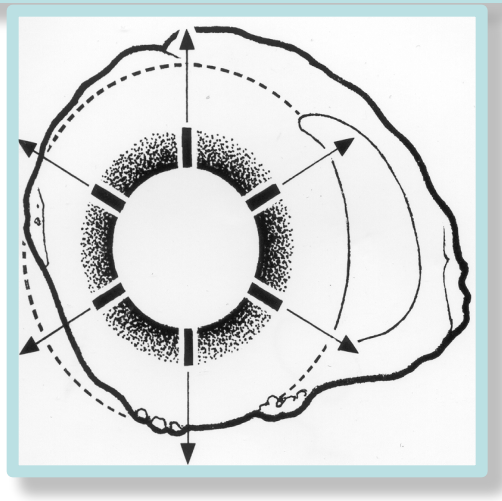
Unstable Angina With ST Segment Depression: With Negative T-Wave Versus Positive T Wave

Sclarovsky S. Electrocardiography of acute myocardial ischaemic syndromes. London: Martin Dunitz









Sclarovsky S al. Am Heart J 1988;116:933-41

The significance of T-wave direction in ACS with ST depression

Table 4. In-Hospital Follow-Up

	Group I (T−) n = 25 (%)	Group II (T+) n = 25 (%)	P-value
Clinical signs of heart failure	40	4	0.005
Ejection fraction			
30–49%	42	8	0.008
≥50%	58	92	0.008
CABG	76	20	<0.001
PCI	12	52	0.005
In-hospital mortality	24	0	0.02

CABG = coronary artery bypass grafting; PCI = percutaneous coronary intervention.

The significance of T-wave direction in ACS with ST depression

Table 2. Coronary Angiography Findings

Number of Diseased Vessel	Group I (T−) n = 25 (%)	Group II (T+) n = 25 (%)	P Value
0-VD	0	8	0.49
1-VD	0	56	<0.001
2-VD	0	8	0.49
Nonsevere 3-VD	0	20	0.05
Severe 3-VD	24	0	0.02
LM-CAD or LME-CAD	76	8	<0.001

LM-CAD = left main coronary artery disease; LME-CAD = left main equivalent coronary artery disease; VD = vessel disease.

Table 3. The Sensitivity, Specificity , Positive Predictive Value (PPV) and Negative Predictive Value (NPV) for the ECG Pattern with Transient ST-Segment Depression and Negative T Waves During Pain, Maximally in Leads V_{4-5}, to Predict Different Coronary Artery Disease Severity in Angiography

Angiography Findings	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Severe 3-VD	100	57	24	100
LM- or LME-CAD	91	79	76	92
Severe 3-VD or LM- or LME-CAD	93	100	100	92

Circumferential subendocardial ischemia is an independent marker of poor outcome in ACS

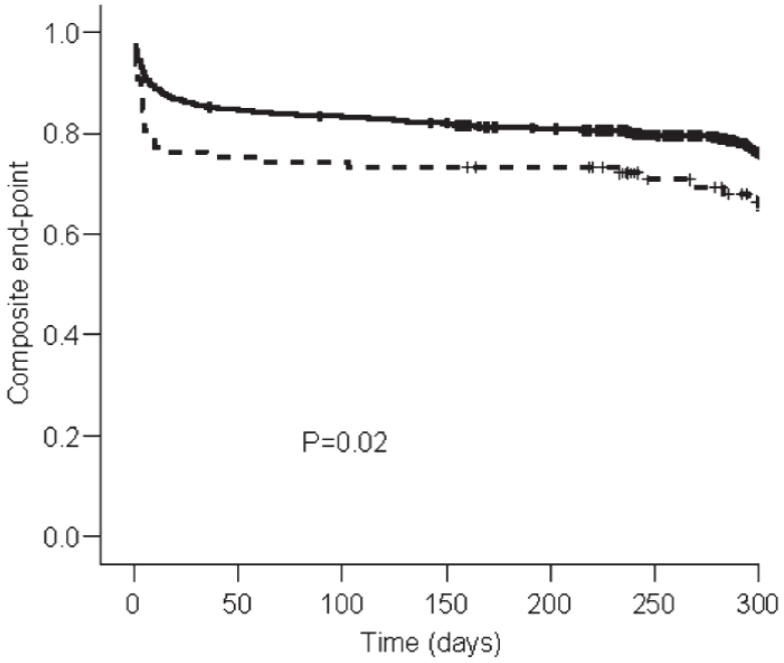


Figure 3. The rate of composite end-points at 10-month follow-up according to the ECG at admission presented by the Kaplan–Meier curve (dashed line: global ischemia ECG, solid line: all other ECG categories).

Table III. Variables retained in the final multivariate Cox proportional hazards model examining the rate of composite end-points at 10-month follow-up.

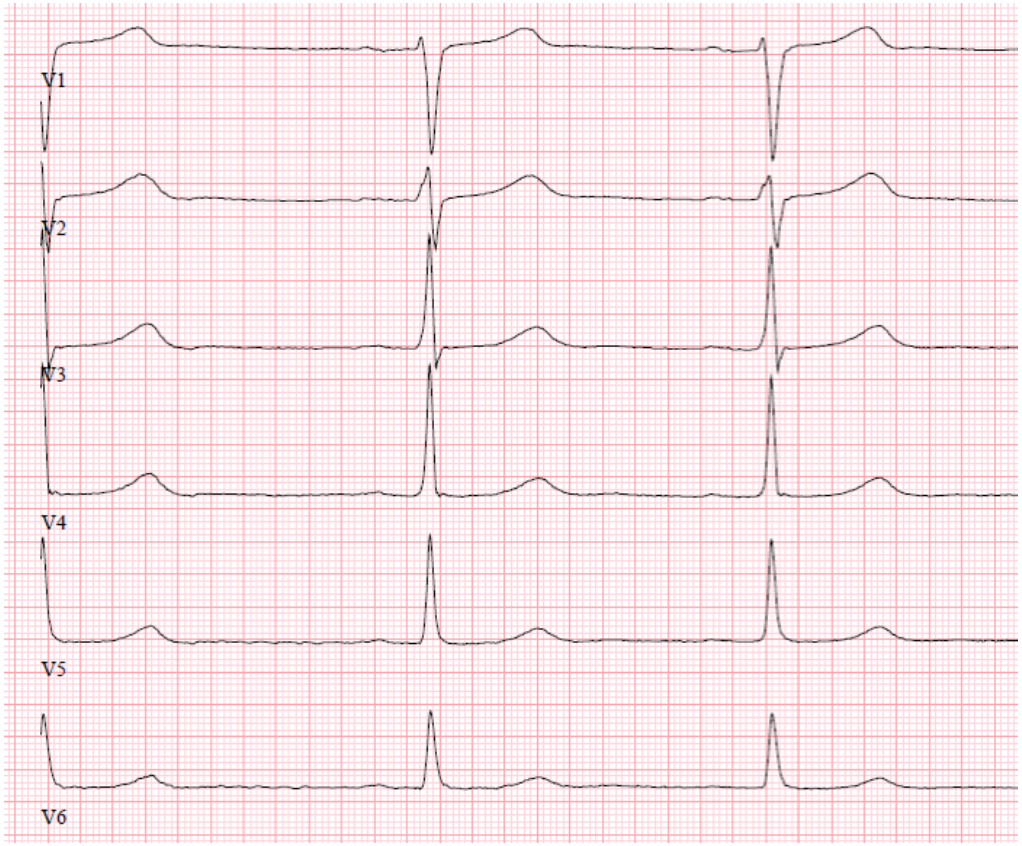
	Hazard ratio	95% CI	*P* value
Age	1.04	1.03–1.05	<0.001
Global ischemia ECG pattern	1.40	1.02–1.91	0.035
Gender	1.10	0.90–1.36	0.363
Systolic blood pressure	0.97	0.94–1.00	0.053
Plasma creatinine	1.003	1.002–1.004	<0.001
Diabetes	1.48	1.07–2.05	0.017
No diabetes	1		
Diabetes mellitus type I	2.65	1.16–6.07	0.021
Diabetes mellitus type II	1.12	0.91–1.39	0.227
Diuretic use on admission	1.24	0.998–1.54	0.052

CI = confidence interval; ECG = electrocardiogram.

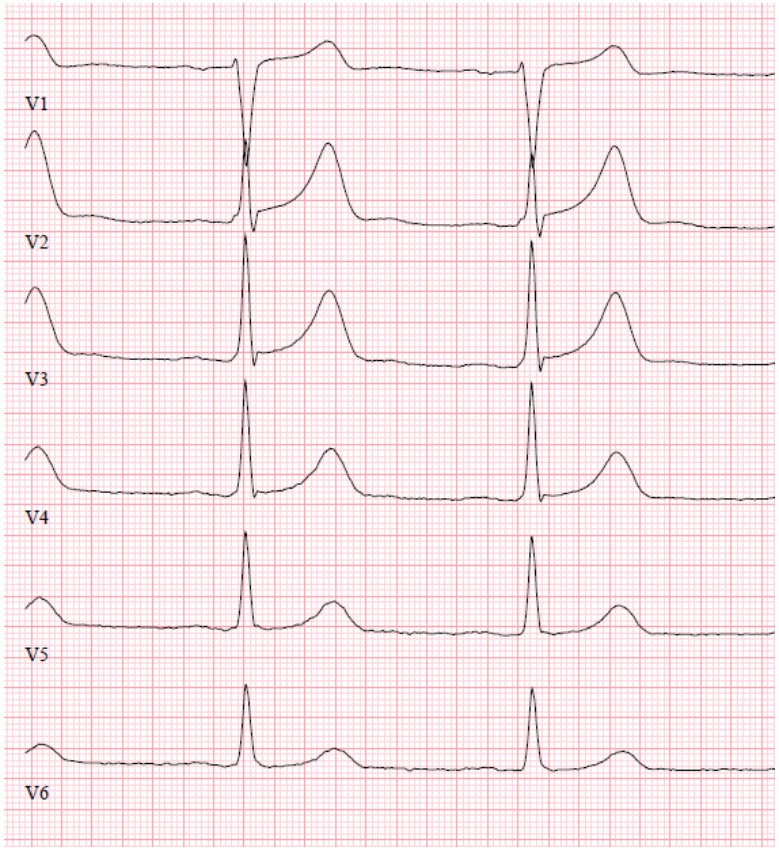
Nikus K et al. Ann Med. 2012

3. T-wave changes

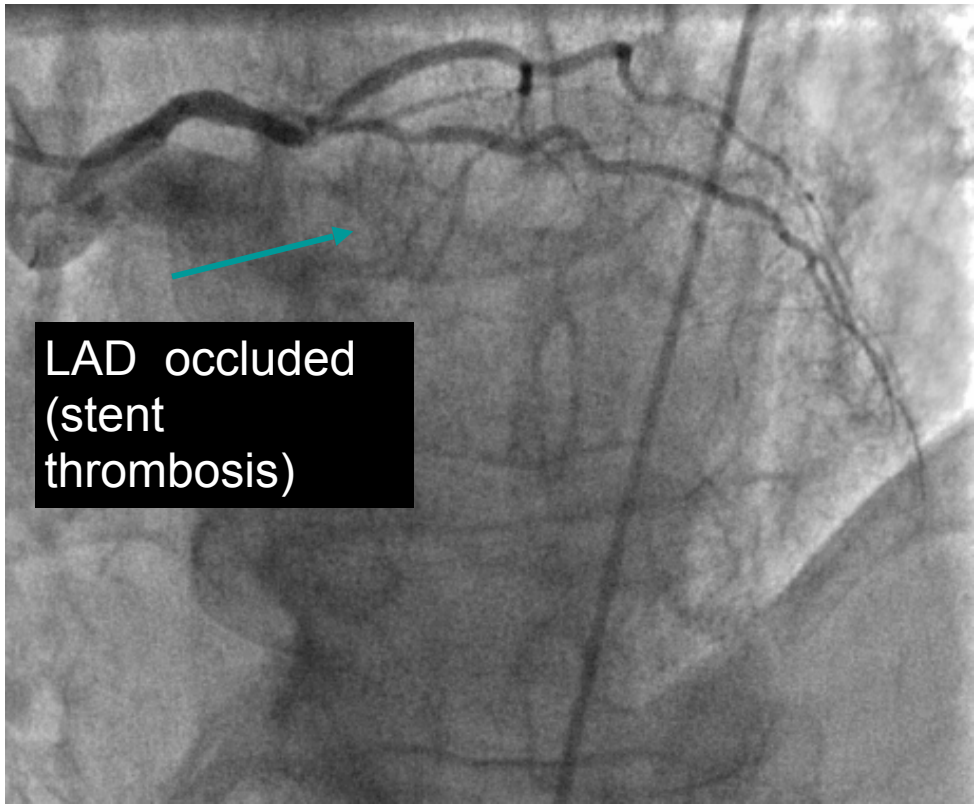
Old ECG

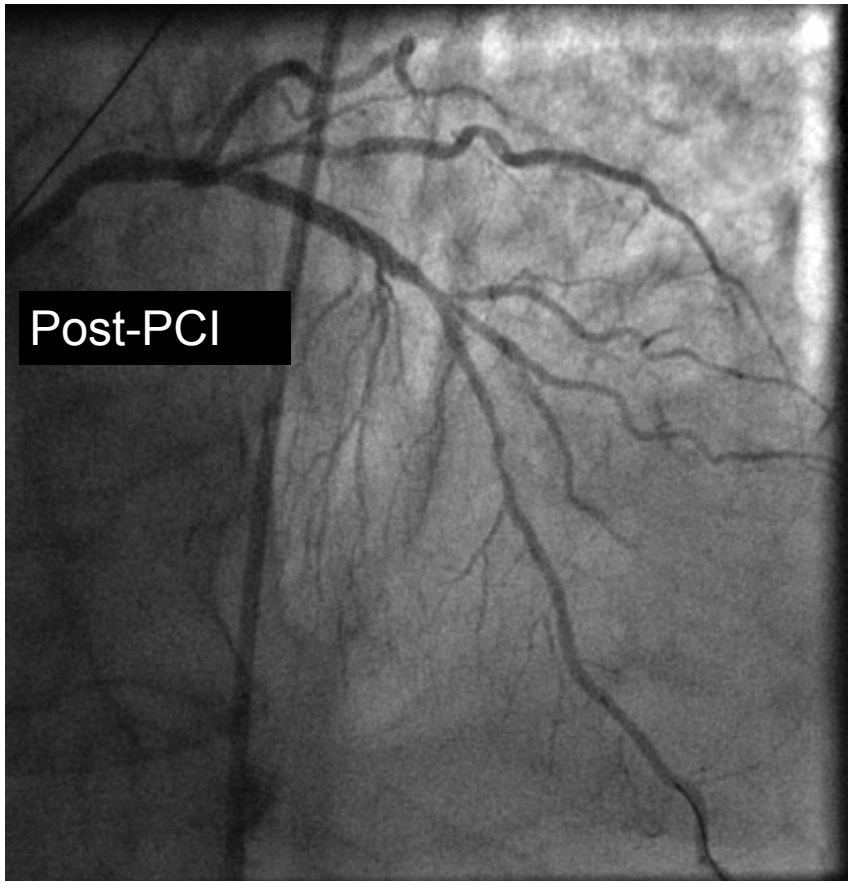


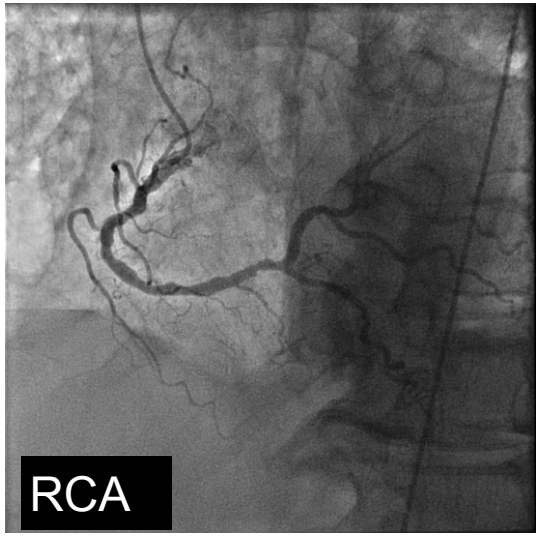
Chest pain



ECG 50 mm/sec





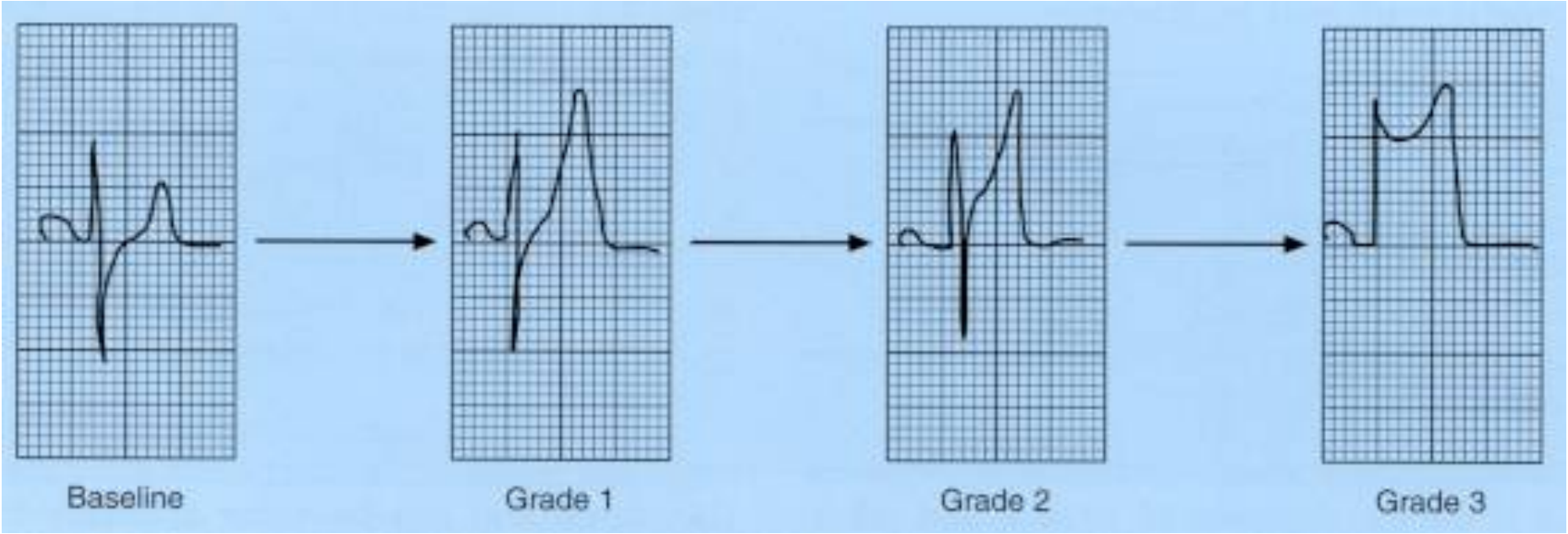


New prominent T waves V1-V4 (=LAD) and symptoms compatible with acute MI → consider acute angiography (STEMI protocol)

At least: follow-up ECG within 15-30 min

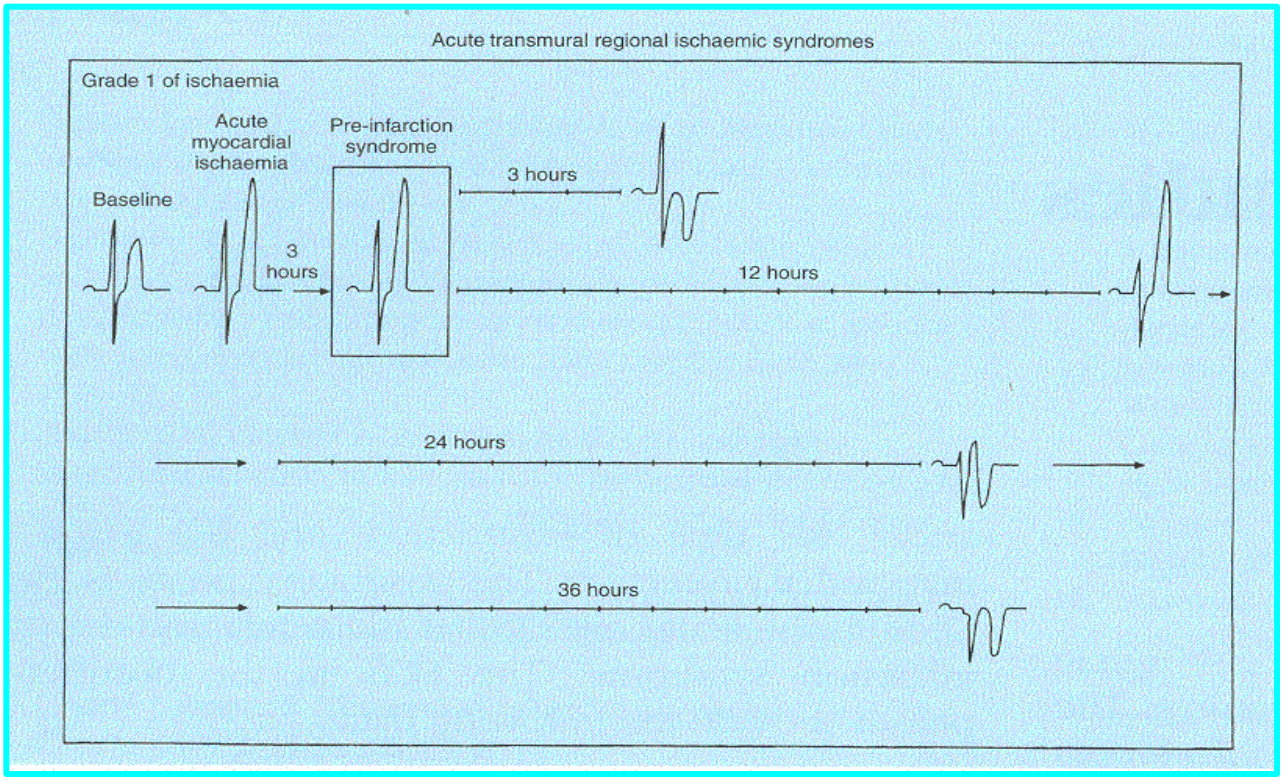
But: Hyperkalemia, individual differences in T-wave amplitude…

Sclarovsky-Birnbaum grade of ischemia



Sclarovsky S et al. Isr J Med Sci 1990;26:525-33

Grade 1 ischemia: slow development of Q waves due to well protected myocardium

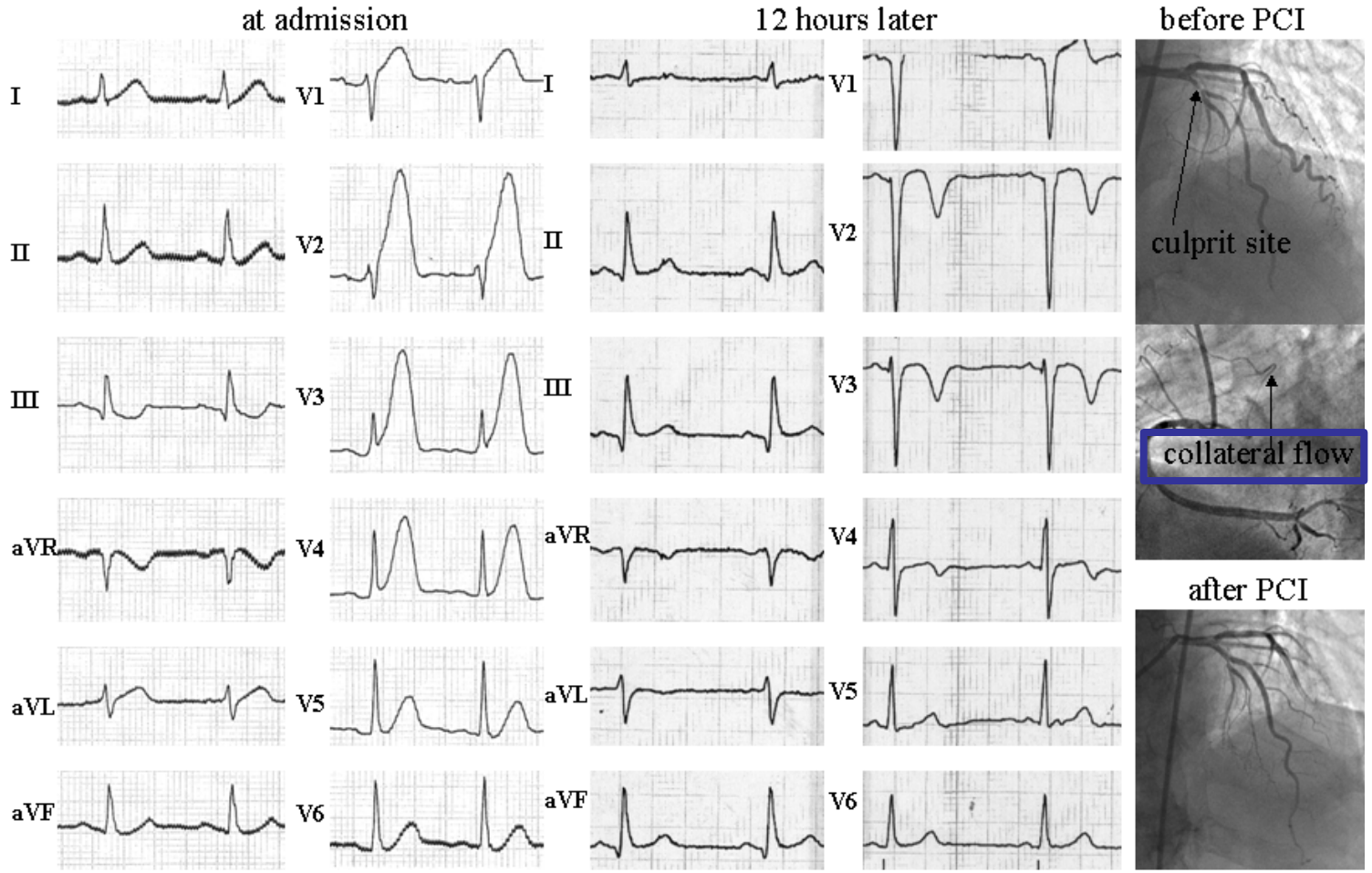


Sclarovsky S. Electrocardiography of acute myocardial ischaemic syndromes. London: Martin Dunitz

ACCF/AHA STEMI guidelines 2013

artery occlusion (9). Rarely, hyperacute T-wave changes may be observed in the very early phase of STEMI, before the development of ST elevation. Transthoracic echocardiography may provide evidence of focal wall motion abnormalities and facilitate triage in patients with ECG findings that are difficult to interpret. If doubt persists, immediate referral for invasive angiography may be necessary to guide therapy in the appropriate clinical context (10,11). Cardiac troponin is the preferred biomarker for diagnosis of MI.

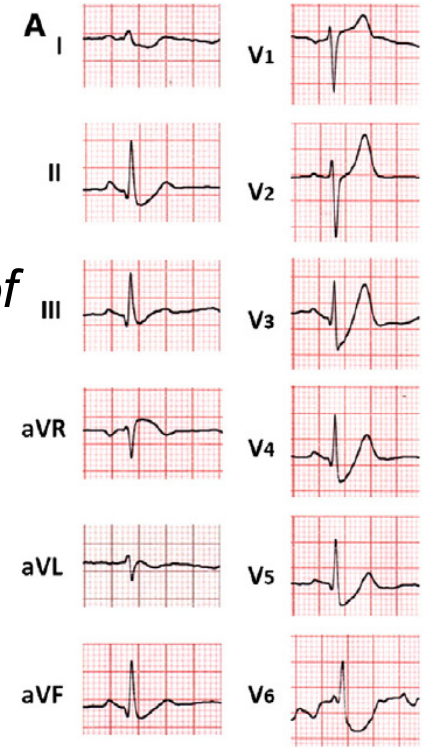
Prominent T wave and subtotal LAD occlusion

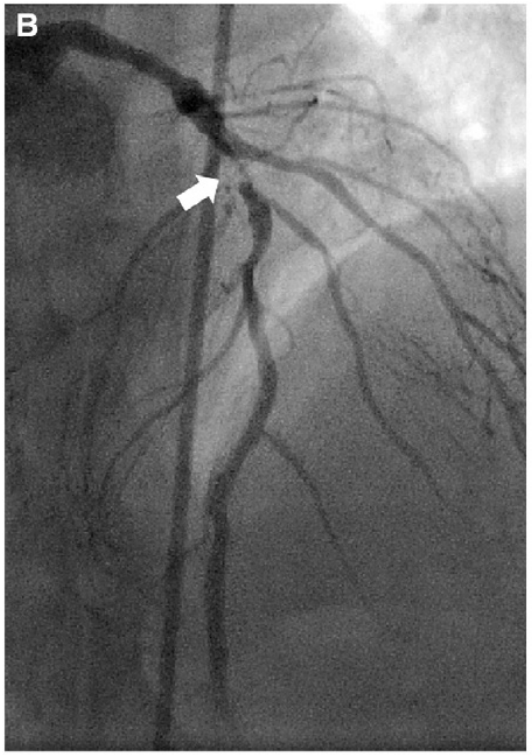


Courtesy: Zhan Zhong-qun

Regional subendocardial ischemia
-ST depression
-Positive T wave

Sclarovsky S. Electrocardiography of acute myocardial ischaemic syndromes. London: Martin Dunitz





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Journal of Electrocardiology 44 (2011) 533 – 537

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Prominent precordial T waves as a sign of acute anterior myocardial infarction: electrocardiographic and angiographic correlations☆,☆☆

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Received 3 May 2011

”Persistent hyperacute T wave”

Europ Heart J Acute Cardiovasc Care. 2012 Dec;1(4):344-8. doi: 10.1177/2048872612466537.

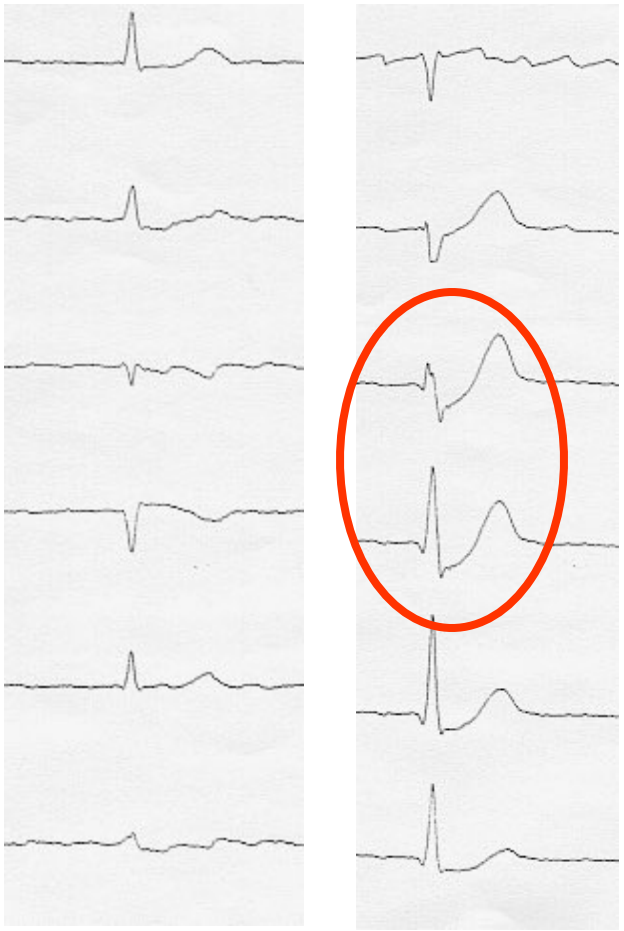
Interpretation of acute myocardial infarction with persistent 'hyperacute T waves' by cardiac magnetic resonance.

Zorzi A, Perazzolo Marra M, Migliore F, Tarantini G, Iliceto S, Corrado D.

CMR findings resembled those of typical anterior myocardial infarction with nearly transmural necrosis in the large myocardial area supplied by LAD. Accordingly, persistent hyperacute T waves should be regarded as an equivalent to ST-segment elevation and immediate reperfusion therapy should be considered.

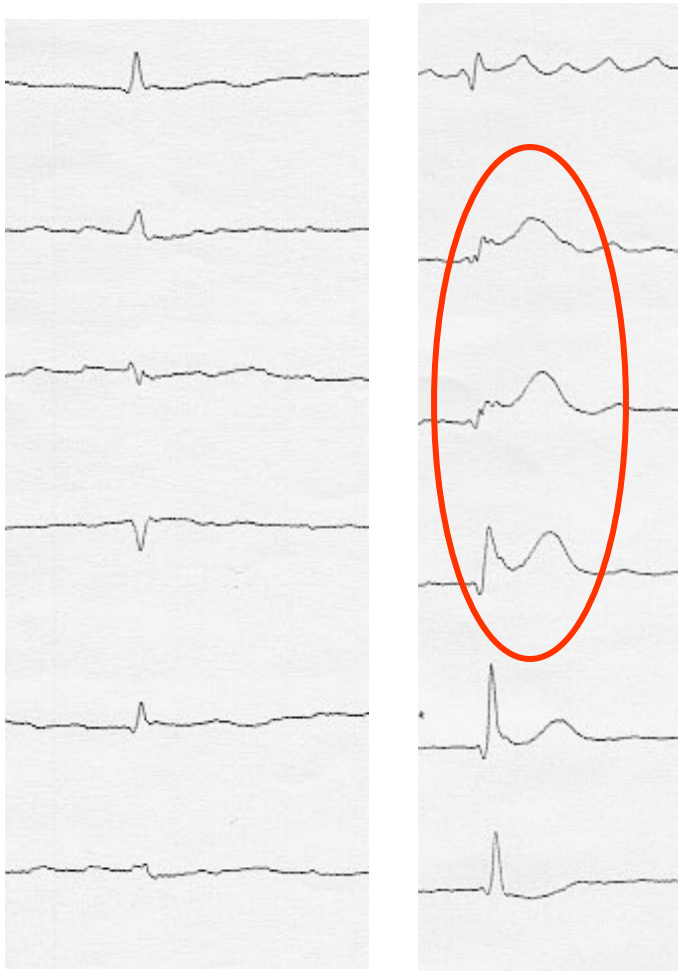
Regional subendocardial ischemia progressing to transmural ischemia grade 3

16.33



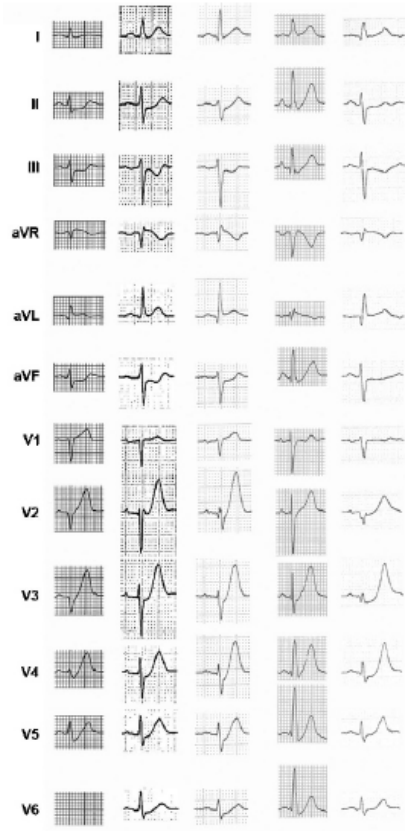
Ventricular fibrillation
Resuscitation

18.20



Persistent precordial "hyperacute" T-waves signify proximal left anterior descending artery occlusion

N J Verouden,[1] K T Koch,[1] R J Peters,[1] J P Henriques,[1] J Baan,[1] R J van der Schaaf,[1] M M Vis,[1] J G Tijssen,[1] J J Piek,[1] H J Wellens,[2] A A Wilde,[1] R J de Winter[1]



Results: We identified patients with a static, distinct ECG pattern without ST-segment elevation and an occlusion of the proximal LAD artery during urgent coronary angiography before PCI. Of 1890 patients who underwent primary PCI of the LAD artery, we could identify 35 patients (2%) with this distinct ECG pattern. The ECG showed ST-segment depression at the J-point of at least 1 mm in precordial leads with upsloping ST-segments continuing into tall, symmetrical T-waves. Patients with this distinct ECG pattern were younger, more often male and more often had hypercholesterolaemia compared to patients with anterior myocardial infarction and ST-segment elevation.

Time from symptom onset to ECG recording (minutes) (median (IQR))	98 (57–145)

This ECG pattern was invariably associated with a culprit lesion located in the proximal LAD artery, which was occluded in the majority of cases. Therefore, these patients qualify for immediate reperfusion therapy, preferably with primary PCI. In all patients included in this study, the characteristic ECG pattern immediately resolved after PCI of the LAD artery. The

Heart 2009;**95**:1701–1706.

Despite acute coronary occlusion the 12-lead ECG may be normal or without new changes

- ECG not recorded during symptoms
- Distal occlusion of the left circumflex coronary artery (LCx)
- Small area of ischemia (side branch occlusion)
- LBBB or non-specific intraventricular conduction delay (QRS>120 ms)
- Pacemaker ECG

Final remarks

- From an ECG standpoint, early signs of acute STEMI (~ sudden acute coronary artery occlusion) are: hyper-acute prominent T waves, ST elevation without Q waves or T-wave inversions, and ST depression in V1/V2-V3/V4 (mirror-image STEMI equivalent)

Final remarks

- Due to the sometimes very dynamic ECG changes, also later signs of the evolving ischemia/infarction process may be present early after symptom onset
- Telecardiology within regional STEMI networks are recommended to improve the diagnostics and to shorten ECG to device times