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Culprit Vessel Percutaneous Coronary Intervention Versus Multivessel and Staged Percutaneous Coronary Intervention for ST-Segment Elevation Myocardial Infarction Patients With Multivessel Disease

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Objectives The purpose of this study was to examine the differences in in-hospital and longer-term mortality for ST-segment elevation myocardial infarction (STEMI) patients with multivessel disease as a function of whether they underwent single-vessel (culprit vessel) percutaneous coronary interventions (PCIs) or multivessel PCI.

Background The optimal treatment of patients with STEMI and multivessel disease is of continuing interest in the era of drug-eluting stents.

Methods STEMI patients with multivessel disease undergoing PCIs in New York between January 1, 2003, and June 30, 2006, were subdivided into those who underwent culprit vessel PCI and those who underwent multivessel PCI during the index procedure, during the index admission, or staged within 60 days of the index admission. Patients were propensity-matched and mortality rates were calculated at 12, 24, and 42 months.

Results A total of 3,521 patients (87.5%) underwent culprit vessel PCI during the index procedure. A total of 259 of them underwent staged PCI during the index admission and 538 patients underwent staged PCI within 60 days of the index procedure. For patients without hemodynamic compromise, culprit vessel PCI during the index procedure was associated with lower in-hospital mortality than multivessel PCI during the index procedure (0.9% vs. 2.4%, $p = 0.04$). Patients undergoing staged multivessel PCI within 60 days after the index procedure had a significantly lower 12-month mortality rate than patients undergoing culprit vessel PCI only (1.3% vs. 3.3%, $p = 0.04$).

Conclusions Our findings support the American College of Cardiology/American Heart Association (ACC/AHA) recommendation that culprit vessel PCI be used for STEMI patients with multivessel disease at the time of the index PCI when patients are not hemodynamically compromised. However, staged PCI within 60 days after the index procedure, including during the index admission, is associated with risk-adjusted mortality rates that are comparable with the rate for culprit vessel PCI alone. (J Am Coll Cardiol Intv 2010;3:22–31) © 2010 by the American College of Cardiology Foundation

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The current American College of Cardiology/American Heart Association (ACC/AHA) guidelines for the management of patients with ST-segment elevation myocardial infarction (STEMI) recommend primary percutaneous coronary intervention (PCI) as the treatment of choice (1,2). For most patients with multivessel disease who undergo primary PCI for STEMI, it is recommended that only the culprit vessel be treated and that other diseased vessels be addressed in an elective procedure at another time. Acute multivessel PCI is recommended during the index procedure only for patients with hemodynamic compromise (3).

See page 32

The purpose of this study was to examine differences in in-hospital and longer-term mortality for STEMI patients with multivessel disease as a function of whether they underwent single-vessel (culprit vessel) PCI or multivessel PCI. Because multivessel PCI can be performed at the same time as culprit vessel PCI or at a later time, we compared 2 strategies for multivessel PCI with culprit vessel PCI-multivessel during the same catheterization laboratory visit as the culprit vessel PCI and multivessel PCI where the nonculprit vessel is not attempted in the same visit but is attempted within 60 days of the index procedure. Also, for patients undergoing a staged multivessel PCI within 60 days, we compared the subset undergoing staged PCI during the index admission with patients undergoing culprit vessel PCI.

Methods

Databases. Data were obtained from New York State's Percutaneous Coronary Interventions Reporting System (PCIRS), a mandatory registry in New York that was initially developed in 1991. The PCIRS contains detailed information for each patient undergoing PCI in the state regarding demographic data; pre-procedural risk factors; periprocedural complications; types of devices used; extent of disease and lesions treated; dates of admission, discharge, and procedure; discharge disposition and destination; and hospital and operator identifiers. These data were recorded at the time of the procedure and discharge by catheterization laboratory personnel. Definitions of some variables are contained in the Online Appendix; all definitions can be obtained from the New York State Department of Health. These data were matched to New York administrative data and were audited by the New York State Department of Health's utilization review agent to ensure completeness and accuracy.

For this study, the PCIRS data were matched to New York's vital statistics data with patient identifiers so that patients who are New York residents could be followed after discharge for evidence of subsequent death.

Patients and end points. All multivessel disease patients who are New York State residents who experienced an STEMI within 24 h before undergoing PCI between January 1, 2003, and June 30, 2006, were included in the study, except those with missing ejection fraction (n = 703), left main disease (n = 216), previous open heart surgery (n = 503), shock (n = 126), or thrombolytic therapy before PCI (n = 1,059). The number of patients in the study group was 4,024. The short-term end point in the study was in-hospital mortality, and the longer-term end points were mortality at 12, 24, and 42 months.

Statistical analysis. Differences between patients undergoing culprit vessel primary PCI and multivessel PCI at the time of primary PCI in the prevalence of various patient risk factors (demographic data, comorbidities, left ventricular function, hemodynamic state, vessels diseased, time since onset of symptoms) as well as differences in in-hospital mortality were tested with chi-square tests and Fisher exact tests.

Because patients were not randomized to the 2 types of intervention (culprit-only vs. multivessel PCI), we identified patients' pre-procedural characteristics that were potentially related to whether patients underwent single-vessel or multivessel PCI and matched patients on the basis of those characteristics with propensity-matched samples (4).

Abbreviations and Acronyms

ACC/AHA = American College of Cardiology/American Heart Association

PCI = percutaneous coronary intervention

PCIRS = Percutaneous Coronary Interventions Reporting System

STEMI = ST-segment elevation myocardial infarction

TIMI = Thrombolysis In Myocardial Infarction

The matching characteristics included demographic data, left ventricular function, hemodynamic status, the number and location (left anterior descending coronary artery/no left anterior descending coronary artery) of diseased coronary vessels, congestive heart failure, Thrombolysis In Myocardial Infarction (TIMI) flow, several comorbidities, and device used.

For each of 3 sets of analyses (culprit vessel PCI vs. multivessel PCI during the index procedure, culprit vessel PCI vs. staged multivessel PCI during the index admission, culprit vessel PCI vs. staged multivessel PCI within 60 days), these characteristics were used to develop a logistic regression model that predicted the probability that a given STEMI patient would undergo culprit vessel PCI. This value, the propensity score, was used to match patients without replacement on a 1-to-1 basis. For the first set of analyses, a patient undergoing multivessel PCI was randomly selected and then matched to a patient undergoing culprit vessel PCI to minimize the overall distance in propensity scores between the groups (5–7). Differences between the 2 matched samples in the prevalence of propensity model variables were tested with standardized differences in the observed prevalence of the variables in the matched groups (7,8). The propensity matched pairs were then

used to analyze differences in mortality outcomes between the 2 groups.

The second set of analyses compared the subset of 259 patients undergoing staged PCI who underwent the second PCI during the index admission but not the index procedure with a group of propensity-matched culprit vessel-only PCI patients. In this case, 12-, 24-, and 42-month mortality were compared for the propensity-matched groups.

In the third set of analyses, the first group of patients was defined to be patients who did not undergo multivessel PCI during the index PCI but did undergo multivessel PCI within 60 days of discharge. These (n = 538) patients consisted of the 259 patients noted in the preceding text who underwent staged multivessel PCI during the index admission but not the index procedure and an additional 279 patients who underwent (nonemergency) staged multivessel PCI after the index admission but within 60 days of the index procedure. These patients were propensity-matched to 538 patients who underwent culprit vessel PCI in the index admission and who were alive 60 days after discharge. The propensity matching process was identical to that described in the preceding text for the other 2 propensity-matched groups. The 12-, 24-, and 42-month mortality were compared for the propensity-matched groups.

For in-hospital mortality, McNemar's Test was used to test for differences in the propensity-matched samples. For the 3 longer-term outcomes, methods were used to compare mortality that take into account that the samples were matched (9).

All tests were 2-sided and conducted at the 0.05 level, and all analyses were conducted in SAS version 9.1 (SAS, Cary, North Carolina).

Results

Of the 4,024 patients in the study, 3,521 (87.5%) underwent only culprit vessel revascularization at the time of primary PCI, and the remainder underwent multivessel revascularization at the time of primary PCI. The patients who underwent multivessel revascularization at the time of primary PCI were younger, more likely to have low or higher ejection fractions, less likely to have a chronic total occlusion, less likely to have TIMI flow grade ≤2 in the culprit vessel before PCI, and more likely to have had bare-metal stents (Table 1).

Tables 2 to 4 present patient characteristic prevalences after each of the respective 3 types of multivessel PCI patients were matched on a 1-to-1 basis with a culprit vessel PCI patient. As indicated in the tables, the C statistics for the 3 models ranged from 0.62 to 0.69, and no standardized differences in prevalences of patient characteristics in the 3 models exceeded 10%.

Table 5 presents mortality rates for in-hospital, 12-, 24-, and 42-month mortality for the propensity-matched patients with culprit vessel PCI and multivessel PCI during the index procedure. Although the mortality rates for culprit vessel patients were lower for each of the time points represented, none of the mortality differences reached statistical significance. At discharge from the hospital, the rates were 2.0% and 3.4% (p = 0.48), and at 42 months, the rates were 10.8% and 11.8% (p = 0.72).

For patients with 2-vessel disease (374 pairs), the rates were 2.7% versus 3.8% (p = 0.41) at discharge and 9.2% versus 11.7% (p = 0.28) at 42 months, whereas for patients with 3-vessel disease (129 pairs), the rates were 1.6% versus 2.4% (p = 0.61) at discharge and 10.0% versus 12.2% (p = 0.83) at 42 months. For patients with complete revascularization (370 pairs, all major epicardial vessels with >70% stenosis revascularized), the rates were 2.2% versus 3.6% (p = 0.23) at discharge and 9.2% versus 12.3% (p = 0.16) at 42 months. Coronary artery bypass graft surgery rates after PCI in the index admission were 3.10% versus 0.80% (p = 0.003).

When the analyses were restricted to patients without hemodynamic compromise (defined as best we could, given available data elements, as patients without hemodynamic instability or ejection fraction <20% or severe ventricular arrhythmia), mortality rates again favored patients treated with culprit vessel revascularization. At discharge from the hospital, the rates were significantly different in favor of culprit vessel PCI (0.9% and 2.4%, p = 0.04). At 24 and 46 months the mortality differences trended toward significance.

Table 6 presents differences between the subset of staged multivessel PCI patients who underwent multivessel PCI in the index admission and patients who underwent only culprit vessel PCI. The staged group experienced lower mortality rates at all the time intervals examined, but none of the differences was significant. At 42 months, the mortality rates were 6.3% and 8.4%, respectively (p = 0.72).

The 12-, 24-, and 42-month mortality rates for multivessel disease STEMI patients staged to undergo PCI for nonculprit vessel PCI within 60 days of the index procedure and patients undergoing only culprit vessel PCI are presented in Table 7. These rates are lower than the ones presented in Table 5, because they represent culprit vessel PCI patients who survived for at least 60 days and multivessel PCI patients who underwent PCI after discharge. As noted, the multivessel PCI patients had lower mortality rates at all time intervals, and the rate was significantly lower at 12 months (1.3% vs. 3.3%, p = 0.04).

Discussion

Current guidelines recommend that elective PCI should not be performed in a noninfarct-related artery at the time of primary PCI of the infarct-related artery in patients without hemodynamic compromise (3). It is an open question whether this remains a good idea in the era of drug-eluting stents, which have been demonstrated by randomized controlled trials and observational studies to be associated with lower subsequent revascularization rates and by several

Table 1. Risk Factor Prevalence Before Propensity Matching According to Index Procedure Revascularization Strategy in STEMI Patients With Multivessel CAD

Risk Factor	% in Study Population (n = 4,024)	% With Culprit Vessel Revascularization at the Time of PPCI (n = 3,521)	% With Multivessel Revascularization at the Time of PPCI (n = 503)	p Value
Demographic factors				
Age, yrs				0.001
59 or less	46.94	45.84	54.67	
60–69	24.18	24.54	21.67	
70–79	18.84	19.51	14.12	
80 or more	10.04	10.11	9.54	
Female	26.09	26.24	25.05	0.57
Race				0.31
White	84.37	84.13	86.08	
Black	7.88	8.12	6.17	
Other	7.75	7.75	7.75	
Cardiac factors				
No. of vessels diseased				0.46
2 no proximal LAD	53.16	53.56	50.30	
2 with proximal LAD	21.89	21.58	24.06	
3 no proximal LAD	16.05	15.90	17.10	
3 with proximal LAD	8.90	8.95	8.55	
Ejection fraction				0.01
19% or less	1.94	1.73	3.38	
20%–29%	8.28	8.38	7.55	
30%–39%	18.24	18.52	16.30	
40%–49%	31.56	32.04	28.23	
50% or more	39.99	39.34	44.53	
Hemodynamic instability				
Unstable	4.40	4.35	4.77	0.66
CHF history				
This admission	7.08	6.96	7.95	0.41
Chronic total occlusion	17.77	19.54	5.37	<0.0001
TIMI flow grade ≤2 in culprit vessel	50.89	51.95	43.54	0.0004
Comorbidities				
Cerebrovascular	4.60	4.71	3.78	0.35
Peripheral vascular	4.13	4.12	4.17	0.95
Diabetes	21.69	21.41	23.66	0.25
Ventricular arrhythmia	1.47	1.42	1.79	0.52
COPD	4.75	4.66	5.37	0.48
Renal dialysis	0.72	0.71	0.80	0.83
Creatinine >2.5 mg	1.02	1.05	0.80	0.59
Type of PCI				<0.0001
Only drug-eluting stent used	60.59	61.09	57.06	
Bare-metal stent used	34.74	33.80	41.35	
No stent used	4.67	5.11	1.59	

New York State, January 1, 2003, to June 30, 2006.

CAD = coronary artery disease; CHF = congestive heart failure; COPD = chronic obstructive pulmonary disease; LAD = left anterior descending coronary artery; PCI = percutaneous coronary intervention; PPCI = primary percutaneous coronary intervention; STEMI = ST-segment elevation myocardial infarction; TIMI = Thrombolysis In Myocardial Infarction.

observational studies to be associated with lower mortality for primary PCI and PCI for STEMI patients (10–13).

Several earlier studies have examined the impact of multivessel PCI on primary PCI patients with a variety of inclusion criteria, time frames for nonculprit vessel PCI, outcomes used, and conclusions. Patients studied have included acute coronary syndromes (14), primary, facilitated, and rescue PCI patients (15,16); primary PCI patients (17–21); and STEMI patients (22). Mortality outcomes have included in-hospital mortality (14,15),

Table 2. Risk Factor Prevalence After Propensity Match According to Revascularization Strategy During Index Procedure in STEMI Patients With Multivessel CAD: Culprit Vessel Only Versus Multivessel at the Time of PPCI

Risk Factor	% in Study Population (n = 1,006)	% With Culprit Vessel Revascularization at the Time of PPCI (n = 503)	% With Multivessel Revascularization at the Time of PPCI (n = 503)	Standardized Difference (%)
Demographic factors				
Age, yrs				
59 or less	55.07	55.47	54.67	1.60
60–69	21.17	20.68	21.67	2.43
70–79	14.91	15.71	14.12	4.47
80 or more	8.85	8.15	9.54	4.90
Female	23.16	21.27	25.05	8.96
Cardiac factors				
No. of vessels diseased				
2 no proximal LAD	49.80	49.30	50.30	1.99
2 with proximal LAD	24.16	24.25	24.06	0.46
3 no proximal LAD	16.40	15.71	17.10	3.76
3 with proximal LAD	9.64	10.74	8.55	7.41
Ejection fraction				
19% or less	2.88	2.39	3.38	5.94
20%–29%	6.86	6.16	7.55	5.51
30%–39%	16.30	16.30	16.30	0.00
40%–49%	28.43	28.63	28.23	0.88
50% or more	45.53	46.52	44.53	3.99
Hemodynamic status				
Unstable	3.88	2.98	4.77	9.28
CHF history				
This admission	7.06	6.16	7.95	6.99
Chronic total occlusion	5.47	5.57	5.37	0.87
TIMI flow grade ≤2	41.85	40.16	43.54	6.86
Comorbidities				
Cerebrovascular	3.58	3.38	3.78	2.14
Peripheral vascular	3.88	3.58	4.17	3.09
Ventricular arrhythmia	1.79	1.79	1.79	0.00
COPD	5.17	4.97	5.37	1.80
Renal failure	1.19	0.80	1.60	7.33
Type of PCI				
Only drug-eluting stent	57.46	57.85	57.06	1.61
Bare-metal stent	41.15	40.95	41.35	0.81
No stent	1.39	1.19	1.59	3.39

New York State, January 1, 2003, to June 30, 2006. C statistic = 0.67.
Abbreviations as in Table 1.

in-hospital/30-day mortality (18), and a combination of short-term and longer-term mortality (16,17,19–22). The definition of timing of multivessel PCI has also varied and has included: during the index procedure (14,16,19,21), during the index procedure or hospital stay (17,18), staged PCI during the index hospital stay (20), during the index hospital stay or within 7 days of myocardial infarction (22), and within 24 h of myocardial infarction (15).

Conclusions have ranged from significantly lower adverse outcome rates for culprit vessel PCI (17), trending in favor of culprit vessel PCI (16), no significant difference (21,22), trending in favor of multivessel PCI (14), and significantly lower rates for multivessel PCI (15,18–20).

Our study is one of the few multicenter population-based studies that have been conducted on this topic and the only one that examines long-term outcomes and the use of multivessel PCI after discharge as well as during the index admission. Predictors of use of multivessel PCI at the time of primary PCI were younger age, lower and higher ejection fractions (as opposed to ejection fractions in the middle range), absence of chronic total occlusion, increased TIMI flow grade ≤2, and the use of bare-metal stents.

Table 3. Risk Factor Prevalence After Propensity Match According to Revascularization Strategy During Index Procedure in STEMI Patients With Multivessel CAD: Culprit Vessel Versus Staged In-Hospital Multivessel Revascularization

Risk Factor	% in Study Population (n = 518)	% With Culprit Vessel Revascularization at the Time of PPCI (n = 259)	% With Staged In-Hospital Multivessel Revascularization (n = 259)	Standardized Difference (%)
Demographic factors				
Age, yrs				
59 or less	48.46	47.88	49.03	2.32
60–69	28.96	28.96	28.96	0.00
70–79	16.80	16.60	16.99	1.03
80 or more	5.79	6.56	5.02	6.62
Female	17.37	18.92	15.83	8.16
Cardiac factors				
No. of vessels diseased				
2 no proximal LAD	41.12	40.15	42.08	3.92
2 with proximal LAD	16.99	18.15	15.83	6.17
3 no proximal LAD	27.22	26.64	27.80	2.60
3 with proximal LAD	14.67	15.06	14.29	2.18
Ejection fraction				
19% or less	1.16	1.16	1.16	0.00
20%–29%	6.56	7.34	5.79	6.24
30%–39%	18.92	18.53	19.31	1.97
40%–49%	30.50	31.66	29.34	5.03
50% or more	42.86	41.31	44.40	6.24
Hemodynamic status				
Unstable	3.28	3.47	3.09	2.17
CHF history				
This admission	3.21	4.10	2.32	9.08
Chronic total occlusion	7.14	6.56	7.72	4.50
TIMI flow grade ≤2	51.93	50.58	53.28	5.41
Comorbidities				
Cerebrovascular	4.25	3.86	4.63	3.83
Peripheral vascular	2.51	2.70	2.32	2.47
Ventricular arrhythmia	0.77	0.39	1.16	8.83
COPD	6.76	6.56	6.95	1.54
Renal failure	0.39	0.39	0.39	0.00
Type of PCI				
Only drug-eluting stent	66.22	65.64	66.80	2.45
Bare-metal stent	30.89	31.27	30.50	1.67
No stent	2.90	3.09	2.70	2.30

New York State, January 1, 2003, to June 30, 2006. C statistic = 0.69.
Abbreviations as in Table 1.

We found that patients with multivessel disease STEMI undergoing multivessel primary PCI at the time of the index procedure had mortality rates that were trending higher than rates for patients with culprit vessel PCI alone. Also, when outcomes for the subset of patients without hemodynamic instability, ejection fraction <20%, or malignant ventricular arrhythmia were examined, patients with culprit vessel PCI alone had lower in-hospital mortality rates (0.9% vs. 2.4%, p = 0.04). This subset was chosen because it was the group of patients in our database that came closest to the definition of hemodynamic compromise in the ACC/AHA recommendations. Because the current ACC/AHA guidelines recommend culprit vessel PCI for patients without hemodynamic compromise, our findings support the recommendations (3).

Another part of our study consisted of comparing differences in mortality between multivessel disease STEMI patients treated with culprit vessel PCI and those patients who did not undergo multivessel PCI during the index procedure but did undergo multivessel PCI within 60 days after the index procedure, either during the index admission or afterward. Conclusions from these analyses were that patients who underwent multivessel PCI within 60 days of the index procedure fared better than patients who were

Table 4. Risk Factor Prevalence After Propensity Match According to Revascularization Strategy During Index Procedure in STEMI Patients With Multivessel CAD: Culprit Vessel Versus Staged Multivessel Revascularization Within 60 Days of Index Procedure

Risk Factor	% in Study Population (n = 1,056)	% With Culprit Vessel Revascularization (n = 538)	% With Multivessel Revascularization Within 60 days (n = 538)	Standardized Difference (%)
Demographic factors				
Age, yrs				
59 or less	52.32	53.53	51.12	4.84
60–69	25.84	26.02	25.65	0.85
70–79	14.31	13.01	15.61	7.44
80 or more	7.53	7.43	7.62	0.70
Female	22.03	22.86	21.19	4.04
Cardiac factors				
No. of vessels diseased				
2 no proximal LAD	43.77	43.49	44.05	1.12
2 with proximal LAD	20.82	21.00	20.63	0.92
3 no proximal LAD	24.07	24.72	23.42	3.04
3 with proximal LAD	11.34	10.78	11.90	3.52
Ejection fraction				
19% or less	1.30	1.49	1.12	3.28
20%–29%	6.23	6.51	5.95	2.31
30%–39%	18.12	18.40	17.84	1.45
40%–49%	32.06	31.97	32.16	0.40
50% or more	42.29	41.64	42.94	2.63
Hemodynamic status				
Unstable	2.70	2.42	2.97	3.44
CHF history				
This admission	3.81	3.35	4.28	4.86
Chronic total occlusion	8.55	8.92	8.18	2.66
TIMI flow grade ≤2	53.62	54.65	52.60	4.10
Comorbidities				
Cerebrovascular	3.53	3.35	3.72	2.01
Peripheral vascular	3.81	4.09	3.53	2.91
Ventricular arrhythmia	0.84	1.12	0.56	6.13
COPD	4.83	4.09	5.58	6.94
Renal failure	0.56	0.56	0.56	0.00
Type of PCI				
Only drug-eluting stent	69.14	71.00	67.29	8.05
Bare-metal stent	28.07	26.02	30.11	9.11
No stent	2.79	2.97	2.60	2.26

New York State, January 1, 2003, to June 30, 2006. C statistic = 0.62.
Abbreviations as in Table 1.

limited to culprit vessel PCI within 60 days. The multivessel PCI patients had lower mortality rates at all time intervals that were examined, and their mortality rate was significantly lower at 12 months (1.3% vs. 3.3%, p = 0.04). A limitation of this set of analyses is that the multivessel PCI group underwent the second procedure sometime within 60 days after discharge, and the culprit vessel group to which it was matched was alive at 60 days without multivessel PCI. However, this should favor the culprit vessel revascularization group, so the findings are conservative with regard to the advantage of staged revascularization.

When the staged PCI patients were limited to patients who underwent the second procedure during the index admission but not during the index procedure, none of the mortality differences was statistically significant, although the staged revascularization group had lower mortality rates at all time intervals examined.

A caveat regarding the methodology of the study is that it is an observational study and is therefore subject to selection bias, whereby patients were chosen for 1 of the treatment options because of characteristics that would make that option more preferable and the other option less

Table 5. Mortality Rates (%) for Propensity Matched Multivessel Disease STEMI Patients by Revascularization Strategy During the Index Procedure

Outcome by Subgroup	Culprit Vessel Revascularization at the Time of PPCI	Multivessel Revascularization at the Time of PPCI	Percentage Difference	p Value
All patients	n = 503	n = 503		
Death, %				
In-hospital	2.0	3.4	1.4	0.14
12 months	5.5	7.1	1.6	0.23
24 months	6.6	8.6	2.0	0.17
42 months	10.8	11.8	1.0	0.23
Patients without hemodynamic instability, LVEF <20%, malignant ventricular arrhythmia	n = 458	n = 458		
Death, %				
In-hospital	0.9	2.4	1.5	0.04
12 months	4.2	5.8	1.6	0.13
24 months	4.9	7.2	2.3	0.07
42 months	6.7	10.4	3.7	0.08

Median follow-up = 22.54 months.
LVEF = left ventricular ejection fraction; PPCI = primary percutaneous coronary intervention; STEMI = ST-segment elevation myocardial infarction.

preferable. We tried to control for this bias by propensity matching patients so that each patient with culprit vessel PCI would be matched with a patient with similar characteristics that had a bearing on outcomes. The fact that the percent standardized differences in prevalence of the various patient characteristics were all <10% supports the assumption that there is good balance between the propensity matched groups (23). Also, the C statistic, a measure of the discrimination of the model, ranged from 0.63 to 0.69. These values are reasonably good for propensity models, where high values are not as desirable because there is a greater likelihood that there will be difficulty matching patients on numerous intersecting characteristics.

Nevertheless, residual bias might still exist. This is particularly true when there are many potentially unmeasured confounders that could explain why multivessel PCI is performed during the primary PCI. These include persistent pain/ST-segment elevation after dilation of the culprit vessel or another lesion causing compromised TIMI flow as well as situations in which the culprit lesion has been easily fixed. To the extent that these confounders affect outcomes, the results reported here might contain biases in either direction.

Another caveat of the study is that we were only able to capture mortality in New York State with New York's vital statistics data. Consequently, if New York patients moved out of state and died there, the mortality was not recorded in our study. If this occurred substantially more often in either subgroup, the results would be biased. However, we see no reason why there would be a bias in favor of either type of strategy, and an earlier study demonstrated that there was not a bias in this regard (9).

Also, like previous studies comparing culprit vessel and multivessel PCI for STEMI patients, the statistical power of our study was limited. For example, assuming an in-hospital mortality rate of 2% for culprit vessel PCI, a sample of 500 pairs, and a Type I error of 0.05, the power to detect a 5% mortality rate in multivessel PCI as significantly different is 0.67. In patients without hemodynamic compromise, an in-hospital mortality rate of 1% for culprit vessel PCI is more reasonable, and for 500 pairs of patients and a

Table 6. Mortality Rates (%) for Propensity Matched Multivessel Disease STEMI Patients With Culprit Vessel PCI With and Without Staged In-Hospital Multivessel Revascularization

Outcome by Subgroup	Culprit Vessel Revascularization	Staged Multivessel Revascularization During Index Hospital Stay	Percentage Difference	p Value
All patients	n = 259	n = 259		
Death, %				
In-hospital	1.9	1.2	0.7	0.48
12 months	5.5	3.9	1.6	0.53
24 months	7.4	6.3	1.1	0.71
42 months	8.4	6.3	2.1	0.72

Median follow-up = 21.91 months.
PCI = percutaneous coronary intervention; STEMI = ST-segment elevation myocardial infarction.

Table 7. Mortality Rates (%) for Propensity Matched Multivessel Disease STEMI Patients With Culprit Vessel PCI With and Without Staged Revascularization Within 60 Days

Outcomes	Culprit Vessel Revascularization Patients Alive at 60 Days	Multivessel Revascularization Within 60 Days	Percentage Difference	p Value
All patients	n = 538	n = 538		
Death, %				
12 months	3.3	1.3	2.0	0.04
24 months	4.3	3.7	0.6	0.21
42 months	7.4	5.6	1.8	0.17

Median follow-up = 21.82 months.
Abbreviations as in Table 6.

Type I error of 0.05, the power to detect a significant difference in a mortality rate of 3% for multivessel PCI is 0.54. This power rises to 0.83 when distinguishing between samples with mortality rates of 1% and 4%.

In conclusion, the findings of our study support the ACC/AHA recommendations regarding the use of culprit vessel PCI for STEMI patients with multivessel disease at the time of the index revascularization except when patients are hemodynamically compromised. However, we also found that, when patients undergo staged multivessel revascularization after the index procedure but within 60 days, mortality rates were significantly lower at 12 months. Also, for the subset of patients undergoing staged PCI in the index admission, there was no difference in outcomes between culprit vessel PCI and staged PCI. Thus, our findings indicate that, for STEMI patients with multivessel disease, staged PCI after the index procedure is associated with risk-adjusted mortality rates that are comparable to the rate for culprit vessel PCI.

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REFERENCES

1. Antman EM, Anbe DT, Armstrong PW, et al. ACC/AHA guidelines for the management of patients with ST-elevation myocardial infarction: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee to Revise the 1999 Guidelines for the Management of Patients With Acute Myocardial Infarction). J Am Coll Cardiol 2004;44:E1–211.
2. Antman EM, Hand M, Armstrong PW, et al. 2007 focused update of the ACC/AHA 2004 guidelines for the management of patients with ST-elevation myocardial infarction: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. J Am Coll Cardiol 2008;51:210–47.
3. Smith SC Jr., Feldman TE, Hirshfield JW Jr., et al. ACC/AHA/SCAI 2005 guideline update for percutaneous coronary intervention: a report of the American College of Cardiology/American Heart Association Task force on Practice Guidelines (ACC/AHA/SCAI Writing Committee to Update the 2001 Guidelines for Percutaneous Coronary Intervention). J Am Coll Cardiol 2006;47:e1–121.
4. Rosenbaum PR, Rubin DB. The central role of the propensity score in observational studies for causal effects. Biometrika 1983;70:41–55.
5. Rosenbaum PR. Optimal matching for observational studies. J Am Stat Assoc 1989;84:41–55.
6. Ming K, Rosenbaum PR. A note on optimal matching with variable controls using the assignment algorithm. J Comput Graph Stat 2001;10:455–63.
7. Gu XS, Rosenbaum PR. Comparison of multivariate matching methods, structures, differences, and algorithms. J Comput Graph Stat 1993;2:405–20.
8. Mauri L, Silbaugh TS, Wolf RE, et al. Long-term outcomes after drug-eluting and bare-metal stenting in Massachusetts. Circulation 2008;118:1817–27.
9. Klein JP, Moeschberger ML. Survival Analysis: Techniques for Censored and Truncated Data. New York, NY: Springer-Verlag, 1997.
10. Hannan EL, Racz MJ, McCallister BD, et al. A comparison of three-year survival after coronary artery bypass graft surgery and percutaneous transluminal coronary angioplasty. J Am Coll Cardiol 1999;33:63–72.
11. Mauri L, Silbaugh TS, Garg P, et al. Drug-eluting or bare-metal stents for acute myocardial infarction. N Engl J Med 2008;359:1330–42.
12. Kastrati A, Dibra A, Spaulding C, et al. Meta-analysis of randomized trials on drug-eluting stents vs. bare-metal stents in patients with acute myocardial infarction. Eur Heart J 2007;28:2706–13.
13. De Luca G, Stone G, Suryapranata H, et al. Efficacy and safety of drug-eluting stents in ST-segment elevation myocardial infarction: meta-analysis of randomized trials. Int J Cardiol 2009;133:213–22.
14. Brener SJ, Milford-Beland S, Roe MT, Bhatt DL, Weintraub WS, Brindis RG. Culprit-only or multivessel revascularization in patients with acute coronary syndromes: an American College of Cardiology National Cardiovascular Database Registry report. Am Heart J 2008;155:140–6.
15. Kong JA, Chou ET, Minutello RM, Wong SC, Hong MK. Safety of single versus multi-vessel angioplasty for patients with acute myocardial infarction and multi-vessel coronary artery disease: report from the New York State Angioplasty Registry. Coron Artery Dis 2006;17:71–5.
16. Roe MT, Cura FA, Joski PS, et al. Initial experience with multivessel coronary intervention during mechanical reperfusion for acute myocardial infarction. Am J Cardiol 2001;88:170–3.
17. Corpus RA, House JA, Marso SP, et al. Multivessel percutaneous coronary intervention in patients with multivessel disease and acute myocardial infarction. Am Heart J 2004;148:493–500.

18. Varani E, Balducelli M, Aquilina M, et al. Single or multivessel percutaneous coronary intervention in ST-elevation myocardial infarction patients. Catheter Cardiovasc Interv 2008;72:927–33.
19. Qarawani D, Nahir M, Abboud M, Hazanov Y, Hasin Y. Culprit only versus complete coronary revascularization during primary PCI. Int J Cardiol 2008;123:288–92.
20. Rigattieri S, Biondi-Zoccai G, Silvestri P, et al. Management of multivessel coronary disease after ST elevation myocardial infarction treated by primary angioplasty. J Interven Cardiol 2008;21:1–7.
21. Carlo DM, Mara S, Flavio A, et al. Single vs. multivessel treatment during primary angioplasty: results of the multicentre randomized HEpacoat for culprit or multivessel stenting for Acute Myocardial Infarction (HELP AMI) study. Int J Cardiovasc Int 2004;34: 128–33.
22. Chen LY, Lennon RJ, Grantham JA, et al. In-hospital and long-term outcomes of multivessel percutaneous coronary revascularization after acute myocardial infarction. Am J Cardiol 2005;95;349–54.
23. Normand ST, Landrum MB, Guadagnoli E, et al. Validating recommendations for coronary angiography following acute myocardial infarction in the elderly: a matched analysis using propensity scores. J Clin Epidemiol 2001;54:387–98.

Key Words: culprit vessel revascularization ■ multivessel revascularization ■ primary PCI ■ ST-segment elevation myocardial infarction.

APPENDIX

For supplementary PCI risk factor definitions, please see the online version of this article.