

# Trends in Death Rate 2009 to 2018 Following Percutaneous Coronary Intervention Stratified by Acuteness of Presentation



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**Percutaneous coronary intervention (PCI) has evolved dramatically, along with patient complexity. We studied trends in in-hospital mortality with changes in patient complexity over the last decade stratified by clinical presentation. The study population included all patients presenting to the cardiac catheterization lab between January 2009 and July 2018. Expected in-hospital mortality was calculated using the National Cardiovascular Data Registry Cath-PCI risk scoring system. Yearly mean in-hospital mortality rates (%) were plotted and smoothed by weighted least squares regression for each presentation: ST-elevation myocardial infarction (STEMI), non-ST-elevation acute coronary syndrome (NSTEMI-ACS), and stable ischemic coronary artery disease (SI CAD). The overall cohort included 13,732 patients who underwent PCI during the study period, of whom 2,142 were for STEMI, 2,836 for NSTEMI-ACS, and 8,754 for SI CAD. Indications for PCI have changed over time, with more PCIs being performed for NSTEMI-ACS and STEMI than for SI CAD. NSTEMI-ACS and STEMI patients had a steady decrease in in-hospital mortality over time compared with SI CAD patients. Overall observed mortality continues to decrease in NSTEMI-ACS patients, with reduction in the observed mortality rate within the STEMI population to below expected since 2013. Patient complexity has not changed significantly. These results may be attributed to improved patient selection coupled with optimal pharmacotherapy with more robust therapies during procedure and hospitalization. © 2019 Published by Elsevier Inc. (Am J Cardiol 2019;124:1349–1356)**

Coronary artery disease (CAD) is a major public health problem in the United States, with an estimated 370,000 deaths annually.<sup>1</sup> Percutaneous coronary intervention (PCI) remains the standard of care in patients presenting with ST-elevation myocardial infarction (STEMI), non-STEMI, and in appropriate patients with stable ischemic (SI) CAD.<sup>2,3</sup> Over the last 2 decades, PCI and adjunctive antithrombotic therapies have undergone major developments in terms of safety and efficacy, expanding use in the elderly with increasingly complex coronary anatomy.<sup>4</sup> Compared with the young, octogenarians who underwent PCI have more calcified lesions, multivessel disease, and left main stenosis and are under-represented in clinical trials.<sup>5</sup> Registry studies have shown progressively increasing age and acuteness of patient presentation over time.<sup>6</sup> We sought to answer 3 questions: first, has there been a change in acuteness of presentation before PCI over the years? Second, have

patient characteristics, along with their impact on mortality, changed over time? Third, what was the impact of cardiogenic shock on mortality in STEMI patients?

## Methods

The study population included all patients who underwent PCI in a single center between January 2009 and July 2018. Baseline characteristics, procedural, and in-hospital outcomes were prospectively collected and recorded in a central database and retrospectively analyzed. Prespecified clinical and laboratory data during the hospital-stay periods were obtained from hospital charts and reviewed by independent research personnel blinded to the objectives of the study. The study was approved by the institutional review board at MedStar Washington Hospital Center. All patients provided informed consent for both the procedure and subsequent data collection and analysis for research purposes.

The primary outcome was all-cause in-hospital mortality. Other in-hospital outcomes included access site hematoma >4 cm, major bleeding, any gastrointestinal bleeding, need for blood transfusion, and vascular complications requiring intervention. Major bleeding was defined as any gastrointestinal bleeding, hematocrit decrease >15, or major hematoma with hematocrit >15. Gastrointestinal bleeding was defined as evidence of upper (coffee-ground

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See page 1355 for disclosure information.

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emesis, endoscopic demonstration of active bleeding) or lower (melena, hematochezia, or endoscopic evidence of an active bleeding site). Major hematoma was defined as hematomas  $2 \times 4$  cm or greater or those requiring transfusion or prolonged hospitalization. Access-site bleeding was a composite of major hematoma or any vascular complications. Clinical outcomes, including Q-wave myocardial infarction, stent thrombosis, any cerebrovascular accident, or transient ischemic attack, were as defined by the Academic Research Consortium.<sup>7</sup>

Expected in-hospital mortality was calculated using National Cardiovascular Data Registry CathPCI risk scoring system. The CathPCI Registry is an initiative of the American College of Cardiology Foundation and the Society for Cardiovascular Angiography and Interventions.<sup>8</sup> The CathPCI Registry data clarification form version 4, developed in 2009, incorporated several updated and new variables for better prediction of PCI outcomes. To emphasize the preprocedural patient's risk, one of the composite variables included was cardiogenic shock and procedural status.<sup>9</sup> Our study period incorporates version 4 of the CathPCI Registry data clarification form.

Baseline characteristics are presented as mean  $\pm$  standard deviation for continuous variables and percentages for categorical variables. For variables with missing data, percentages were calculated using the number of patients with data present for that variable. Differences in continuous variables were compared with Student's *t* test. Categorical

variables were compared with chi-square test or Fisher's exact test where appropriate. Yearly mean in-hospital mortality rates (%) were plotted and smoothed by fractional polynomial regression for each presentation. Fractional polynomial regression was used to assess potential nonlinearity. All statistical analyses were performed using Stata version 15 (Stata Corp., College Station, Texas).

## Results

Patient population was divided in cohorts of 3 years to study the change in demographics over time, as shown in Table 1. Baseline characteristics stratified by acuteness of presentation are shown in Table 2. Figure 1 plots the yearly average percentage of patients who underwent PCI. For NSTEMI-ACS patients, PCI increased by a little more than 2% per year ( $p < 0.001$ ), whereas PCI in SI CAD patients decreased by about 1.9% per year ( $p = 0.028$ ). The proportion of STEMI patients evidenced little change over the study period ( $p = 0.474$ ). The percentage of patients presenting with cardiogenic shock was higher in the STEMI group than in the NSTEMI-ACS and SI CAD groups. Angiographic and procedural characteristics stratified by presentation are shown in Table 3. Given the higher rates of cardiogenic shock in the STEMI group, the utilization of intra-aortic balloon pump was significantly higher in STEMI patients than in NSTEMI-ACS or SI CAD patients (19.5%, 6%, and 2.3%, respectively,  $p < 0.001$ ).

Table 1  
Patient demographics over time

Variables	2009-2011 (n = 5653, 41%)	2012-2014 (n = 4433, 32%)	2015-2018 (n = 3646, 27%)	p Value
Age (years)	66 $\pm$ 12	66 $\pm$ 13	64 $\pm$ 8	0.2
Men	3666 (65%)	2924 (66%)	2468 (67%)	0.02
Black	2026 (36%)	1556 (35%)	1314 (36%)	<0.001
White	3218 (57%)	2505 (57%)	1916 (53%)	0.65
Others	409 (7%)	372 (8%)	416 (11%)	0.6
Indication				
NSTEMI-ACS	2543 (45%)	1673 (38%)	1295 (36%)	<0.001
STEMI	1131 (20%)	1655 (37%)	1943 (53%)	<0.001
SI CAD	1735 (31%)	1060 (24%)	353 (10%)	<0.001
Body mass index (kg/m <sup>2</sup> )	30 $\pm$ 6.5	30 $\pm$ 6.8	30 $\pm$ 6.4	0.86
Hypertension	4970 (88%)	3712 (84%)	3127 (86%)	<0.001
Hypercholesterolemia	4726/5651 (84%)	3324/4433 (75%)	2838/3642 (78%)	0.06
Diabetes mellitus	2223/5641 (39%)	1713/4433 (39%)	1494/3635 (41%)	0.24
Peripheral vascular disease	919/5652 (16%)	594/4430 (13.4%)	502/3622 (14%)	<0.001
Current smoker	1439/5656 (25%)	1071/4434 (24%)	869/3641 (24%)	0.14
Previous coronary bypass	1145/5652 (20%)	753/4432 (17%)	638/3634 (17%)	<0.001
Previous history of coronary artery disease	2622/5656 (46%)	1781/4433 (40%)	1437/3642 (39%)	<0.001
Left ventricular ejection fraction (%)*	46 $\pm$ 17 (4457/5653)	45 $\pm$ 18 (3157/4433)	48 $\pm$ 14 (2702/3646)	<0.001
Cardiogenic shock	128/5654 (2.3%)	116/4429 (2.6%)	95/3634 (2.6%)	0.4
End-stage renal disease, on hemodialysis	246/5648 (4.4%)	183/4430 (4.1%)	161/3638(4.4%)	0.7

NSTEMI-ACS = non-ST elevation acute coronary syndrome; SI CAD = stable ischemic coronary artery disease; STEMI = ST-elevation myocardial infarction.

Hypertension: defined as systolic blood pressure  $>130$  mm Hg or diastolic  $>89$  mm Hg. Previous history of hypertension diagnosed and/or treated with medication or currently being treated with diet and/or medications were included.

Hypercholesterolemia: defined as elevated cholesterol  $>250$ mg/dl. Included patients with previously documented diagnosis of hypercholesterolemia, treated with diet or medication.

Previous coronary artery disease: defined as previous myocardial infarction, angina pectoris, or requirement of revascularization procedure (coronary bypass or percutaneous coronary intervention)

\* Data are presented as mean  $\pm$  standard deviation.

Table 2  
Baseline characteristics stratified by acuteness of presentation

Variables	NSTE-ACS (n = 2836, 21%)	STEMI (n = 2142, 16%)	SI CAD (n = 8754, 63%)	p Value
Age – years (mean ± SD)	66 ± 12	63 ± 13	66 ± 12	<0.001
Men	1816 (64%)	1404(66%)	5838 (67%)	0.03
Black	1126 (40%)	888 (41%)	2882 (33%)	<0.001
White	1438 (51%)	1013 (47%)	5188 (59%)	<0.001
Others	272 (9%)	241 (12%)	684 (8%)	
Body mass index (kg/m <sup>2</sup> )	30 ± 6.7	29.4 ± 6.4	30 ± 6.7	<0.001
Hypertension	2376/2836 (84%)	1630/2143 (76%)	7803/8753 (89%)	<0.001
Hypercholesterolemia	2108/2829 (75%)	1286/2144 (60%)	7494/8752 (86%)	<0.001
Diabetes mellitus	1102/2830 (39%)	675/2139 (31%)	3653/8740 (42%)	0.001
Peripheral vascular disease	383/2826 (14%)	184/2136 (8.6%)	1448/8742 (17%)	<0.001
Current smoker	758/2837 (27%)	841/2145 (39%)	1780/8759 (20%)	0.04
Previous coronary bypass	453/2830 (16%)	138/2143 (6.4%)	1945/8745 (22%)	<0.001
Previous history of coronary artery disease	1007/2834 (35.5%)	495/2144 (23%)	4338/8753 (50%)	<0.001
Left ventricular ejection fraction (%)*	43 ± 18 (2114/2836)	39 ± 15 (1500/2142)	49 ± 16 (6693/8754)	<0.001
Cardiogenic shock	76/2831 (2.7%)	211/2139 (10%)	52/8747 (0.6%)	<0.001
End-stage renal disease, on hemodialysis	152/2828 (5.4%)	142/2143 (2%)	396/8745 (4.5%)	<0.001

Hypertension: defined as systolic blood pressure >130 mm Hg or diastolic >89 mm Hg. Previous history of hypertension diagnosed and/or treated with medication or currently being treated with diet and or medications were included.

Hypercholesterolemia: defined as elevated cholesterol >250 ng/dl. Included patients with previously documented diagnosis of hypercholesterolemia, treated with diet or medication.

Previous coronary artery disease: defined as previous myocardial infarction, angina pectoris, or requirement of revascularization procedure (coronary bypass or percutaneous coronary intervention).

\* Data are presented as mean ± standard deviation.

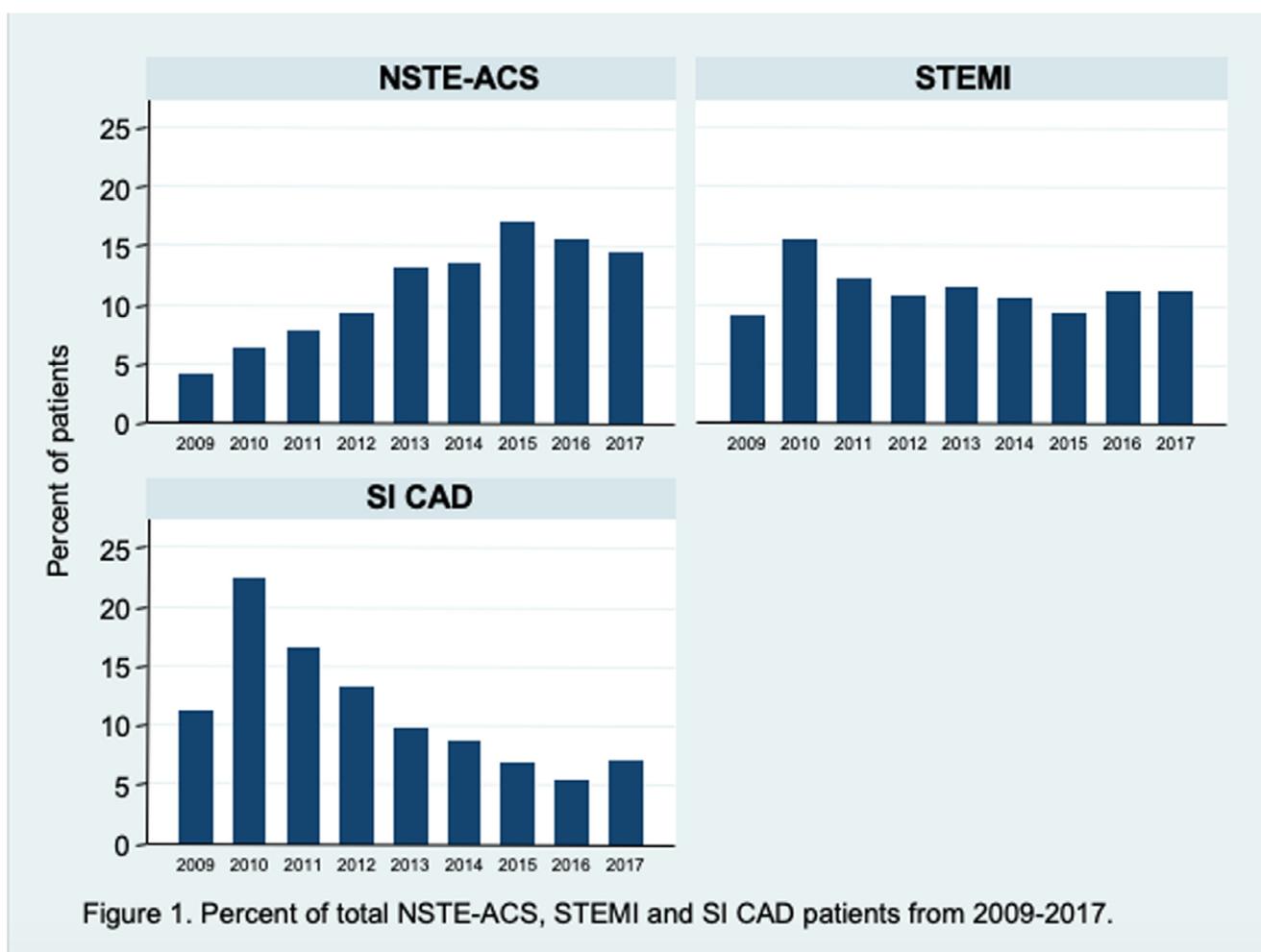


Figure 1. PCI distributions for NSTE-ACS, STEMI, and SI CAD patients from 2009 to 2018. Bar graph represents yearly average percentage of patients who underwent PCI.

Table 3  
Angiographic and procedural characteristics

Variables	NSTE-ACS (n = 2836, 21%)	STEMI (n = 2142, 16%)	SI CAD (n = 8754, 63%)	p Value
Left main disease intervention	2.4%	1.6%	2.4%	0.049
Left anterior descending artery intervention	33.6%	40.3%	35.2%	<0.001
Right coronary artery disease intervention	30.8%	39.4%	32%	<0.001
Left circumflex artery intervention	29.3%	17%	25.2%	<0.001
Saphenous vein graft intervention	3.6%	1.5%	4.9%	<0.001
Anatomical location				
Ostial portion	5 (167/3817)	75/2776 (4%)	389/12403 (4%)	<0.001
Proximal segment	34 (1287/3817)	878/2776 (32%)	3346/12403 (27%)	<0.001
Mid segment	40 (1508/3817)	927/2776 (34%)	4342/12403 (35%)	<0.001
Distal segment	20 (750/3817)	825/2776 (30%)	4022/12403 (33%)	<0.001
Type of lesion				
Type A	297/3831 (8%)	185/2765 (7%)	1242/12426 (10%)	<0.001
Type B1 B2	2193/3831 (58%)	1340/2765 (48%)	6281/12426 (51%)	<0.001
Type C	1341/3831 (35%)	1240/2765 (45%)	4903/12426 (39%)	<0.001
Glycoprotein IIb IIIa use	139/2825 (4.9%)	375/2131 (17.6%)	212/8725 (2.4%)	<0.001
Bare-metal stents	505/3831 (13.2%)	842/12782 (30.3%)	1823/12333 (14.8%)	<0.001
Drug-eluting stents	2927/3850 (76%)	1582/2785 (57%)	8992/12470 (72%)	0.3
Coronary dissection	57/3849 (1.5%)	11/2789 (0.4%)	111/12468 (0.9%)	0.03
Intra-aortic balloon pump	168/2820 (6%)	416/2136 (19.5%)	203/8732 (2.3%)	<0.001

NSTE-ACS = non-ST-elevation acute coronary syndrome; SI CAD = stable ischemic coronary artery disease; STEMI = ST-elevation myocardial infarction.

In-hospital clinical outcomes for the entire cohort are shown in Table 4. Major bleeding and in-hospital mortality were significantly higher in STEMI patients than in NSTE-ACS or SI CAD patients. For NSTE-ACS patients, there was a significant decrease in observed in-hospital mortality of 0.5% per year ( $p = 0.001$ ), resulting in a rate similar to the expected in-hospital mortality during the study period, 2015 to 2016 (Figure 2). Observed in-hospital mortality for STEMI patients decreased at a rate of 0.50% per year ( $p = 0.036$ ) and was similar to the expected in-hospital mortality rate by 2013, and thereafter continued to decrease through 2017 (Figure 3). SI CAD observed in-hospital mortality was slightly more than 1% at the beginning of the study period (2009) and decreased at a rate of 0.08% per year ( $p = 0.005$ ). Regardless of statistical significance, the observed and expected in-hospital mortality rates were <1% over most of the study period (Figure 4). Figure 5 plots yearly average in-hospital mortality for STEMI with

and without cardiogenic shock. For patients with shock, there was no change in in-hospital mortality between 2009 and 2017 ( $p = 0.266$ ). For patients without shock, in-hospital mortality remained essentially the same, <5%, over the study period ( $p = 0.13$ ).

## Discussion

The main findings of this study are as follows: first, the acuteness of presentation before PCI has changed over time, with more PCIs being performed for NSTE-ACS and STEMI and fewer for SI CAD. Second, there has been a steady decrease over time in in-hospital mortality for NSTE-ACS and STEMI patients, and little change for SI CAD patients. Third, in STEMI patients with cardiogenic shock, there was a nonsignificant decrease in in-hospital mortality compared with those without shock. Fourth, the overall patient complexity has not changed significantly.

Table 4  
In-hospital clinical outcomes

Variables	NSTE-ACS (n = 2836, 21%)	STEMI (n = 2142, 16%)	SI CAD (n = 8754, 63%)	p Value
Procedural success	2746/2838 (96.8%)	1930/2146 (90%)	8622/8759 (98.4%)	<0.001
Any gastrointestinal bleeding	21/2827 (0.7%)	29/2143 (1.4%)	21/8754 (0.2%)	<0.001
Major bleeding	80/2834 (3%)	122/2145 (5.7%)	95/8757 (1.1%)	<0.001
Hematoma >4 cm	53/2830 (1.9%)	62/2143 (3%)	124/8756 (1.4%)	<0.001
Need for transfusion	148/2473 (6%)	169/1954 (8.6%)	214/7906 (2.7%)	<0.001
Cerebrovascular accident	2/2524 (0.1%)	28/1949 (1.4%)	20/8223 (0.2%)	<0.001
In-hospital death	65/2838 (2.3%)	123/2146 (5.7%)	79/8759 (0.9%)	<0.001
Need for in-hospital coronary bypass surgery	24/2825 (1%)	80/2140 (4%)	36/8736 (8%)	<0.001
Length of stay (days)*	3.9 ± 4.9	5.1 ± 5.5	2.7 ± 3.6	<0.001
Intensive care unit stay (days)	0.6 ± 2	1.8 ± 3.1	0.2 ± 1.1	<0.001
Procedure-related acute renal failure	57/2830 (2%)	61/2145 (2.8%)	77/8756 (0.9%)	<0.001

NSTE-ACS = non-ST-elevation acute coronary syndrome; SI CAD = stable ischemic coronary artery disease; STEMI = ST-elevation myocardial infarction.

\* Data are presented as mean ± standard deviation.

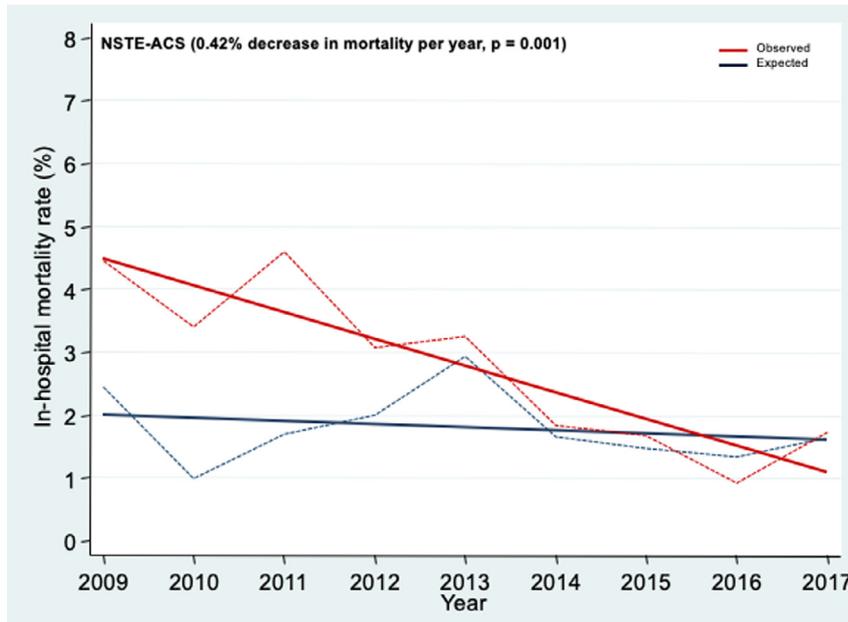


Figure 2. Change in in-hospital mortality of NSTE-ACS patients from 2009 to 2018. *Dotted lines* represent yearly average mortality rates; *solid lines* represent fractional polynomial smoothed trend.

Our study reflects the changing trend in current clinical practice in patients who underwent PCI. Previous studies showed that there has been a change in patient characteristics presenting to the catheterization lab over the past 2 decades.<sup>6</sup> Our study was limited to the time period 2009 to 2018, during which there was no significant change in patient characteristics other than acuteness of presentation. More PCIs are being performed for NSTE-ACS and STEMI over time than for SI CAD. The advent of high-sensitivity troponins might also contribute to an increasing number of patients being diagnosed with NSTE-ACS. Before pivotal

clinical trials such as Clinical Outcomes Utilization Revascularization and Aggressive Drug Evaluation (COURAGE) and Bypass Angioplasty Revascularization Investigation 2 Diabetes, PCI was being routinely offered to the patients with SI CAD. The COURAGE<sup>10–12</sup> and Bypass Angioplasty Revascularization Investigation 2 Diabetes<sup>13</sup> trials demonstrated that in patients with SI CAD, it was safe to defer revascularization in patients with mild-to-moderate CAD complexity. Optimal medical therapy, antianginal medication strategy, lifestyle modification, and aggressive risk factor modification were as effective as PCI in a

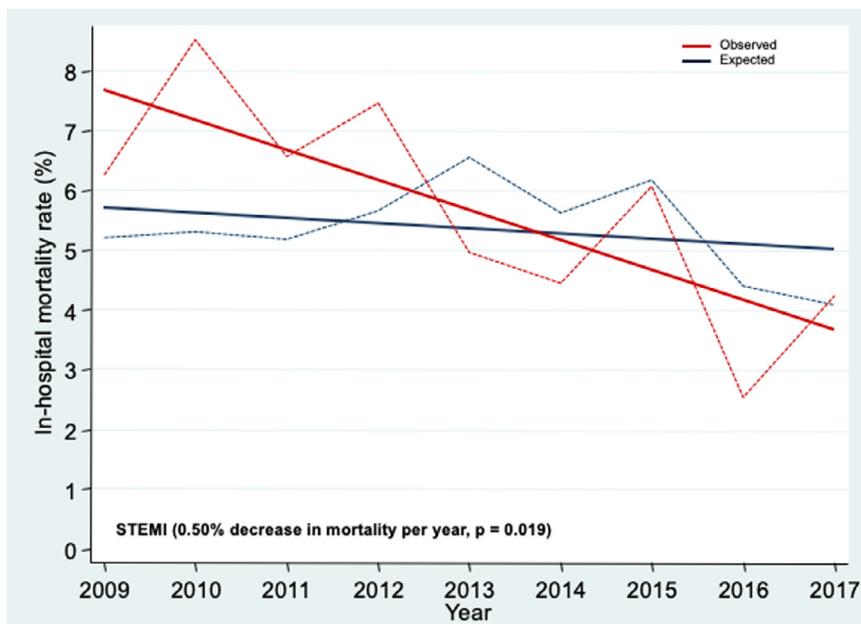


Figure 3. Change in in-hospital mortality of STEMI patients from 2009 to 2018. *Dotted lines* represent yearly average mortality rates; *solid lines* represent fractional polynomial smoothed trend.

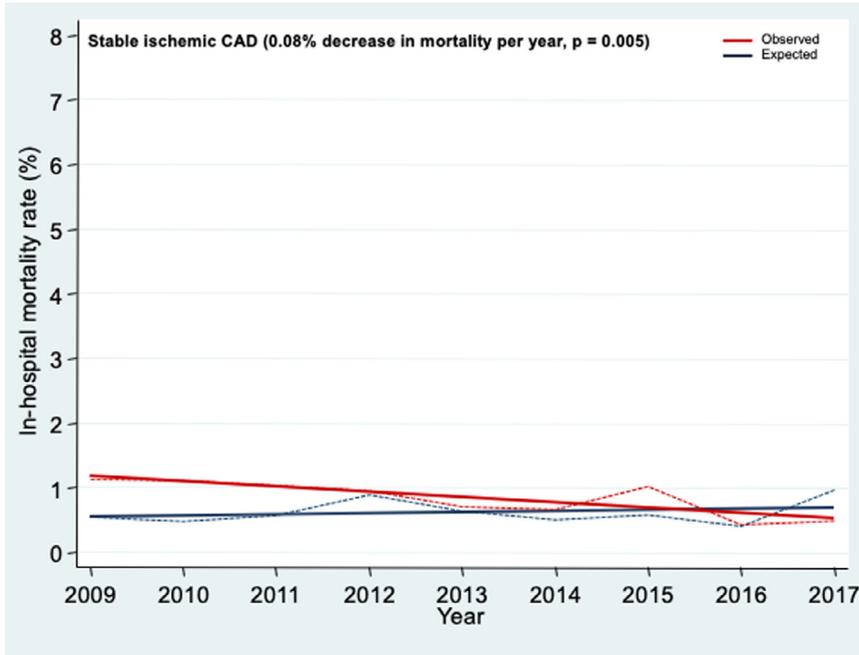


Figure 4. Change in in-hospital mortality of SI CAD patients from 2009 to 2018. Dotted lines represent yearly average mortality rates; solid lines represent fractional polynomial smoothed trend.

majority of patients, except for a subgroup of patients with a severe coronary atherosclerotic or ischemic burden, or both.<sup>14</sup> Since then, guidelines and appropriate use criteria have recommended an initial noninvasive strategy and optimization of medical management with lifestyle changes before considering revascularization.<sup>15,16</sup> This would likely explain the decreasing frequency of patients with SI CAD who underwent PCI over the course of our study.

In our study, the utilization of bare metal stents was higher in STEMI patients than in NSTEMI-ACS or SI CAD

patients. The heightened thrombogenic state, coupled with delayed arterial healing in STEMI, could contribute to late stent thrombosis.<sup>17</sup> Meta-analyses have shown that in STEMI patients receiving first-generation DES, there was a concern for late stent thrombosis.<sup>18</sup> This may explain the higher utilization of bare metal stents. Given the safety and efficacy of second-generation DES, in current clinical practice, bare metal stents are more sparingly used.<sup>19</sup>

In STEMI complicated by cardiogenic shock, mortality is significantly higher still, despite early revascularization.<sup>20–22</sup>

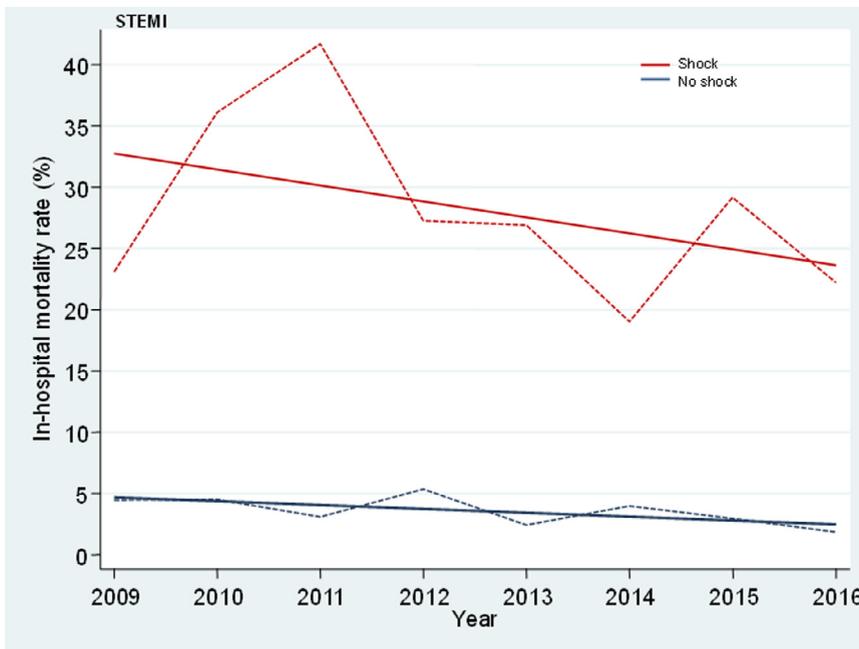


Figure 5. STEMI patients with and without cardiogenic shock in-hospital mortality trends from 2009 to 2018. Dotted lines represent yearly average mortality rates; solid lines represent fractional polynomial smoothed trend.

Hemodynamic compromise and multiorgan dysfunction are likely causes of early mortality.<sup>23,24</sup> Despite early use of mechanical circulatory support devices such as intra-aortic balloon pumps, there had historically been little impact on mortality.<sup>25</sup> In another study, early use of the Impella mechanical circulatory support device was associated with a 59% survival rate.<sup>26</sup> In our study, although mortality was as high as 45% early in the study period (2010 to 2011), there has been a downward trend more recently. Several factors might have affected our findings. Our observed in-hospital mortality trend in STEMI patients showed significant improvement and was below the expected in-hospital mortality rate from the year 2012 to 2013. Greater access to early revascularization, advances in pharmacotherapy, and appropriate use of mechanical circulatory support devices might improve overall outcomes.<sup>27</sup>

Improved outcomes might also have been due to our change in practice with regard to patients presenting with out-of-hospital cardiac arrest. It has been shown that in patients with out-of-hospital cardiac arrest, the initial rhythm is often pulseless ventricular tachycardia or ventricular fibrillation.<sup>28,29</sup> Guidelines recommend emergent coronary angiography in patients presenting with STEMI or new left bundle branch block, and in patients with no STEMI but with suspected cardiac origin as the cause of cardiac arrest.<sup>30</sup> Previous studies have shown favorable outcomes in terms of neurological recovery and survival to discharge when these patients undergo emergent coronary angiography and PCI.<sup>31,32</sup> Before 2012 to 2013, it was our standard of care for STEMI patients presenting with cardiogenic shock to undergo coronary angiography and PCI as appropriate. Since 2012 to 2013, patients with STEMI and cardiogenic shock but with unfavorable prognostic features undergo careful assessment before undergoing coronary angiography and PCI.

We acknowledge several limitations. This is an observational study of patients who underwent PCI during a specific time period. A comparison of patients who underwent PCI in previous decades would have been helpful. However, previous studies have demonstrated that over the past 2 decades, patient characteristics have changed. Also, the CathPCI Registry data clarification form version 4 was developed in 2009 with important updates in patient characteristics and angiographic details. In STEMI with cardiogenic shock, the details of other mechanical support devices were not available.

In summary, there has been a change in patient characteristics presenting to the cardiac catheterization lab. The observed in-hospital mortality shows steady improvement for NSTEMI-ACS and STEMI patients. Further research is needed in the management of STEMI patients with cardiogenic shock.

## Disclosures

Toby Rogers—Consultant: Medtronic; Proctor: Edwards Lifesciences. Ron Waksman—Advisory Board: Amgen, Boston Scientific, Cardioset, Cardiovascular Systems Inc., Medtronic, Philips Volcano, Pi-Cardia Ltd.; Consultant: Amgen, Biotronik, Boston Scientific, Cardioset, Cardiovascular Systems Inc., Medtronic, Philips Volcano, Pi-Cardia

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