Resolution of ST-segment depression: a new prognostic marker in ST-segment elevation myocardial infarction

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Aims
To evaluate the prognostic impact of ST depression resolution among patients with ST-segment elevation myocardial infarction (STEMI) undergoing primary PCI in the Assessment of Pexelizumab in Acute Myocardial Infarction (APEX-AMI) trial.

Methods and results
In this study, 4729 of 5745 patients had analysable ECGs demonstrating concomitant ST-segment depression. Resolution of STE elevation (STE-R) and STD depression (STD-R) on 30 min post-PCI ECGs was dichotomized into those with ≥50 vs. <50% ST-segment resolution. Overall, 1143 patients (24%) had STD-R ≥50%. These patients had higher risk characteristics including older age, female sex, diabetes, hypertension, prior CHF/MI, Killip class I, triple vessel disease, and less frequent TIMI 3 flow in the culprit coronary vessel post-PCI. After multivariable adjustment and accounting for STE-R, STD-R ≥50% remained an independent predictor for 90 day death and the composite of death, cardiogenic shock, or CHF. When compared with patients with both STE-R and STD-R ≥50%, patients with both STE-R and STD-R <50% had the worst outcomes [hazard ratios (HR) 90 day death: 2.54; 95% confidence intervals (CI): 1.71–3.77; HR 90 day composite: 2.18; 95% CI: 1.63–2.91].

Conclusion
When ST depression is present in STEMI patients undergoing primary PCI, STD-R ≥50% provides independent prognostic value that is incremental to STE-R.

Keywords
Myocardial infarction • ECG • Prognosis • Clinical trials

Introduction
The ECG remains a simple yet powerful tool in the assessment of reperfusion efficacy and prognosis following ST-segment elevation myocardial infarction (STEMI). The current ESC and ACC/AHA guidelines advocate greater than 50% resolution of ST-segment elevation at 60–90 min following fibrinolysis as a marker of successful reperfusion. This metric is also associated with enhanced myocardial perfusion, recovery of left ventricular function, reduced infarct size, and improved outcomes. Contemporary studies have also affirmed the prognostic utility of ST-segment elevation resolution following primary PCI independent of procedural outcome and final TIMI flow grade in the culprit artery.

Less attention has been given towards the evolution of concomitant ST-segment depression in patients with STEMI. Despite uncertainty as to its mechanism, concomitant ST-segment depression has been associated with poorer clinical outcomes. It is recognized from the work of Schroder et al. and others that the extent of ST-segment deviation (elevation plus depression) defines the territory at risk and its overall resolution is prognostically relevant. However, it remains unclear whether resolution of ST-segment depression alone is associated with improved...
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<th>ST elevation resolution ≥50%</th>
<th>ST depression resolution ≥50%</th>
<th>ST depression resolution &lt;50%</th>
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<td>54.1</td>
<td>80.4</td>
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<td>Time from symptoms to PCI, h</td>
<td>3.28 (2.50–4.42)</td>
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<td>Baseline SST elevation, mm</td>
<td>10.0 (7.0–5.5)</td>
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<td>Baseline SST depression, mm</td>
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<td>3.5 (1.5–7.0)</td>
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<td>1800 (779–3316)</td>
<td>2215 (1097–3926)</td>
<td>2239 (1130–3902)</td>
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<td>Peak CKMB (µg/L)</td>
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<td>150 (66–279)</td>
<td>183 (75–306)</td>
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<td>Peak TnT (µg/L), n</td>
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<td>6.3 (3.2–10.7), (194)</td>
<td>5.7 (2.6–10.8), (161)</td>
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<td>Peak Tnl (µg/L), n</td>
<td>50.0 (19.3–100.0), (1624)</td>
<td>54.6 (22.9–118.2), (2660)</td>
<td>75.9 (25.3–128.2), (372)</td>
<td>73.2 (33.4–152.0), (281)</td>
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*Only vessels with >50% stenosis were considered.

*P < 0.01; †P < 0.05; ‡P < 0.001 for pairwise comparison.
Methods

The APEX-AMI trial was a multicenter, randomized, double-blind, placebo-controlled trial of intravenous pexelizumab (a novel huma-
nized monoclonal antibody to C5 complement) in conjunction with
primary PCI for patients presenting with acute STEMI. The specific
entry criteria have been described previously. Briefly, patients
were ≥ 18 years old, with symptom onset < 6 h, and had an ECG
indicative of acute STEMI that fulfilled any of the following three
criteria:

1. ≥ 2 mm ST elevation in two anterior or lateral leads; or
2. ≥ 2 mm ST elevation in two inferior leads coupled with ST
depression in two contiguous anterior leads for a total ST devi-
ation of ≥ 8 mm; or
3. New left bundle branch block (LBBB) with at least 1 mm concor-
dant ST elevation.

Prospectively identified endpoints included 90 day mortality and the
composite of death, cardiogenic shock, or CHF. Enrolment began on
13 July 2004 and ended 11 May 2006, resulting in a final population
of 5745 patients who met criteria:

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The importance of the ST-segment resolution factors was assessed
by the Schmerf and Henderson’s19 V, which is analogous to R² in
measuring explained variation in linear regression models. Specifically,
the marginal proportion of explained variation (PEV) is a measure of
the variation due to the factors in the model, whereas the partial
PEV measures the decrease in explained variation when removing
the prognostic factor of interest.20 The typical range for overall PEV
explained by prognostic factors in survival models is 10–35%.

All hypotheses were determined ‘a priori’ and as such no
adjustments were made for multiple comparisons (i.e. all tests were
two-sided, with a 5% level of significance).

All analyses were performed with SAS statistical software (version
9.1.3, SAS Institute, Cary, NC, USA).

Results

Among 5745 patients enrolled in APEX-AMI, 4729 patients constit-
tute our study cohort. Patients excluded were those with missing

Figure 1 Kaplan–Meier curves according to ST elevation reso-

- lution. (A) 90 day death, log-rank P < 0.001, (B) 90 day death,
cardiogenic shock, or CHF, log-rank P < 0.001.
or uninterpretable ECGs ($n = 500$), those with LBBB ($n = 98$), and those who did not have ST depression at baseline ($n = 418$). Hence, the final study cohort consisted of 2123 patients with inferior MI and 2606 patients with non-inferior MI.

Table 1 shows baseline and pre- and post-PCI patient characteristics. Data are initially partitioned according to ST elevation resolution (STE-R), then subsequently according to ST depression resolution (STD-R) and both use a 50% cut point. Overall 24% of patients ($n = 1143$) had STE-R $<50\%$; this occurred more often in patients without STE-R i.e. $<50\%$ (44.4%) vs. those with STE-R $\geq 50\%$ (16.4%; $P < 0.001$). Irrespective of STE-R status, patients with STD-R $<50\%$ were more likely to be older, female, diabetic, and have a history of prior CHF. Patients with STD-R $<50\%$ were also more likely to have hypertension, a history of prior MI, Killip class $>1$, and triple vessel disease especially when accompanied by STE-R $\geq 50\%$. There were no significant differences in time from symptom onset to PCI according to STD-R.

Examination of the angiographic procedural outcomes revealed that overall those with STE-R $<50\%$ were less likely to have TIMI 3 culprit coronary flow post-PCI when compared with patients with STE-R $\geq 50\%$ (80.2 vs. 90.8%; $P < 0.001$). Irrespective of their STE-R status, patients with STD-R $<50\%$ had less frequent TIMI 3 flow post-PCI when compared with those with STD-R $\geq 50\%$ especially among the 28% of patients ($n = 1313$) with STE-R $<50\%$. Whereas no significant differences in peak CK or CKMB measurements were evident across groups, patients with STE-R $\geq 50\%$ who had $<50\%$STD-R tended to have a greater rise in cardiac troponins.

Ninety-day death and the 90 day composite of death, cardiogenic shock or CHF are shown according to STE-R only (Figure 1A and B) and both STE-R and STD-R (Figure 2A and B). Compared with patients with STE-R $\geq 50\%$, those with STE-R $<50\%$ had higher 90 day mortality (Figure 1A, 6.5 vs. 3.1%; $P < 0.001$) and the 90 day composite (Figure 1B, 11.6 vs. 5.9%; $P < 0.001$). Irrespective of STE-R status, patients with STD-R $<50\%$ had significantly worse 90 day clinical outcomes when compared with those with STD-R $\geq 50\%$ (Figure 2). Of note among patients with STE-R $\geq 50\%$, the 90 day mortality for those with STD-R $<50\%$ was more than twice as high (5.4 vs. 2.6%; $P = 0.001$). The most favourable outcomes were seen in patients with STE-R and STD-R both $\geq 50\%$, whereas the worst outcomes were evident in the 12% of patients with $<50\%$ STE-R and STD-R. The two groups in whom STE-R and STD-R

![Figure 2](https://academic.oup.com/eurheartj/article-abstract/31/5/573/513153/3.155752/513153)
were discordant (i.e. STE-R≥50% and STD-R<50%, or STE-R<50% and STD-R≥50%) had similar intermediate outcomes.

Ninety day outcomes according to STE-R and STD-R are presented separately for patients with inferior MI (Figure 3) and non-inferior MI (Figure 4). The proportion of patients with STD-R<50% was 22% and 26% among inferior MI and non-inferior MI patients, respectively. The worst outcomes were seen in patients with STE-R and STD-R both <50% (% of total patients, inferior MI: 10%, non-inferior MI: 14%). These patients had a 90 day mortality rate of 8.8% that was identical for those with either inferior or non-inferior MI. Regardless of infarct location, the risk separation afforded by STE-R and STD-R was preserved and generally tracked that of the overall population.

The multivariable-adjusted HR for ST-segment resolution measures in relation to 90 day clinical outcomes (i.e. Model 1: STE-R and STD-R as individual covariates; Model 2: combined STE-R/STD-R; Model 3: Schroder’s ST deviation resolution) are presented in Table 2. As individual covariates, both STE-R and STD-R had comparably strong and independent associations with 90 day mortality and the 90 day composite of death, cardiogenic shock, or CHF (Table 2: Model 1). Relative to STE-R, STD-R had a similar or higher marginal PEV (90 day death: 0.57 vs. 0.33%; 90 day composite: 0.63 vs. 0.62%).

When the combination of STE-R and STD-R was examined, a risk gradient was observed with patients experiencing both STE-R and STD-R<50% having a more than two-fold increase in the hazard of dying within 90 days (compared with the reference group of patients with STE-R and STD-R both ≥50%; adjusted HR 2.54) and experiencing the composite outcome (adjusted HR 2.18; Table 2: Model 2). Relative to the model with Schroder’s ST deviation resolution (Table 2: Model 3), the combined STE-R/STD-R had higher partial PEV (90 day death: 1.14 vs. 0.60%, \( P < 0.0001 \); 90 day composite: 0.90 vs. 0.53%, \( P < 0.0001 \)).

![Figure 3](https://academic.oup.com/eurheartj/article-abstract/31/5/573/513153/573)  
**Figure 3** Kaplan–Meier curves according to ST elevation resolution (STE-R) and ST-depression resolution (STD-R) among patients with inferior MI (\( n = 2123 \)). (A) 90 day death, pairwise log-rank \( P \)-values: \( *P = 0.105, \ \dagger P = 0.012 \) and (B) 90 day death, cardiogenic shock, or CHF, pairwise log-rank \( P \)-values: \( *P = 0.033, \ \dagger P < 0.001 \).
Discussion

The principal novel finding of this study is that when concomitant ST depression is present in patients with STEMI undergoing primary PCI (representing 92% of the trial population with suitable ECGs), a high risk subset with less than 50% resolution of ST depression after primary PCI exists. This subset constitutes one in four patients with initial ST depression and they experience worse 90 day clinical outcomes. This finding from a large clinical trial of primary PCI in STEMI was independent of baseline co-morbidities, infarct location, TIMI flow grade in the culprit artery, and notably resolution of ST elevation. Hence evaluation of ST depression resolution appears particularly useful in further partitioning risk in patients who achieve apparently successful reperfusion as defined by ST elevation resolution ≥50%. Among these patients in whom favourable outcomes are generally anticipated, 16% failed to resolve at least 50% of concomitant ST depression and experienced over a two-fold increase in 90 day mortality.

Whereas prior studies have examined resolution of ST depression in the context of ST elevation, they have grouped the changes under the general category of total ST deviation precluding a separate assessment of their relative contribution to outcomes.3,4,10,17 To our knowledge, only two studies to date have addressed ST depression resolution as a distinct metric in patients with STEMI. Shah et al.15 utilized continuous 12-lead ECG monitoring for 24 h in 261 patients treated with fibrinolysis. Patients with persistent ST-segment depression despite resolution of ST-segment elevation sustained higher in-hospital mortality (13%) compared with those in whom ST-segment depression resolved simultaneously with ST-segment elevation (1%), and to those without baseline ST-segment depression (0%). De Luca et al.21 examined 610 STEMI patients with baseline ST-segment depression and successful primary PCI defined as TIMI 3 flow and ≥70% ST elevation resolution at 3 h. Less than 70% resolution of ST-segment depression in these patients was associated with larger infarcts and greater 1 year mortality. It remains unclear from these studies whether ST depression resolution retains its
Resolution of ST-segment depression

Our study complements the previous literature by showing that resolution of ST depression retains its prognostic impact irrespective of anatomical infarct location—a strong predictor of outcomes—modulates the impact of ST elevation resolution.

Using data from the APEX-AMI trial, Buller et al. recently demonstrated that overall ST deviation resolution had comparable discriminatory prognostic power when compared with the simpler clinical standard of ST elevation resolution with a 50% cut point. The current study extends these observations by showing that, compared with an approach using overall ST deviation resolution, greater prognostic information is obtained when resolution of ST elevation and ST depression are evaluated as discrete metrics.

The mechanism of concomitant ST-segment depression in patients presenting with STEMI continues to be the subject of debate. ST depression may represent: (i) the reciprocal image of ST elevation;21–23 (ii) larger, more extensive infarction;12–14 (iii) ischaemia beyond the infarcted territory i.e. at a distance;24,25 or (iv) posterior wall injury in patients presenting with inferior infarction.26,27 The additional prognostic insight offered by resolution of ST depression supports a pathophysiologic underpinning. We found that patients who failed to resolve ST depression ≥50% less frequently had post-PCI TIMI 3 flow and a tendency for greater myocardial necrosis based on changes in cardiac troponins. The absence of regional wall motion data precluded an assessment of either posterior wall involvement or myocardial segments beyond the infarcted territory. Failure to resolve ≥50% of ST depression may represent a proxy for more diffuse coronary artery disease given its association with older age, diabetes, triple vessel disease (among those with ≥50% ST elevation resolution), and impaired post-PCI TIMI flow in our study.

Our study has some limitations. While the ST resolution metrics were statistically significant predictors in the models, their marginal PEVs were relatively modest with respect to the other adjusting factors in the model. The APEX-AMI trial utilized high-risk ECG
admissibility criteria as represented by the majority of inferior MI patients having concomitant anterior ST depression. Although our findings may not apply to STEMI patients without these characteristics, they remain broadly applicable since previous registry and clinical trial-based studies have shown that up to two-thirds of inferior MI patients have concomitant anterior ST depression.28–30 Not surprisingly, all 418 patients who were excluded from our analysis due to absence of baseline ST depression (7% of the population) had non-inferior MI. Because the focus of our study was ST-segment depression and to avoid underestimating its impact, we calculated ST-segment shift from all leads except aVR which departs from the method of Schroder (i.e. taking account of infarct location to determine which leads to include).31 This is also simpler at the bedside to estimate.

**Conclusion**

When concomitant ST depression is present in patients with STEMI undergoing primary PCI, less than 50% resolution of ST depression was associated with worse 90 day clinical outcomes even after accounting for the baseline risk profile, infarct location, PCI procedural outcome, and resolution of ST elevation. Although favourable outcomes are generally anticipated in patients with ST elevation resolution >50%, our data indicate that ST depression resolution adds additional important prognostic insight and deserves consideration in the management of these patients and future STEMI guidelines.

**Acknowledgements**

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**Conflict of interest:** M.C.T., Y.F., C.M.W., and G.S.W. have no conflict to declare. H.D.W., F.W., K.W.M., C.B.G., and P.W.A. received research grants from the above named sponsors. T.G.T. is employed by Procter & Gamble.

**References**


**CARDIOVASCULAR FLASHLIGHT**

**Giant post-traumatic coronary aneurysm as an infrequent cause of inferior ST elevation myocardial infarction**

**Luis Díaz de la Llera, Nieves Romero-Rodriguez*, and Jose Miguel Borrego Dominguez**

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A 64-year-old woman with diabetes as the only known cardiovascular risk factor was admitted to the emergency department with ischaemic chest pain and inferior ST elevation on the electrocardiogram and complete atrioventricular block. Primary coronary angiography was immediately performed, 2.5 h after the beginning of the pain, showing a calcified round mass (Panel A) together with total occlusion of the proximal right coronary artery with contrast flow entering a giant calcified round anterior mass after a wire was introduced (Panel B). Left coronary artery was dominant and normal and the procedure was interrupted.

Urgent computed tomography (Panel C) revealed a giant round image (12 × 11 × 13 cm) with density suggesting thrombus inside, causing compression of right atrium and ventricle. Echocardiography did not reveal further information except from haemodynamic data supporting partial cardiac tamponade with no pericardial effusion. Emergent cardiac surgery was developed finding a giant aneurysm (Panel D) with thrombus inside connected with the right coronary. Empty aneurysm after resection was sent to pathological examination, which confirmed the existence of adventitial layer.

The woman had suffered a strong accidental thoracic traumatism 9 years before presumably causing deep vessel injury and a slowly growing aneurysm. The patient had been completely asymptomatic until 2 weeks before admission, when she was referring moderate exercise dyspnoea. Posterior occlusion of the right coronary artery caused the acute inferior myocardial infarction. The woman was discharged a week after the surgery with no overt complications.

Panel A. Urgent catheterization showed the calcified anterior round mass (arrows) and the transient pacemaker (PM) together with a total occlusion of the proximal right coronary artery (RCA) (Panel B) with contrast (cont) entering a giant calcified round anterior mass. w, wire.

Panel C. Urgent computed tomography revealing the giant aneurysm (An) with thrombus inside. RV, right ventricle; LV, left ventricle.

Panel D. Emergent surgery showing giant coronary aneurysm.

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