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Yama Fakhri MD, Maria Sejersten MD, DMSc, Mikkel Malby Schoos MD, PhD, Henrik Steen Hansen MD, DMSc, Jean-Luc Dubois-Rande MD, Trygve S. Hall MD, PhD, Alf-Inge Larsen MD, PhD, Svend Eggert Jensen MD, PhD, Henrik Engblom MD, PhD, Hakon Arheden MD, PhD, Jens Kastrup MD, DMSc, Dan Atar MD, PhD, Peter Clemmensen MD, DMSc

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Electrocardiographic Scores of Severity and Acuteness of Myocardial Ischemia Predict Myocardial Salvage in Patients with Anterior ST-segment Elevation Myocardial Infarction

Yama Fakhri, MD[a,b]; Maria Sejersten, MD, DMSc[c]; Mikkel Malby Schoos, MD, PhD[d]; Henrik Steen Hansen, MD, DMSc[e]; Jean-Luc Dubois-Rande, MD[f]; Trygve S. Hall, MD, PhD[g]; Alf-Inge Larsen, MD, PhD[h]; Svend Eggert Jensen, MD, PhD[i]; Henrik Engblom, MD, PhD[j]; Hakon Arheden, MD, PhD[j]; Jens Kastrup, MD, DMSc[a]; Dan Atar, MD, PhD[g]; Peter Clemmensen, MD, DMSc[b,k,l]

[a]Department of Cardiology, The Heart Centre, Rigshospitalet, Copenhagen, Denmark; [b]Department of Medicine, Division of Cardiology, Nykøbing F Hospital, Nykøbing F, Denmark; [c]Department of Cardiology, Herlev University Hospital, Herlev, Denmark; [d]Department of Cardiology, Zealand University Hospital, Roskilde, Denmark; [e]Department of Cardiology B, Odense University Hospital, Odense, Denmark; [f]Assistance Publique Hôpitaux de Paris, Hôpital Henri Mondor, Créteil, France; [g]Department of Cardiology B, Oslo University Hospital Ullevål, and Faculty of Medicine, University of Oslo, Oslo, Norway; [h]Department of Cardiology, Stavanger University Hospital, Stavanger, Norway, and Institute of Clinical Science, University of Begen, Norway; [i]Department of Cardiology, Aalborg University Hospital, Aalborg, Denmark; [j]Department of Clinical Physiology, Lund University, Skåne University Hospital, Lund, Sweden; [k]Institute of Regional Health Research, University of Southern Denmark, Odense, Denmark; [l]Department of General and Interventional Cardiology, University Heart Center Hamburg, Hamburg-Eppendorf, Germany

Corresponding author:

Yama Fakhri, MD

The Heart Centre, Department of Cardiology, B9441, Rigshospitalet

Blegdamsvej 9, DK-2100 Copenhagen, Denmark

E-mail: yfakhri@gmail.com

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Abstract

Background: Terminal "QRS distortion" on the electrocardiogram (ECG) (based on Sclarovsky-Birnbaum's Grades of Ischemia Score) is a sign of severe ischemia, associated with adverse cardiovascular outcome in ST-segment elevation myocardial infarction (STEMI). In addition, ECG indices of the acuteness of ischemia (based on Anderson-Wilkins Acuteness Score) indicate myocardial salvage potential. We assessed whether severe ischemia with or without acute ischemia is predictive of infarct size (IS), myocardial salvage index (MSI) and left ventricular ejection fraction (LVEF) in anterior versus inferior infarct locations.

Methods: In STEMI patients, the severity and acuteness scores were obtained from the admission ECG. Based on the ECG patients were assigned with severe or non-severe ischemia and acute or non-acute ischemia. Cardiac magnetic resonance (CMR) was performed 2-6 days after primary percutaneous coronary intervention (pPCI). LVEF was measured by echocardiography 30 days after pPCI.

Results: ECG analysis of 85 patients with available CMR resulted in 20 (23%) cases with severe and non-acute ischemia, 43 (51%) with non-severe and non-acute ischemia, 17 (20%) with non-severe and acute ischemia, and 5 (6%) patients with severe and acute ischemia. In patients with anterior STEMI (n=35), ECG measures of severity and acuteness of ischemia identified significant and stepwise differences in myocardial damage and function. Patients with severe and non-acute ischemia had the largest IS, smallest MSI and lowest LVEF. In contrast, no difference was observed in patients with inferior STEMI (n=50).

Conclusions: The applicability of ECG indices of severity and acuteness of myocardial ischemia to estimate myocardial damage and salvage potential in STEMI patients treated with pPCI, is confined to anterior myocardial infarction.

Introduction

The acuteness-score, measured by the modified Anderson-Wilkins Acuteness Score, quantifies the acuteness of myocardial ischemia from the electrocardiogram (ECG) (1;2). In patients with ST-segment elevation myocardial infarction (STEMI) treated with primary percutaneuous coronary intervention (pPCI), acute ischemia in their presenting ECG identifies salvage potential and predicts smaller infarct size independent of symptom durations (3-6). Distortion of the terminal portion of the QRS complexes in leads with ST elevation, due to myocardial vulnerability, has been defined as severe ischemia (7), is associated with rapid progression of necrosis and predicts adverse cardiovascular outcome (8-11). Thus, STEMI patients presenting with severe and acute ischemia on their ECG might particularly benefit from immediate coronary reperfusion. We assessed whether severe ischemia with or without acute ischemia is predictive of infarct size (IS), myocardial salvage index (MSI) and left ventricular ejection fraction (LVEF) in anterior versus inferior infarct locations.

Methods

Study population

Patients included in the MITOCARE study (12), a prospective, multicenter, randomized, double-blind cardioprotection trial, were considered in the present study. In brief, the MITOCARE trial examined the potential for adjunctive TRO40303 to limit reperfusion injury in STEMI patients undergoing pPCI. Patients with first STEMI and symptom duration of <6 hours, underwent Cardiac Magnetic Resonance (CMR) imaging within 2 to 6 days after being treated with pPCI. In total, 165 included patients were randomized to receive either TRO40303 or placebo after coronary

angiography. The results demonstrated that TRO40303 did not limit reperfusion injury of the infarcted myocardium (13).

ECG collection and ECG measurement

Electrocardiograms were recorded at hospital admission (baseline ECG). The electrocardiographic analyses were performed in the ECG Core Laboratory at the Rigshospitalet (Copenhagen, Denmark). ST-segment deviation was measured manually to the nearest 0.5 mm at the J-point in all 12 ECG leads using the TP-segment as the isoelectric line. Alternatively, the PR-segment was used if the TP-segment was not distinct. Patients with maximal ST elevation in leads V1 to V6 or I and aVL were classified as the anterior infarct group, while those with maximal ST elevation in leads II, III and aVF and/or ST-segment depression in V1-V3 were classified as the inferior infarct group. The ECG investigators were blinded to all patient data.

The severity score

Severity of ischemia was determined by Sclarovsky-Birnbaum's grades of ischemia, which is based on the presence or absence of distortion of the terminal portion of the QRS complex in leads with ST-segment elevation (14). Distortion of the terminal QRS complex was defined as: 1: Absence of an S-wave in ≥ 2 adjacent leads that usually have a terminal S configuration (leads V1 to V3); or 2: ST-J point amplitude ≥ 50% of the R-wave amplitude measured from the TP baseline in ≥ 2 adjacent leads in all other leads. In addition, leads with ST-segment elevation and negative T-waves were excluded. Detailed criteria of the Sclarovsky-Birnbaum’s grades of ischemia are described elsewhere (15).

We defined severe ischemia in the presence of QRS distortion in ≥2 contiguous leads and non-severe ischemia in the absence of QRS distortion.

The acuteness-score

The ischemia acuteness-score was based on the modified Anderson-Wilkins acuteness score (1), which assesses changes in ST-T segments, T-waves and Q-waves. Each lead was designated an acuteness phase (1A, 1B, 2A or 2B) based on the presence or absence of a tall T-wave or an abnormal Q-wave; Phase 1A: tall T-wave and no abnormal Q-wave; Phase 1B: positive T-wave and no abnormal Q-wave; Phase 2A: tall T-wave and an abnormal Q-wave; Phase 2B: positive T-wave and an abnormal Q-wave (2). Criteria for abnormal Q-waves and tall T-waves are presented in table 1. The acuteness-score ranges from 1 (non-acute ischemia/least acute) to 4 (early ischemia/most acute) and was calculated from the formula:

$$\text{Acuteness-score} = \frac{4(\#\ leads\ 1A)+3(\#\ leads\ 1B)+2(\#\ leads\ 2A)+1(\#\ leads\ 2B)}{\sum \#\ leads\ with\ 1A,1B,2A\ or\ 2B}.$$

Also, it has been shown that STEMI patients with ECG acuteness-score ≥3 and treated with pPCI, have better outcome independent of symptom durations (3;5;6). Accordingly, the ECG acuteness-score was dichotomized as ≥3 and <3. We defined acute ischemia as ECG acuteness-score ≥3 and non-acute ischemia as ECG acuteness-score <3.

ECG score analysis

Each lead with ST elevation ≥0.10 mV was considered for the severity and acuteness-score of ischemia.

All ECGs were analyzed manually by 3 investigators blinded to clinical, angiographic and CMR data as well as information on randomization arm. A manual non statistical reliability test was done by the ECG expert (MS) who controlled 25 random ECGs. No disagreements between the 3 investigators and MS were observed.

Patients were then stratified according to severity and acuteness scores in 4 ischemia groups. Severe and non-acute ischemia; Non-severe and non-acute ischemia; Non-severe and acute ischemia; and Severe and acute ischemia (Figure 1).

CMR Image Acquisition and analysis

Complete CMR examination was done in 93 patients. The CMR examinations were performed on a 1.5 T system from either Philips (Philips Healthcare, Best, The Netherlands), Siemens (Siemens AG, Erlangen, Germany) or General Electrics (GE Healthcare, Fairfield). All subjects were placed in a supine position, and images were acquired at end-expiratory breath hold with ECG gating. Initial scout images were acquired to locate the heart. For assessment of myocardial area at risk (MaR) and left ventricular ejection fraction (LVEF), a short-axis multislice multiphase steady-state free precession (SSFP) sequence was applied ≈5 minutes after intravenous administration of a gadolinium-based extracellular contrast agent (0.2 mmol/kg) from base to apex. The slice thickness was 8 mm with no slice gap, and the in-plane resolution was typically 1.5×1.5 mm with a temporal resolution of 20 to 30 frames per cardiac cycle. Left ventricular endo- and epicardial borders were manually delineated in end-diastole and end-systole for assessment of end-diastolic volume (EDV) and end-systolic volume (ESV). The LVEF was calculated as ((EDV-ESV) / EDV). Myocardium at

risk was analyzed according to previously described methodology (16) and was expressed as % of left ventricle (LV).

For infarct visualization, long- and short-axis late gadolinium enhancement (LGE) images covering the LV from base to apex were acquired ≈15 minutes after injection of gadolinium. The LGE images were acquired using an inversion-recovery gradient-recalled echo sequence with a slice thickness of 8 mm with no slice gap. In-plane resolution was typically 1.5×1.5 mm. Inversion time was adjusted to null the signal from viable myocardium (17). Infarct size (% of LV) was quantified according to previously described methodology taking partial volume effects into account (18). Microvascular obstruction (MVO) was defined as the hypo-enhanced myocardium within the hyper-enhanced regions of infarction and was expressed as % of LV.

Myocardial salvage index was calculated as (MaR-IS)/MaR. LVEF was measured by echocardiography 30 days after pPCI.

Biomarkers

Serial Creatine Kinase Myocardial Band (CK-MB) and Troponin (Tn) T and I were measured by a core lab (Firalis SAS, Huningue, France, http://www.firalis.com) from blood samples taken before and after pPCI. Infarct size was biochemically estimated by peak CK-MB and peak TnT levels.

Statistical analysis

Categorical data are presented as numbers (percentages) and continuous data are reported as mean ± SD or median (25^{th} – 75^{th} interquartile). Baseline clinical and angiographic data were analyzed according to patients with severe or non-severe ischemia as well as acute or non-acute ischemia

groups. LV CMR measures and 30-day echocardiographic measures of LV were compared within the 4 ischemia groups for anterior vs. inferior STEMI. Groups were compared using Student's t test or ANOVA. Variables not normally distributed were log transformed in analysis models, as appropriate. All tests were two-sided and the level of statistical significance was defined as $p< 0.05$. All analyses were performed using SPSS statistical software (SPSS version 20.0, SPSS Inc, Chicago, IL).

Results

Patient demographics

The ECG severity and acuteness-scores were measured in 147 and 165 patients, respectively. There were 86% male and mean age was 61 (±11) years old. Sixty five (40%) patients had anterior STEMI and 98 (60%) patients had non-anterior STEMI. Baseline characteristics according to patients with severe vs. non-severe ischemia and patients with acute vs. non-acute ischemia are shown in Table 2.

LV outcomes according to electrocardiographic severity of ischemia

LV outcome measures by biomarkers (n=161), CMR (n=93) and echocardiography (n=146) in patients with severe vs. non-severe ischemia and patients with acute vs. non-acute ischemia are shown in Table 3. Patients with severe ischemia had significantly larger infarct size estimated by peak CK-MB and CMR (21% (9-28) vs. 14% (10-19), p = 0.006) compared to those with non-severe ischemia. MSI was significantly lower (50% (32-63) vs 56% (46-70), p = 0.035) in patients with severe ischemia compared to those with non-severe ischemia. Patients with severe ischemia

had also a significant higher extent of MVO and lower LVEF measured by CMR. There was no difference in N-terminal pro-brain natriuretic peptide (NTproBNP) levels or LVEF at follow up 30 days after pPCI in patients with severe vs. non-severe ischemia.

LV outcomes according to electrocardiographic acuteness of ischemia

Patients with acute ischemia had smaller infarct size (10% (9-16) vs. 15% (10-25), p = 0.004) and larger MSI (61% (55-74) vs. 50% (10-25), p = 0.013) compared to those with non-acute ischemia. In addition, patients with acute ischemia had a significant higher LVEF (56% (51-64) vs. 52% (45-56), p = 0.001) and two-fold lower levels of NTproBNP (p = 0.009) 30 days after pPCI, Table 3.

LV outcomes according to combination of severity and acuteness of ischemia

Four ECG ischemia groups were formed by combination of severity and acuteness-scores in 85 patients with available CMR data and resulted in 20 (23%) cases with severe and non-acute ischemia, 43 (51%) with non-severe and non-acute ischemia, 17 (20%) with non-severe and acute ischemia, and 5 (6%) patients with severe and acute ischemia. LV outcome measures by biomarkers, CMR and echocardiography, across the ECG ischemia groups for anterior and non-anterior STEMI are shown in Table 4.

In patients with anterior STEMI, ECG measures of severity and acuteness of myocardial ischemia identified significant and stepwise differences in myocardial damage and function. Patients with severe ischemia and non-acute ischemia had the largest IS, smallest MSI and worst LVEF at follow up. In contrast, no differences in IS or MSI were observed in patients with inferior STEMI (Figure 2).

Discussion

Main findings

In the present study, we investigated the combination of the severity and acuteness of ischemia, obtained from admission ECG, in relation to left ventricular outcomes estimated by cardiac magnetic resonance in the acute phase, and by echocardiography 30 days after pPCI in patients with ST-segment elevation myocardial infarction. We demonstrated that patients with anterior STEMI and severe and non-acute ischemia on the admission ECG had the largest infarct size, smallest myocardial salvage and most impaired left ventricular function (Figure 2).

Possible electrophysiological mechanisms of ECG patterns

The process of evolving myocardial infarction begins rapidly after an acute coronary artery occlusion, where ischemia develops causing dynamic ECG changes. Initially tall T-waves develop. These are followed by evolvement of ST-segment elevation, abnormal Q-waves, T-wave inversion, and finally resolution of the ST-segment elevation. The changes reflect 1- presence, location and extent (ST-segment elevation), 2- severity (distortion of the terminal portion of the QRS) and 3- timing of the infarction process (tall T-waves versus abnormal Q-waves). In leads with ST-segment elevation, distortion of the terminal portion of the QRS are explained by prolongation of the electrical conduction in the purkinje fibers in the ischemic zone, resulting in increase of R-wave amplitude in leads with terminal R-wave (I, II, III, aVL, aVF, V4-V6) and decrease in S-wave amplitude in leads with terminal S-wave (leads V1- V3). Because purkinje fibers are believed to be less sensitive to ischemia than myocytes, they would in theory only be affected when the ischemia

is severe and prolonged, hence resulting in distortion of the terminal portion of the QRS complex (19). However, pre-disposing features of cardioprotection might have crucial role for protecting the jeopardized myocardium during the ischemic process. Several studies have demonstrated that patients with non-severe ischemia have higher incidence of collateral flow compared to patients with severe ischemia (19). Thus, absence of distortion of the terminal portion of the QRS complex, despite prolonged ischemia, might indicate myocardial protection (19). It has further been shown that distortion of the terminal portion of the QRS complex alongside with ST-segment elevation has been associated with larger infarct size and a rapid progression of myocardial necrosis over time (10). In addition, severe ischemia measured as distortion of the terminal portion of the QRS complex is an independent predictor of myocardial damage and clinical prognosis in STEMI patients (20). A faster (than recommended in guidelines) reperfusion strategy in these patients could therefore stop the progression of necrosis, thus salvage the jeopardized myocardium from infarction. However, since the myocardial infarction already has evolved in patients presenting with non-acute ischemia, a faster reperfusion strategy might only be beneficial in patients presenting with severe and acute ischemia on the ECG. The mechanism behind tall T-waves is not fully understood but a theory is that the repolarization of ischemic tissue is prolonged due to a delay in recovery of the membrane potential, which then causes tall T-waves (21). These changes are present temporarily after the onset of the infarction. Difference in gradients across the boundary between normal and ischemic myocardium changes the electrical currents in the myocardium causing ST-segment elevation, while persistent Q-waves represent loss of electrically activity and are a sign of necrosis.

Time delays for reperfusion therapy

Currently the triage for pPCI in STEMI is solely based on patient reported symptom durations. Primary PCI is the preferred choice of reperfusion therapy if it is provided within 60-90 minutes of first medical contact in STEMI patients with symptom duration <12 hours (22-25). However, time of symptom onset estimation is often biased by inaccurate patient recollection and other factors that might pre-condition the ischemic myocardium leading to cardioprotection. The benefit from a faster reperfusion strategy by prehospital fibrinolysis has not been shown to be superior to pPCI in STEMI patients presenting early after symptom onset (26). Prehospital fibrinolysis is shown to be non-superior over pPCI in clinical trials. However, some patients may have great benefit from this early approach of reperfusion. In cases of severe ischemia the progression of necrosis is very rapid and the jeopardized myocardium might evolve faster to myocardial infarction in patients presenting with severe and acute ischemia on the ECG. Consequently, these patients might have outstanding benefits from prehospital fibrinolysis, which basically reduces ischemia duration significantly, in addition to achieving reperfusion of the culprit artery onsite. Our findings illustrate that the combined application of ECG scores of the severity and acuteness of myocardial ischemia from the ECG is a useful clinical tool that identifies patients with severe and acute ischemia, who may potentially have the most benefit for a faster reperfusion strategy. More research is warranted to confirm this hypothesis. Severity score and acuteness-scores of myocardial ischemia from the prehospital ECG may be of value as a stratification and inclusion parameter in designing future clinical trials of reperfusion strategies in patients with STEMI (27).

Limitations

The present study has several limitations. Since this study was a sub-study from the MITOCARE trial, the study population is considered relatively small sized when stratified in 4 ECG groups. In the severe and acute ischemia group, there were no patients with anterior infarction. Thus, the analysis was based on the remaining 3 ECG groups in the anterior infarction group. Larger studies will be of great value, providing results based on statistical tests within the 4 groups. ECGs were analyzed manually by 3 independent investigators and no statistical reliability was performed. However, a forth investigator (MS) has manually controlled 25 random ECGs, without finding any discrepancies between the investigators and MS. Due to the complexity of the ECG scores and availability of digital ECG, development of the automatic algorithms for acuteness-score (28) and severity of ischemia could facilitate clinical applications of these scores.

Conclusion

The applicability of ECG indices of severity and acuteness of myocardial ischemia to estimate myocardial damage and salvage potential in STEMI patients treated with pPCI, is confined to anterior myocardial infarction.

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Disclosures

The authors have no disclosures relevant to the present study.

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Figure legend:

Figure 1: Stratification of patients according to severity and acuteness of ischemia from the admission electrocardiogram (25mm/s, 10mm/mV, 150Hz). A: Severe and non-acute ischemia: Severe ischemia due to terminal QRS distortion in V2-V4 and non-acute ischemia due to acuteness-score <3. B: Non-severe and non-acute ischemia: No terminal QRS distortion in leads with ST-segment elevation and acuteness-score <3. C: Non-severe and acute ischemia: No terminal QRS distortion in leads with ST-segment elevation and acuteness-score >3. D: Severe and acute ischemia: Terminal QRS distortion in > 2 leads with ST-segment elevation (V2-V4) and acuteness-score >3.

Figure 2: Median left ventricular cardiac magnetic resonance and echocardiographic measures according to combination of electrocardiographic severity and acuteness of ischemia.

LVEF: Left ventricular ejection fraction by echocardiography 30 days after index hospitalization.

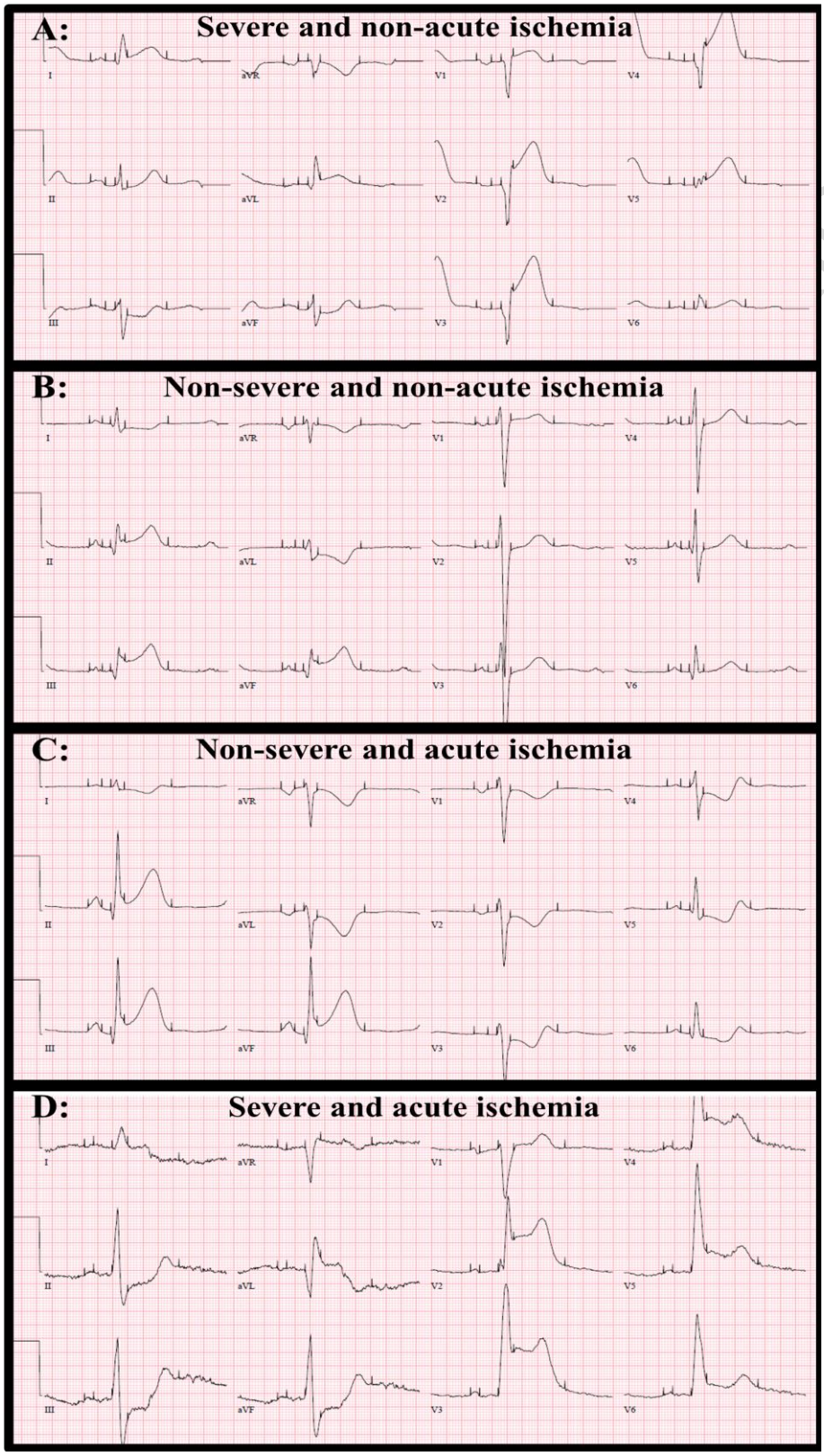
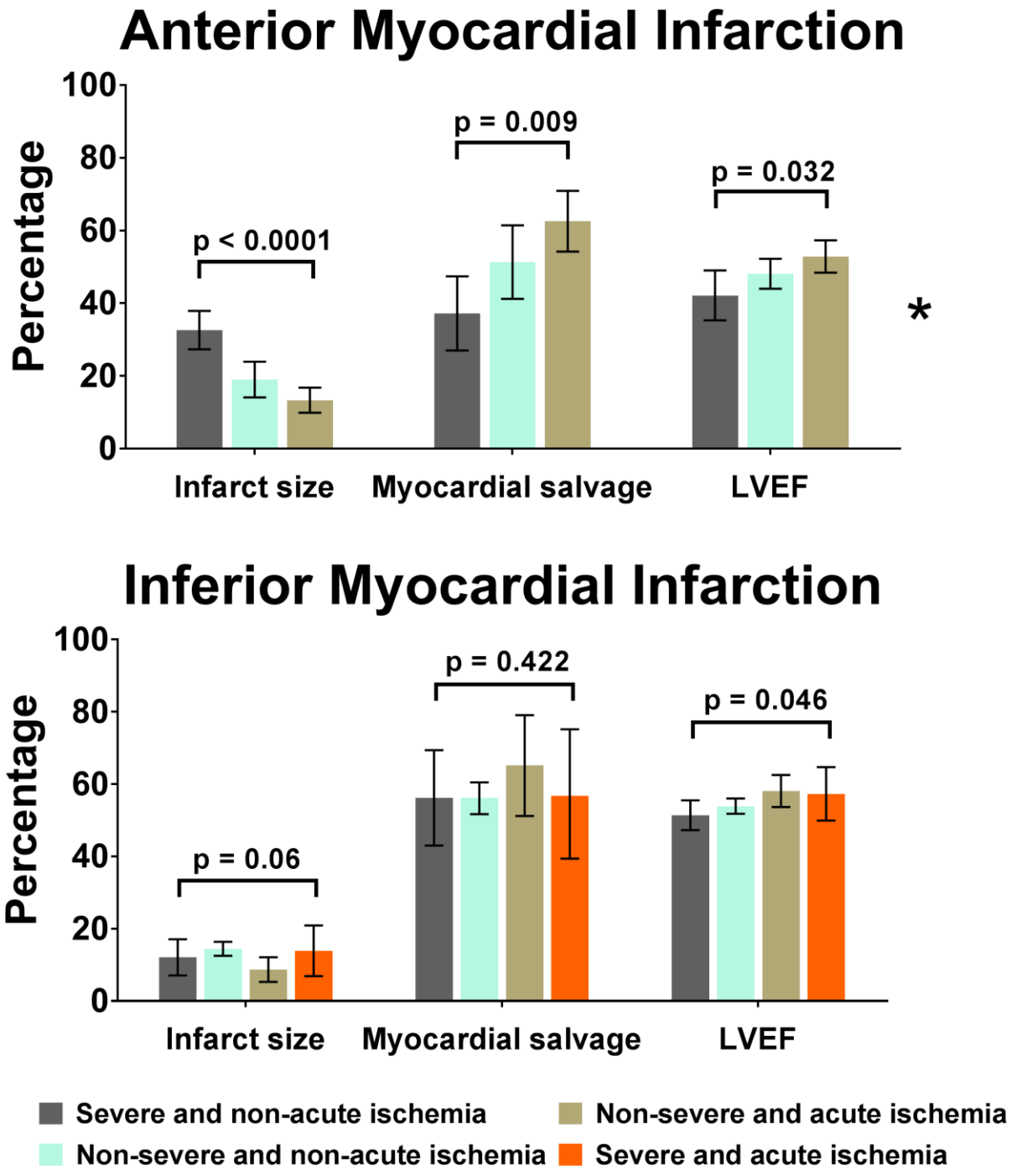


Figure 1



* No patients with anterior myocardial infarction were classified with severe and acute myocadial ischemia by ECG analysis.

Figure 2

Table 1 Lead specific criteria for abnormal Q-waves and tall T-waves

Lead	**Abnormal Q-wave**	**Tall T-wave**
I	≥30 ms	≥0.50 mV
II	≥30 ms	≥0.50 mV
III	≥ 30 ms and abnormal Q in aVF	≥0.25 mV
aVR	–	–
aVL	≥30 ms	≥0.25 mV
aVF	≥30 ms	≥0.50 mV
V_1	Any Q-wave	≥0.50 mV
V_2	Any Q-wave	≥1.0 mV
V_3	Any Q-wave	≥1.0 mV
V_4	≥30 ms	≥1.0 mV
V_5	≥30 ms	≥0.75 mV
V_6	≥30 ms	≥0.50 mV

ms, milliseconds; mV, millivolts

Table 2: Baseline characteristics according to electrocardiographic ischemia scores

	Electrocardiographic severity of ischemia		
Patient characteristics	**Severe ischemia (n = 41)**	**Non-severe ischemia (n = 106)**	**p-value**
Age, years	63 ±11	60 ±11	0.203
Male gender	34 (83)	92 (87)	0.548
Smoker	19 (46)	44 (42)	0.596
Hypertension	14 (34)	29 (27)	0.417
Diabetes mellitus	1 (2)	10 (9)	0.148
Killip class>1	32 (94)	68 (96)	0.709
Symptom to ballon inflation, min	200 (157-253)	173 (146-228)	0.229
Angiographic data			
Culprit vessel			0.330
LAD	12 (29)	43 (41)	
RCA	22 (54)	52 (49)	
LCX	7 (17)	11 (10)	
TIMI flow before pPCI			
0	37 (90)	97 (92)	0.809
1	4 (10)	9 (8)	
TIMI flow after pPCI			
2	3 (7)	4 (4)	0.878
3	34 (83)	90 (85)	
Treatment (TRO40303)	23 (56%)	50 (49%)	0.463
	Electrocardiographic acuteness of ischemia		

Patient characteristics	Acute ischemia (n = 41)	non-acute ischemia (n = 124)	p-value
Age, years	57±11	64±11	0.003
Male gender	35 (85)	103 (83)	0.729
Smoker	18 (44)	81 (65)	0.015
Hypertension	12 (29)	36 (29)	0.977
Diabetes mellitus	1 (2)	11 (9)	0.169
Killip class>1	26 (100)	89 (93)	0.189
Symptom to ballon inflation, min	167 (128-230)	184 (159-252)	0.099
Angiographic data			
Culprit vessel			0.403
LAD	14 (34)	48 (39)	
RCA	19 (46)	62 (50)	
LCX	8 (20)	14 (11)	
TIMI flow before pPCI			0.425
0	36 (88)	114 (92)	
1	5 (12)	10 (8)	
TIMI flow after pPCI			0.836
2	1 (2)	7 (6)	
3	35 (85)	105 (85)	
Treatment (TRO40303)	19 (48%)	64 (52%)	0.716

Values are given in n (%), mean (±SD) or median (interquartile range).

LAD, Left Anterior Descending coronary artery; LXC, Left Circumflex coronary artery; RCA, Right Coronary Artery; pPCI, Primary Percutaneous Coronary Intervention; TIMI, Thrombolysis in myocardial infarction

Table 3: Left ventricular measures according to electrocardiographic ischemia scores

	Electrocardiographic Severity of ischemia		
Biomarkers	**Severe ischemia n = 41**	**Non-severe ischemia n = 106**	**p-value**
TNTmax	9647 (6084 – 19502)	10003 (5406 – 15042)	0.375
CK-MBmax	268 (172 – 434)	175 (73-273)	0.001
NTproBNP at baseline	85 (61-193)	77 (44-180)	0.812
CMR data (n = 85)	**n = 25**	**n = 60**	
Infarct transmurality %	80 (68-86)	75 (64-82)	0.162
MVO %	0.04 (0-7)	0.01 (0-0.9)	0.001
LVEF %	43 (41-50)	50 (43-55)	0.002
MAR %	37 (27-49)	33 (28-39)	0.019
IS %	21 (9-28)	14 (10-19)	0.006
MSI %	50 (32-63)	56 (46-70)	0.035
30-day follow-up	**n = 37**	**n = 89**	
LVEF*	50 (44-58)	53 (47-59)	0.077
NTproBNP	1037 (513-1815)	588 (366-1049)	0.156
	Electrocardiographic acuteness of ischemia		
Biomarkers	**Acute ischemia n = 41**	**Non-acute ischemia n = 120**	**p-value**
TNTmax	7662 (4742-12554)	9988 (6553-17788)	0.266
CK-MBmax	156 (71-261)	197 (84-334)	0.092
NTproBNP at baseline	70 (43-149)	92 (50-219)	0.328

CMR data	**n = 22**	**n = 71**	
Infarct transmurality %	73 (56-80)	78 (67-85)	0.036
MVO %	0.005 (0-0.01)	0.04 (0-2)	0.074
LVEF %	52 (45-55)	48 (42-53)	0.065
MAR %	31 (24-37)	35 (28-42)	0.028
IS %	10 (9-16)	15 (10-25)	0.004
MSI %	61 (55-74)	50 (43-63)	0.013
30-day follow-up	**n = 36**	**n = 103**	
LVEF*	56 (51-64)	52 (45-56)	0.001
NTproBNP	424 (234-728)	819 (463-1745)	0.009

Values are given in median (interquartile range).

TNTmax; Peak Troponin T, CK-MBmax; Peak Creatinine Kinase Myocardial Band, MVO; Microvascular Obstruction, LVEF; Left Ventricular Ejection Fraction, MAR; Myocardial Area at Risk, IS; Infarct Size, MSI; Myocardial Salvage Index. NTproBNP; N-terminal pro-brain natriuretic peptide

*By echocardiography

Table 4: Left ventricular measures according to combination of electrocardiographic severity and acuteness of ischemia

Anterior STEMI	**Combination of ECG severity and acuteness of ischemia**				
	Severe and non-acute ischemia n = 12	**Non-severe and non-acute ischemia n = 30**	**Non-severe and acute ischemia n = 14**	**Severe and acute ischemia n = 0**	**p-value**
TNTmax	15176 (9519-28786)	10050 (6888-21869)	9499 (4618-25384)	-	0.539
CK-MBmax	416 (280-615)	197 (93-415)	131 (30-260)	-	0.008
CMR data	**n = 10**	**n = 17**	**n = 8**	**n = 0**	
Infarct transmurality %	87.2 (82-90)	83.2 (74-86)	76.5 (56-81)	-	0.034
MVO %	7.4 (2-11)	0.01 (0-1)	0.05 (0-2)	-	0.001
LVEF %	37.9 (28-47)	48.3 (42-55)	52.2 (44-55)	-	0.004
MAR %	52.3 (49-56)	39.2 (32-45)	37.2 (31-40)	-	<0.001
IS %	33.7 (26-40)	18.9 (13-26)	13.2 (1-17)	-	<0.001
MSI %	32.2 (28-50)	44.1 (42-70)	59.8 (55-73)	-	0.009
30-day follow-up	**n = 12**	**n = 27**	**n = 13**	**n = 0**	
LVEF*	42.2 (32-50)	50.0 (40-56)	52.0 (46-60)	-	0.032

NTproBNP	1411 (1047-2663)	816 (545-2177)	458 (282-916)	-	0.091
Non-Anterior STEMI					
Biomarkers	**n = 19**	**n = 40**	**n = 17**	**n = 9**	**p-value**
TNTmax	8355 (6173-20077)	10833 (6348-15002)	9404 (4677-12162)	5454 (4673-12901)	0.548
CK-MBmax	237 (192-374)	175 (84-277)	153 (84-211)	235 (132-378)	0.037
CMR data	**n = 10**	**n = 26**	**n = 9**	**n = 5**	
Infarct transmurality %	69.0 (56-81)	66.9 (65-79)	58.1 (49-76)	77.9 (62-82)	0.297
MVO %	0.08 (0-3)	0.01 (0-1)	0.00 (0-0.01)	0.00 (0-1)	0.599
LVEF %	41.9 (41-51)	50.0 (44-53)	54.3 (46-56)	50.4 (44-55)	0.193
MAR %	30.1 (22-38)	32.3 (27-36)	24.9 (21-31)	30.2 (27-38)	0.095
IS %	8.9 (8-19)	13.8 (11-18)	8.6 (5-13)	15.5 (9-19)	0.060
MSI %	60.9 (37-72)	56.3 (49-61)	65.6 (56-80)	26.0 (43-71)	0.422
30-day follow-up	**n = 18**	**n = 33**	**n = 16**	**n = 7**	
LVEF*	51.0 (45-58)	54.0 (49-58)	58.0 (52-66)	55.0 (50-67)	0.046
NTproBNP	952	578	368	546	0.094

	(420-1967)	(282-1005)	(180-577)	(282-929)	

Values are given in median (interquartile range).

TNTmax; Peak Troponin T, CK-MBmax; Peak CKMB, MVO; Microvascular Obstruction, LVEF; Left Ventricular Ejection Fraction, MAR; Myocardial Area at Risk, IS; Infarct Size, MSI; Myocardial Salvage Index

*By echocardiography

Highlights

- STEMI patients treated with primary PCI
- Terminal portion of QRS as severe ischemia according to Sclarovsky-Birnbaum grades of ischemia
- Ischemia acuteness assessed from admission ECG according to Anderson-Wilkin acuteness of ischmia
- Severe and non-acute ischemia from ECG was associated with damage of myocardium by CMR