ORIGINAL ARTICLES

Comparison of Different Methods of ST Segment Resolution Analysis for Prediction of 1-Year Mortality after Primary Angioplasty for Acute Myocardial Infarction

Jakub Przyłuski, M.D., Maciej Karcz, M.D., Ph.D., Łukasz Kalińczuk, M.D., Mariusz Kruk, M.D., Ph.D., Jerzy Pręgowski, M.D., Edyta Kaczmarska, M.S., Joanna Petryka, M.S., Paweł Bekta, M.D., Tomasz Deptuch, M.D., Cezary Kępka, M.D., Ph.D., Adam Witkowski, M.D., Ph.D., F.E.S.C., and Witold Rużyłło, M.D., Ph.D., F.E.S.C. On behalf of ANIN Myocardial Infarction Registry

From the Institute of Cardiology, Warsaw-Anin, Poland

Background: Resolution of ST segment elevation corresponds with myocardial tissue reperfusion and correlates with clinical outcome after ST elevation myocardial infarction. Simpler method evaluating the extent of maximal deviation persisting in a single ECG lead was an even stronger mortality predictor. Our aim was to evaluate and compare prognostic accuracy of different methods of ST segment elevation resolution analysis after primary percutaneous coronary intervention (PCI) in a real-life setting.

Methods: Paired 12-lead ECGs were analyzed in 324 consecutive and unselected patients treated routinely with primary PCI in a single high-volume center. ST segment resolution was quantified and categorized into complete, partial, or none, upon the (1) sum of multilead ST elevations (sumSTE) and (2) sum of ST elevations plus reciprocal depressions (sumSTE+D); or into the low-, medium-, and high-risk groups by (3) the single-lead extent of maximal postprocedural ST deviation (maxSTE).

Results: Complete, partial, and nonresolution groups by sumSTE constituted 39%, 40%, and 21% of patients, respective groups by sumSTE+D comprised 40%, 39%, and 21%. The low-, medium-, and high-risk groups constituted 43%, 32%, and 25%. One-year mortality rates for rising risk groups by sumSTE were 4.7%, 10.2%, and 14.5% ($P = 0.049$), for sumSTE+D 3.8%, 9.6%, and 17.6% ($P = 0.004$) and for maxSTE 5.1%, 6.7%, and 18.5% ($P = 0.001$), respectively. After adjustment for multiple covariates only maxSTE (high vs low-risk, odds ratio [OR] 3.10; 95% confidence interval [CI] 1.11–8.63; $P = 0.030$) and age (OR 1.07; 95% CI 1.02–1.11; $P = 0.002$) remained independent predictors of mortality.

Conclusions: In unselected population risk stratifications based on the postprocedural ST resolution analysis correlate with 1-year mortality after primary PCI. However, only the single-lead ST deviation analysis allows an independent mortality prediction.

A.N.E. 2007;12(1):5–14

primary PCI; ST segment elevation resolution; clinical prognosis

Address for reprints: Jakub Przyłuski, M.D., Coronary Disease Department and II Haemodynamic Department, Institute of Cardiology, 42 Alpejska Street, 04-628 Warsaw-Anin, Poland. Fax: +48 22 812 13 46; E-mail: jprzyłuski@ikard.pl

Source of Support: Research funds granted by the scientific council of the Institute of Cardiology in Warsaw-Anin. Dr. Pręgowski was supported by an unrestricted grant from the Foundation for Polish Science.

©2007, Copyright the Authors
Journal compilation ©2007, Blackwell Publishing, Inc.

INTRODUCTION

Mechanical reperfusion has for some time been the new paradigm for treatment of ST elevation acute myocardial infarction (STEMI).¹ Successful tissue myocardial reperfusion is the primary determinant of clinical outcome after STEMI treatment. Therefore, assessment of microvascular reperfusion status is crucial for risk prediction and possible initiation of further restorative procedures.²⁻⁵ Early evaluation of ST segment elevation resolution through insight into the status of reperfusion at the microvascular level, proved to be closely related to the amount of myocardial salvage and consequently cardiac mortality.⁶⁻¹⁰

Of several methods of ST segment elevation resolution analysis widely utilized and compared among patients treated with thrombolysis, risk stratification based on the single-lead extent of maximal persisting ST segment deviation proposed by Schröder et al. turned out to possess the best combination of predictive sensitivity and specificity as compared to the multilead methods.¹¹ Some of the methods of resolution analysis were applied in studies on patients treated with primary percutaneous coronary intervention (PCI). However, analysis of extent of residual ST segment elevation or depression in the single ECG lead as proposed by Schröder et al. has not been examined in this new setting.¹²⁻¹⁶ Moreover, prognostic accuracy of risk stratification based on different methods of ST resolution analysis in consecutive, real-life patient populations treated with primary PCI has not been compared.¹⁷⁻²¹

Therefore, we evaluated and compared prognostic value of three common methods of postprocedural ST segment elevation resolution analysis in an unselected patient population treated routinely for STEMI with primary PCI in single high-volume center. The clinical outcome was assessed in terms of 1-year mortality.

METHODS

Study Design and Patient Population

We analyzed 369 patients from the prospective ANIN registry of consecutive, unselected persons treated routinely for STEMI within first 12 hour of pain with primary PCI in the daily practice of single, tertiary, high-volume cath lab (>600 primary PCI/year) between April 2002 and December 2002. Out of them, 324 patients met the fol-

lowing inclusion criteria: (1) presence of ST elevation of ≥ 0.1 mV in at least two limb leads or of ≥ 0.2 mV in contiguous chest leads, (2) presence of paired, diagnostic and recorded within 3 hours after PCI, good quality 12-lead ECGs, (3) absence of left bundle branch blocks or ventricular paced rhythm on any of the paired ECG recordings. Primary PCI was performed according to the standard techniques, after loading doses of ASA and clopidogrel. Abciximab was administered at the discretion of physician performing the procedure; however, encouraged in case of either anterior location of the infarction or known diabetes. Among other data required by the protocol of ANIN registry, time of the pain onset and time of the first balloon inflation were recorded, allowing calculation of the time-to-treatment length. The local council on human research approved the study protocol.

ECG Analysis

Two experienced investigators blinded to the clinical and procedural results made qualitative and quantitative analyses of paired ECGs. Measurements of ST segment deviation were done with the hand held calipers to the nearest 0.05 mV, 20 ms after the end of QRS complex with reference of PR segment. In STEMI of anterior location evaluated leads were I, aVL, and V₁-V₆ whereas in inferior STEMI: II, III, aVF, V₅, V₆. Moreover, ST segment depressions of ≥ 0.1 mV were measured in II, III, aVF leads for anterior, while in V₁-V₄ for inferior myocardial infarctions.

Consistent with previously published definitions three methods of ST resolution analysis have been applied: (1) percent resolution of the initial sum of ST segment elevation (sumSTE),¹⁰ (2) percent resolution of the initial sum of ST segment deviation: elevation plus reciprocal depression (sumSTE+D),²² and (3) extent of maximal ST segment elevation for anterior STEMI or maximal deviation (elevation or depression) for inferior STEMI existing in the single-lead of postprocedural ECG (maxSTE).¹¹

Risk Categories by sumSTE and sumSTE+D

Groups of complete ($\geq 70\%$), partial ($\geq 30\%$ and $< 70\%$), and none ($< 30\%$) resolution were defined upon the calculated percentage normalization of baseline sum of, respectively, ST segment elevations or ST deviations.

Risk Categories by maxSTE

The low-, medium-, and high-risk groups were categorized by the absolute values of maxSTE and respective criteria of baseline ECG. Briefly, in large STEMI of anterior location defined as the maximal ST elevation of >4.5 mm in single lead of baseline ECG, patients were stratified as the high risk if maxSTE was >3 mm contrary to the low-risk group when maxSTE was ≤ 2 mm. In small STEMI of anterior location maximal ST elevation of ≤ 4.5 mm, patients were classified as the high risk if maxSTE was >5 mm and as the low risk when maxSTE was ≤ 1 mm. In the case of STEMI of inferior location, patients with maxSTE (elevation or depression) of >2 mm were stratified as the high risk and patients with maxSTE of ≤ 1 mm were in the low-risk category. Patients who do not fulfill the above criteria were categorized as the medium risk.

Angiography

Postprocedural angiograms were analyzed off-line with respect to the number of vessel disease and final thrombolysis in myocardial infarction flow grade (TIMI).

Follow-Up

The in-hospital stay of all patients was prospectively followed for cardiac death occurrence. In addition, based on telephone interviews with patients or their close relatives, the data from outpatient clinic and the National Population Database, 1-year mortality was obtained for all patients.

Statistics

The primary end point was all-cause mortality at 1-year follow-up. Continuous data are presented as medians with interquartile ranges and were compared by use of Kruskal-Wallis test. Categorical data are presented as frequencies and were analyzed with Fisher's exact or chi-square tests. Measure of agreement between risk groups stratified according to the applied methods of ST resolution analysis, was performed with the cross-tabs procedures. The Spearman correlation coefficient was applied for the bivariate correlation of continuous data. The Kaplan-Meier procedure was used for constructing survival curves. The areas under the receiver-operating characteristics (ROC) curves

were applied for the comparisons of prognostic accuracy of tested stratifications of ST segment elevation resolution. Multivariate regression analysis was used for identification of independent predictors of 1-year mortality and was done on the basis of logistic regressions with applied stepwise method. Separate analyses for each of the tested methods of ST resolution analysis were performed with inclusion of the following covariates: age, female gender, diabetes mellitus, current smoking status, history of hypertension, prior myocardial infarction, anterior location of STEMI, successful epicardial reperfusion defined as the postprocedural TIMI grade 3 flow, time to treatment and evaluated on admission: heart rate, systolic blood pressure, and Killip class >1 .

Significance was assumed at the 2-tailed P value of ≤ 0.05 . Absolute difference of ≥ 0.05 in the respective areas under the ROC curves was considered significant.

RESULTS

Patient Characteristics

Three hundred twenty-four patients (median age 60.4 years; range: 36–90 years) were studied. Females constituted 28% of the population, 3.7% of patients were in cardiogenic shock on admission and 11.4% presented signs of acute heart failure (Killip class >1). Median time to treatment was 4.2 hours. Detailed patients characteristics are presented in Table 1. Distribution of resolution categories by applied methods of ST segment analysis is shown in Figure 1.

Agreement of resolution categories by sumSTE with respective categories by sumSTE+D had homogenous pattern, and was of about 84–93% and 86–90%, respectively. Whereas, agreement of risk groups by maxSTE and respective resolution categories by sumSTE ranged from only 35–41% for the high risk versus none resolution to the 71–77% for the low risk versus complete resolution, respectively. Agreement of maxSTE and sumSTE+D was also heterogeneous and of similar level.

Distributions of atherosclerosis risk factors, female gender, history of myocardial infarction, coronary location of culprit lesion, and the presence of multivessel disease were similar among all risk groups. Significant differences in baseline patient characteristics and in pre- and postprocedural ECG measurements among categories within given

Table 1. Overall Demographic, Clinical, and Procedural Data

Characteristics	All Patients (n = 324)
Age, years (IQR)	60.4 (51.2–69.3)
Female gender (%)	27.8
Anterior myocardial infarction (%)	44.8
Diabetes mellitus (%)	17.0
History of smoking (%)	21.6
Current smokers (%)	54.0
Hypercholesterolemia (%)	37.0
Hypertension (%)	48.5
Prior myocardial infarction (%)	17.3
No. of patients transferred from other hospitals (%)	85.0
Pain-onset to admission, hour (IQR)	3.3 (2.3–5.0)
Time-to-treatment, hour (IQR)	4.2 (3.2–5.9)
No. of patients with time to treatment ≤ 4 hour (%)	56.2
No. of patients with time to treatment > 6 hour, (%)	29.6
Killip class at admission > 1, (%)	11.4
Systolic blood pressure, mmHg (IQR)	135 (120–154)
Heart rate on admission, beat/min (IQR)	80 (68–90)
Cardiogenic shock at admission (%)	3.7
Peak CK, IU/L (IQR)	1335 (697–2380)
Infarct-related artery	
Left anterior descending (%)	41.0
Right coronary artery (%)	44.2
Left circumflex coronary artery (%)	14.8
Culprit lesion stented (%)	83.0
Abciximab administration (%)	49.0
Multivessel disease (%)	47.8
TIMI flow grade	
Preprocedural	
0/1 (%)	75.8
2 (%)	12.5
3 (%)	11.7
Postprocedural	
0/1 (%)	7.1
2 (%)	11.4
3 (%)	81.5
ECG	
Pre sum ST elevation, mm (IQR)	9.5 (6.0–18.0)
Pre sum ST deviation, mm (IQR)	14.5 (8.0–22.0)
Pre maximal ST elevation, mm (IQR)	4.0 (2.5–5.0)
Post sum ST elevation, mm (IQR)	4.0 (2.0–8.0)
Post sum ST deviation, mm (IQR)	5.5 (2.5–10)
Post maximal ST deviation, mm (IQR)	2.0 (1.0–3.0)
Median sumSTE resolution (%) (IQR)	59.0 (32.0–81.0)
Median sumSTE+D resolution (%) (IQR)	61.0 (37.0–82.0)

IQR = interquartile range; CK = creatine kinase; TIMI = thrombolysis in myocardial infarction flow grade; Pre = preprocedural; Post = postprocedural; sumSTE = percent ST resolution of the initial sum of ST segment elevation; sumSTE+D = percent ST resolution of the initial sum of ST segment deviation.

stratification are presented in Table 2. Rising category of risk were associated with increasing age and systolic blood pressure and a greater likelihood of acute heart failure (Killip class > 1), cardiogenic shock at presentation, anterior location of infarction as well as larger electrocardiographic extent of initial ischemia. Of note, ST resolution extent as

analyzed with all three studied methods correlates significantly with final TIMI grade 3 flow.

Mortality and ST-Resolution Analysis

The overall 1-year mortality rate was 8.95% (n = 29). Rising risk categories by all three methods

Figure 1. The overall distribution of resolution categories stratified by applied methods of ST resolution analysis (sumSTE, sumSTE+D, maxSTE). Graph bars represents (1) sumSTE—percent ST resolution of the initial sum of ST segment elevation, (2) sumSTE+D—percent ST resolution of the initial sum of ST segment deviation, (3) maxSTE—extent of maximal ST segment deviation existing in the single-lead of postprocedural ECG but related to the respective criteria of baseline ECG. Complete ($\geq 70\%$), partial ($\geq 30\%$ and $< 70\%$), and none ($< 30\%$) resolution categories by sumSTE and sumSTE+D, and the low-, medium-, and high-risk groups by maxSTE.

of ST resolution analysis correlate significantly with increasing 1-year mortality rate (Table 3). The Kaplan-Meier survival curves for 1-year period, plotted individually for the sumSTE, sumSTE+D, and maxSTE are shown in Figure 2A–C.

In the univariate analysis the following parameters: age, systolic blood pressure, acute heart failure (Killip class > 1) on admission, final TIMI grade < 3 flow, and two of the studied methods of ST resolution analysis: sum STE+D and maxSTE but not sumSTE, were predictive of death at 1-year follow-up (Table 4). After adjustment for multiple covariates only age (odds ratio [OR] 1.07; 95% confidence interval [CI] 1.02–1.11; $P = 0.002$) and maxSTE (high vs low risk, OR 3.10; 95% CI 1.11–8.63; $P = 0.030$) remained predictive of 1-year mortality (Table 4).

DISCUSSION

The present study of unselected patient population treated routinely with primary PCI, proves that early risk stratification based on the analysis of postprocedural ST segment elevation resolution correlates with subsequent 1-year mortality.

Although predictive accuracy of risk stratification based on the extent of maximal ST deviation persisting in a single ECG lead as proposed by Schröders et al. (maxSTE) is same as those of the multilead based, maxSTE features the highest level of significance as the single predictor of 1-year mortality following primary PCI.

Furthermore, of all the studied parameters only age and maxSTE were independent predictors of death during 1-year follow-up.

As primary PCI became more commonly used for STEMI, experience gained in early ST resolution evaluation during the thrombolytic era was utilized in the new setting. Interestingly, in various studies either ST segment elevations alone^{12–18,20} or both, elevations plus reciprocal depressions were measured.¹⁹ Moreover, in one set of studies measurements were done across multi-ECG leads^{12,14–16,18–20} whereas in the other only one lead was assessed.^{13,17,21} However, there are only few studies, investigating in a primarily fashion utility of ST resolution analysis for prediction of cardiac mortality after primary PCI.^{17–21}

In 1997, Van't Hoff et al. have shown that risk stratification performed early after primary PCI upon the evaluation of sum resolution of ST elevations alone, is a strong predictor of clinical outcome.¹⁷ However, only patients with final TIMI grade 3 flow were examined and although evaluating serial ECG recordings, patients were stratified as having complete resolution solitary upon the postprocedural ECG. Moreover, criteria of complete resolution defined as the absence of residual ST elevation of ≥ 0.1 mV in any of 12 leads might resemble criteria of single lead, Schröders stratification. Although investigators reported strong inverse correlation between time-to-treatment length and rising category of risk, they did not include variable of ischemic time in the multivariate analysis. These discrepancies might explain differences between cited and current results, regarding significance of the multilead resolution analysis upon the ST elevations alone.

Whereas subsequent study by Matetzky et al. also showed independent predictive value of postprocedural ST resolution analysis for prediction of in-hospital and long-term mortality after primary PCI, it is of note that only patients with mechanical reperfusion due to contraindication to thrombolysis were examined. Moreover, analysis of resolution was preformed upon serial evaluation of three contiguous leads with maximal ST elevations and

Table 2. Observed Differences in Clinical and Procedural Data among Various ST Resolution Categories, P Values for Comparisons within the Individual Method of ST Resolution Assessment

Resolution/Risk categories	sumSTE			sumSTE+D			maxSTE		
	None n = 69	Partial n = 128	Complete n = 127	None n = 68	Partial n = 125	Complete n = 131	High risk n = 81	Medium risk n = 105	Low risk n = 138
Age, years (SD)	63.4 ± 11.9	60.6 ± 12.3	58.5 ± 10.05 ^a	64.3 ± 11.92	59.9 ± 11.7	58.7 ± 10.6 ^b	62.2 ± 11.5	60.6 ± 12.3	59.1 ± 10.8
Anterior myocardial infarction (%)	37.7	52.3	40.9	33.8	56.8	38.9 ^b	46.9	58.1	33.3 ^c
Systolic blood pressure on admission, mmHg (IQR)	147 (130–160)	140 (118.0–159.5)	129 ^b (115–150)	146.0 (125.8–160.0)	137 (120–158)	130 ^a (115–150)	130 (119.3–150.0)	144 (120–160)	130 ^a (119.5–150.0)
Heart rate on admission, beat/min (IQR)	78.5 (67.0–88.8)	80 (70–90)	79 (68–90)	74 (63–88)	80 (70–90)	80 (68–90)	80 (68–90)	80 (68–90)	75 (66.0–89.8)
Killip class > 1 at admission (%)	18.8	10.9	7.9	20.6	9.6	8.4 ^a	18.5	12.4	6.5 ^a
Cardiogenic shock at admission (%)	7.2	2.3	3.1	8.8	2.4	2.3 ^a	6.2	4.8	1.4
Final TIMI grade 3 flow, (%)	72.8	76.2	90.6 ^c	64.7	77.6	93.9 ^c	68.1	77.3	92.9 ^c
Peak CK, IU/L (IQR)	1664 (835–2545)	1448 (833–2441)	1095 (510–2318)	1691 (831–2326)	1338 (778–2408)	1187 (523–2574)	1466 (863–3017)	1704 (804–2619)	1040 ^a (550–2187)
Pre sum ST elevation, mm (IQR)	7.5 (4.3–10.0)	11.0 (6.5–20.0)	11 ^c (5.5–19.5)	9.5 (5.5–14.4)	18 (11.0–24.8)	15.5 ^c (8–22.5)	21.0 (14.3–32.5)	15 (8.8–19.5)	10.75 ^c (5.5–18.0)
Pre maximal ST elevation, mm (IQR)	3 (2–4)	4.5 (3.0–6.0)	4 ^c (2.5–6.0)	3 (2–4)	4.75 (3.0–6.8)	4 ^c (2.5–6)	5 (4–9.3)	4 (2.8–5.0)	3 ^c (2–5)
Post sum ST deviation, mm (IQR)	7.5 (4.0–11.0)	5.5 (3.5–9.5)	1.5 ^b (0.5–3.5)	10.5 (6–14)	8 (5.0–11.3)	2 ^c (0.5–4)	13 (9.5–19.5)	7 (5–9)	2 ^c (0.5–3.5)
Post maximal ST elevation/ deviation, mm (IQR)	2.5 (1.5–4.0)	2.5 (1.5–3.0)	1 ^c (0.5–1.5)	3 (1.5–4.0)	2 (1.5–3.0)	1 ^c (0.5–1.5)	4 (3–5)	2 (1.5–3.0)	1 ^c (0.5–1.0)
Time to treatment, hour (IQR)	4.4 (3.0–7.0)	4.3 (2.9–6.0)	3.9 (3.2–5.7)	4.3 (2.6–7.4)	4.3 (2.8–5.9)	4.0 (3.2–5.9)	4.0 (2.8–5.6)	4.4 (3.2–6.4)	3.9 (3.2–5.9)

^ap < 0.05; ^bp < 0.01; ^cp < 0.001.

STEMI = ST segment elevation acute myocardial infarction; CK = serum creatine kinase; Pre = preprocedural; Post = postprocedural.

Table 3. The 1-Year Mortality Rates (%) among Risk Groups Stratified by Different Methods of ST Segment Resolution Analysis (sumSTE, sumSTE+D, maxSTE) with Respective ROC Areas are Shown

	Complete/Low Risk	Partial/Medium Risk	None/High Risk	ROC Area (St. Error)	P
sumSTE	4.7%	10.2%	14.5%	0.626 (0.053)	0.049
sumSTE+D	3.8%	9.6%	17.6%	0.667 (0.051)	0.004
maxSTE	5.1%	6.7%	18.5%	0.659 (0.056)	0.001

ROC areas = The areas under the receiver-operating characteristics curves for mortality prediction; St. Error = standard error; SumSTE = ST % resolution of the initial sum of ST segment elevation; sumSTE+D = % ST resolution of the initial sum of ST segment deviation; maxSTE = extent of maximal ST segment deviation existing in the single-lead of postprocedural ECG but related to the respective criteria of baseline ECG.

Complete ($\geq 70\%$), partial ($\geq 30\%$ and $< 70\%$), and none ($< 30\%$) resolution categories by sumSTE and sumSTE+D, and the low-, medium-, and high-risk groups by maxSTE.

other—50% cutoff was used for resolution stratification.¹⁸ Therefore, these results are hardly comparable with ours.

Also, Claves et al. confirmed independent and detrimental impact of persistent ST elevation on clinical outcome after primary PCI.¹⁹ Interestingly, reported 82% rate of final TIMI grade 3 flow is similar to our study but cardiogenic shock was more frequent (13% vs 3.7%). Even though investigators measured both ST elevations and reciprocal depressions, only posterolateral extensions of inferior STEMI defined as allied reciprocal depressions in V1–V2 leads were considered. Notably, it is well proved that reciprocal depressions independently of infarction location correlate linearly with its size and subsequent mortality.²² Therefore, since Claves et al. applied methodology of ST deviations evaluation only in a semi manner and defined clinical outcome as a composite end point with cardiac deaths being only a 25% fraction, his outcomes remain in general agreement with current results.

Finally, the latest studies concerning clinical utility of different methods of ST resolution analysis for risk stratification after primary PCI were designed as substudies of the randomized trial (CADILLAC), signifying highly selected patients population e.g., nonshock subjects with very high, 96% rate of final TIMI grade 3 flow.^{20,21}

As to our knowledge, single-lead risk stratification formulated by Schröder et al. (maxSTE) has been examined currently for the first time in the setting of primary PCI. Present results indicate that 1-year mortality after primary PCI would be correctly predicted in comparable proportion of cases by all of the studied methods; sumSTE, sumSTE+D, and maxSTE (63% vs 67% vs 66%, respectively). Essentially different reperfusion strategies and inclusion of patients in cardiogenic shock might explain why currently examined either the single- or multilead methods of ST deviation analysis were equal with regard to the predictive power whereas accuracy of these methods differed in the study by Schröder et al.¹¹

Table 4. Univariate and Multivariate Predictors of 1-Year Mortality

	Univariate Predictors			Multivariate Predictors		
	OR	95% CI	P	OR	95% CI	P
Age	1.06	1.03–1.10	<0.001	1.07	1.02–1.11	0.002
Systolic blood pressure on admission	0.98	0.97–0.99	0.028	—	—	—
Killip class > 1 on admission	4.29	1.78–10.32	0.001	—	—	—
Final TIMI grade < 3 flow	3.33	1.46–7.60	0.004	—	—	—
sumSTE+D (none vs complete resolution)	5.40	1.82–16.06	0.002	—	—	—
maxSTE (high vs low risk)	4.25	1.65–10.94	0.003	3.10	1.11–8.63	0.030

TIMI = thrombolysis in myocardial infarction flow grade; SumSTE+D = % ST resolution of the initial sum of ST segment deviation; maxSTE = extent of maximal ST segment deviation existing in the single-lead of postprocedural ECG but related to the respective criteria of baseline ECG.

Complete ($\geq 70\%$), partial ($\geq 30\%$ and $< 70\%$), and none ($< 30\%$) resolution categories by sumSTE+D, the low- and high-risk groups by maxSTE.

Figure 2. Kaplan-Meier survival curves plotted for a 360-day-long follow-up, individually for studied risk stratifications upon the different methods of ST resolution analysis (sumSTE, sumSTE+D, maxSTE). SumSTE = ST% resolution of the initial sum of ST segment elevation; sumSTE+D = % ST resolution of the initial sum of ST segment deviation; maxSTE = extent of maximal ST segment deviation existing in the single-lead of postprocedural ECG but related to the respective criteria of baseline ECG. Complete ($\geq 70\%$), partial ($\geq 30\%$ and $< 70\%$), and none ($< 30\%$) resolution categories by sumSTE and sumSTE+D, and the low-, medium-, and high-risk groups by maxSTE.

Currently applied resolution analysis based on the single-lead ST deviation allows early and independent identification of about 43% of patients with 5.1% risk of death within the first year after primary PCI. On the other hand, patients stratified as the high risk by maxSTE comprised 52% of all deaths at 1-year follow-up.

Interestingly, of all examined parameters in the present study only age and maxSTE were independent predictors of death at 1 year, confirming the notion that ST resolution analysis is the most informative and therefore a valuable clinical tool for early reperfusion evaluation.²³

The highest significance level of predictive capability along with the ability of independent 1-year mortality prognosis offered by maxSTE might result from parallel relation of rising category of risk and correspondingly larger electrocardiographic extent of initial ischemia, worse clinical status on admission (e.g., more acute heart failure), as well as worse angiographic result obtained (TIMI grade 3 flow) in the studied now real-life patient populations. Current results of multivariate analyses and pattern of Kaplan-Meier curves divergence, indicate that ST resolution analysis upon the single-lead ST deviation as proposed by Schröder et al. stratifies patients mainly into groups of high versus low-risk of death, what is consistent with previous reports on patients treated with thrombolytic therapy.¹¹

Our results suggest that simple risk stratification based on the extent of maximal ST deviation persisting after primary PCI in a single ECG lead, provide early, specific, and independent prognosis of 1-year mortality. Therefore, this simple, clinically feasible method might identify potential candidates for further interventions aimed at the restoration of adequate microvascular reperfusion after routine primary PCI for STEMI.

LIMITATION

Current methodology of the comparative, two time point analysis of ST resolution might be imperfect as the reperfusion process continues over time. However, advantages of continuous ST segment monitoring as compared to the static assessment are not well documented. Exclusion of patients with conduction abnormalities of bundle branch block patterns or requiring ventricular pacing might cause a selection bias as those subjects have an increased risk of adverse events.^{24,25}

Presented results might be merely a consequence of small number of studied patients; however, observed significant differences between applied methods of risk assessment based on ST resolution analysis, might signify better accuracy of the specific method in "the real-life" setting. Similarly, results of univariate and multivariate analyses were insignificant with respect to the risk comparison between groups of partial versus complete resolution by both sum parameters, and groups of medium versus low risk by maxSTE, probably owing to the relatively small number of studied patients.

Myocardial blush grade, an angiographic score of tissue perfusion was not quantified in the present study and its impact on an independent, prognostic value of risk stratification upon ST resolution could not be excluded.² However, there are studies indicating an independent and additive, prognostic information carried by scores based on the ST resolution as well as myocardial blush grade quantification.¹⁶ Measurements of other ECG variables such as QRS duration/score, T wave inversion, Q wave appearance would apparently add a lot to better understanding of present results and require further as well as prospective studies.^{26–28}

REFERENCES

1. Antman EM, Anbe DT, Armstrong PW, et al. ACC/AHA guidelines for the management of patients with ST-elevation myocardial infarction: Executive summary: A report of the ACC/AHA Task Force on Practice Guidelines [Committee to Revise the 1999 Guidelines on the Management of Patients With Acute Myocardial Infarction]. *J Am Coll Cardiol* 2004;44:671–719.
2. Gibson CM, Cannon CP, Murphy SA, et al. TIMI Study Group. Relationship of TIMI myocardial perfusion grade to mortality after administration of thrombolytic drugs. *Circulation* 2000;101:125–130.
3. The EPIC investigators. Use of a monoclonal antibody directed against the platelet glycoprotein IIb/IIIa receptor in high-risk coronary angioplasty. *N Engl J Med* 1994;330:956–961.
4. Ohman EM, George BS, White CJ, et al. Use of aortic counterpulsation to improve sustained coronary patency during acute myocardial infarction: Results of a randomised trial. *Circulation* 1994;90:792–799.
5. Hillegass WB, Dean NA, Liao L, et al. Treatment of no-reflow and impaired flow with the nitric oxide donor nitroprusside following percutaneous coronary interventions: Initial human clinical experience. *J Am Coll Cardiol* 2001;37:1335–1343.
6. Santoro M, Valenti R, Buonamici P, et al. Relation between ST-segment changes and myocardial perfusion evaluated by myocardial contrast echocardiography in patients with acute myocardial infarction treated with direct angioplasty. *Am J Cardiol* 1998;82:932–937.
7. Feldman LJ, Coste P, Furber A, et al. FRENCH Optimal STenting-2 Invest. Incomplete resolution of ST-segment elevation is a marker of transient microcirculatory dysfunction after stenting for acute myocardial infarction. *Circulation* 2003;107:2684–2689.
8. Dong J, Ndrepepa G, Schmitt C, et al. Early resolution of ST-segment elevation correlates with myocardial salvage assessed by Tc-99m sestamibi scintigraphy in patients with acute myocardial infarction after mechanical or thrombolytic reperfusion therapy. *Circulation* 2002;105:2946–2949.
9. de Lemos JA, Braunwald E. ST segment resolution as a tool for assessing the efficacy of reperfusion therapy. *J Am Coll Cardiol* 2001;38:1283–1294.
10. Schröder R, Dissmann R, Bruggemann T, et al. Extent of early ST segment elevation resolution: A simple but strong predictor of outcome in patients with acute myocardial infarction. *J Am Coll Cardiol* 1994;24:384–391.
11. Schröder K, Wegscheider K, Zeymer U, et al. Extent of ST-segment deviation in a single electrocardiogram lead 90 min after thrombolysis as a predictor of medium-term mortality in acute myocardial infarction. *Lancet* 2001;358:1479–1486.
12. Zeymer U, Schröder R, Machnig T, et al. Primary percutaneous transluminal coronary angioplasty accelerates early myocardial reperfusion compared to thrombolytic therapy in patients with acute myocardial infarction. *Am Heart J* 2003;146:686–691.
13. Antoniucci D, Valenti R, Migliorini A, et al. Comparison of rheolytic thrombectomy before direct infarct artery stenting versus direct stenting alone in patients undergoing percutaneous coronary intervention for acute myocardial infarction. *Am J Cardiol* 2004;93:1033–1035.
14. Santoro GM, Antoniucci D, Valenti R, et al. Rapid reduction of ST-segment elevation after successful direct angioplasty in acute myocardial infarction. *Am J Cardiol* 1997;80:685–689.
15. Limbruno U, Micheli A, De Carlo M, et al. Mechanical prevention of distal embolization during primary angioplasty: Safety, feasibility, and impact on myocardial reperfusion. *Circulation* 2003;108:171–176.
16. Poli A, Fève R, Vandoni P, et al. Integrated analysis of myocardial blush and ST-segment elevation recovery after successful primary angioplasty: Real-time grading of microvascular reperfusion and prediction of early and late recovery of left ventricular function. *Circulation* 2002;106:313–318.
17. Van't Hoff AWJ, Liem A, de Boer MJ, et al. For the Zwolle Myocardial Infarction Study Group. Clinical value of 12-lead electrocardiogram after successful reperfusion therapy for acute myocardial infarction. *Lancet* 1997;350:615–619.
18. Matetzky S, Novikov M, Gruberg L, et al. The significance of persistent ST elevation versus early resolution of ST segment elevation after primary PTCA. *J Am Coll Cardiol* 1999;34:1932–1938.
19. Claeys MJ, Bosmans J, Veenstra L, et al. Determinants and prognostic implications of persistent ST-segment elevation after primary angioplasty for acute myocardial infarction: Importance of microvascular reperfusion injury on clinical outcome. *Circulation* 1999;99:1972–1977.
20. Prasad A, Stone GW, Aymong E, et al. CADILLAC trial. Impact of ST-segment resolution after primary angioplasty on outcomes after myocardial infarction in elderly patients: An analysis from the CADILLAC trial. *Am Heart J* 2004;147:669–675.
21. McLaughlin MG, Stone GW, Aymong E, et al. Controlled Abciximab and Device Investigation to Lower Late Angioplasty Complications trial. Prognostic utility of comparative methods for assessment of ST-segment resolution after primary angioplasty for acute myocardial infarction: The Controlled Abciximab and Device Investigation to Lower

- Late Angioplasty Complications (CADILLAC) trial. *J Am Coll Cardiol* 2004;44:1215-1223.
22. Willems JL, Willems RJ, Willems GM, et al. Significance of initial ST segment elevation and depression for the management of thrombolytic therapy in acute myocardial infarction. European Cooperative Study Group for Recombinant Tissue-Type Plasminogen Activator. *Circulation* 1990;82:1147-1158.
23. Giugliano RP, Sabatine MS, Gibson CM, et al. Combined assessment of thrombolysis in myocardial infarction flow grade, myocardial perfusion grade, and ST-segment resolution to evaluate epicardial and myocardial reperfusion. *Am J Cardiol* 2004;93:1362-1367.
24. Bilbao FJ, Zabalza IE, Vilanova JR, et al. Atrioventricular block in posterior acute myocardial infarction: A clinico-pathologic correlation. *Circulation* 1987;75:733-736.
25. Hathaway WR, Peterson ED, Wagner GS, et al. Prognostic significance of the initial electrocardiogram in patients with acute myocardial infarction. The GUSTO-I Investigators. *JAMA* 1998;279:387-391.
26. Corbalan R, Larrain G, Nazzari C, et al. Association of noninvasive markers of coronary artery reperfusion to assess microvascular obstruction in patients with acute myocardial infarction treated with primary angioplasty. *Am J Cardiol* 2001;88:342-346.
27. Juergens CP, Fernandes C, Hasche ET, et al. Electrocardiographic measurement of infarct size after thrombolytic therapy. *J Am Coll Cardiol* 1996;27:617-624.
28. Lee CW, Hong MK, Yang HS, et al. Determinants and prognostic implications of terminal QRS complex distortion in patients treated primary angioplasty for acute myocardial infarction. *Am J Cardiol* 2001;88:210-213.