Coronary Artery Bypass Grafting After Recent or Remote Percutaneous Coronary Intervention in the Commonwealth of Massachusetts

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**Background**—In this study, we sought to characterize the outcomes after isolated coronary artery bypass grafting (CABG) in patients with a history of remote (≥14 days), and recent (<14 days), percutaneous coronary intervention (PCI).

**Methods and Results**—Patients with PCI within 5 years of CABG were identified among 12 591 primary isolated CABG reported in the mandatory Massachusetts Adult Cardiac Surgery Database. Patients were excluded if they were out-of-state (n=1043, 8%), had undergone primary PCI for acute myocardial infarction (n=401, 3%), had a PCI-CABG interval >5 years or unknown (n=136 and n=673, 1% and 5%). Patients with a history of remote and recent PCI were analyzed separately. Each CABG patient with PCI was matched to 3 patients without PCI using a propensity score. Outcomes were analyzed using generalized estimating equations and stratified proportional hazards models, with a mean follow-up of 4.1±1.2 years. There were 1117 CABG patients (9%) with prior PCI (nremote=823; nrecent=294). In matched CABG patients with remote prior PCI, no differences were found in 30-day mortality (1.1% versus 1.5%; \( P=0.432 \)), hospital morbidity (41% versus 40%; \( P=0.385 \)) and overall survival (hazard ratio, [95% confidence interval] for death for prior PCI, 0.93 [0.74 to 1.18]; \( P=0.555 \)). In matched CABG patients with recent prior PCI, hospital morbidity was higher (59% versus 45%; \( P<0.001 \)), but no differences were found in 30-day mortality (3.5% versus 3.1%; \( P=0.754 \)) and overall survival (HR, 1.18 [0.83 to 1.69]; \( P=0.353 \)).

**Conclusions**—In patients undergoing CABG, remote prior PCI (≥14 days) was not associated with adverse outcomes at 30 days or during long-term follow-up. (Circ Cardiovasc Interv. 2010;3:460-467.)

**Key Words:** angioplasty • bypass • revascularization • epidemiological methods • follow-up studies

The past two decades have witnessed a dramatic increase in the rates of percutaneous coronary interventions (PCI), with this technology expanded to more complex patient subgroups including diabetes, severe left ventricular dysfunction, left main, and triple vessel disease. A recent metaanalysis of randomized controlled trials of PCI stenting versus coronary artery bypass grafting (CABG) for multivessel disease demonstrated a similar cumulative incidence of death, stroke and myocardial infarction at 5 years but an increase in repeat revascularization in the PCI population. Conversely, large real-world registries comparing PCI stenting with bare-metal or drug-eluting stents versus CABG demonstrated a lower incidence of death or myocardial infarction with CABG. In randomized trials and real-world registries, PCI is associated with an increased incidence of symptom recurrence and repeat revascularization compared with CABG.

**Clinical Perspective on p 467**

Several studies have reported worse outcomes for patients undergoing CABG after acute PCI associated with complications, but few studies have assessed outcomes after CABG procedures after initially successful and uneventful PCI. Moreover, no study has explicitly excluded patients undergoing primary PCI for acute myocardial infarction, where patients are more likely to be treated solely for their culprit lesion, with incomplete revascularization.

We hypothesized that patients with a history of prior PCI undergoing primary isolated CABG experience poorer survival compared with CABG patients with no prior PCI, with a greater difference in patients with shorter PCI-to-CABG interval compared with those with longer PCI-to-CABG interval. Our objectives were to describe patient characteristics and outcomes of real-world patients who underwent primary isolated CABG after uneventful PCI and contrast them to a matched...
group of CABG patients with no prior PCI. The primary end point was overall survival and secondary end points were 30-day mortality, hospital morbidity, and length of stay.

Methods

Patients

Ethics approval for this study was obtained from the Partners HealthCare Institutional Review Board. We linked clinical information from the mandatory Massachusetts Adult Cardiac Surgery Database (MASSDAC) to the Massachusetts Inpatient Acute Hospital Case Mix and Charge Database to analyze outcomes of 12,591 adults undergoing primary isolated CABG between 2002 and 2004. All 14 state licensed cardiac surgery programs in Massachusetts submitted patient and surgeon specific data to the MASSDAC coordinating center at Harvard Medical School. Hospital data submission were cleansed and verified using a variety of procedures: continuous feedback via ongoing data quality reports, meetings and communication, review of concordance with administrative data sets, and review of concordance with medical chart audits. However, variables describing whether or not the patient had PCI in the past were not part of the auditing process. Details of PCI interventions, including dates, were not specified. Therefore, inpatient discharge data for all Massachusetts' acute care hospitals (n=84) were used to identify any occurrence of prior PCI in the 5-year interval before the primary CABG (ICD-9-CM codes 36.01 to 36.02, 36.05 to 36.07, and 36.09). There were 61 patients (6%) with prior PCI in the administrative data base who were not coded as prior PCI in MASSDAC. These patients were considered to have an unknown PCI-CABG interval.

We excluded 402 (3%) patients with a Unique Health Information Number not linkable to the inpatient discharge database, 1043 (8%) patients residing outside of Massachusetts at time of primary CABG, 401 (3%) patients with a primary PCI for acute myocardial infarction, 136 (1%) patients with PCI >5 years before CABG and 673 (5%) patients with unknown PCI-CABG intervals. Primary PCI for acute myocardial infarction was defined as PCI during hospitalization with a primary diagnosis of acute myocardial infarction (ICD-9-CM codes 410.X0–410.X1, excluding subendocardial infarction 410.70 to 410.71) or a primary diagnosis of a complication of an acute myocardial infarction (ICD-9-CM codes 785.51, 785.59, 429.5, 429.6, and 429.71) with a secondary diagnosis of acute myocardial infarction.

In this large cohort of 9934 patients, we identified 1117 CABG patients (9%) with prior PCI, including 294 patients with recent PCI and 823 patients with remote PCI. Recent PCI was defined as prior PCI performed 14 days or greater before CABG surgery. Patients with a history of recent and remote PCI. The 1:N greedy matching algorithm starts with a 1:1 match where it determines the “best” match based on the propensity score, with “next-best” matches listed in hierarchical order. Cases are then matched to the set of remaining control subjects in N-1 additional iterations. If a case does not have N matched control subjects, it is removed from the set of matches at the time it fails to receive a matched control. The corresponding control is also removed from the set of matches and added back to the pool of unmatched control subjects for subsequent matching.

Patient characteristics before and after matching were compared using standardized differences. For 30-day mortality and hospital morbidity, logit-link generalized estimating equations were used accounting for clustering among hospitals in the univariable and multivariable nonmatched analyses (ie, without propensity score) and for matching in univariable matched analyses. Similarly, identity-link normal-distribution generalized estimating equations were used for cardiopulmonary bypass time, cross-clamp time, number of grafts performed, and log-transformed length of stay. After verification of proportionality assumptions, survival was compared using stratified proportional hazards models to account for clustering among hospitals in the nonmatched analysis and to account for matching in the matched analysis. We assumed that observations were conditionally independent within hospital or matched clusters. Survival curves were obtained using Kaplan–Meier methods; however, group comparisons were performed using stratified proportional hazards models. Probability values less than 0.05 were considered statistically significant. All statistical analyses were performed using SAS release 9.1 (SAS Institute Inc, Cary, NC).

Results

CABG Patients With Remote Prior PCI (≥14 Days)

In CABG patient with remote PCI, the median interval between PCI and CABG was 236 days [15 to 1825 days] (Figure 1). Patient characteristics for all patients and matched groups with remote prior PCI are reported in Table 1. Compared with nonmatched CABG patients with no prior PCI, nonmatched CABG patients with remote prior PCI were younger, more likely to be female and present with diabetes, angina, dyslipidemia and larger body surface area. They were less likely to present with arrhythmia, left main disease, 3-vessel disease, low left ventricular ejection fraction, an urgent status, or require an intraaortic

Figure 1. Time interval between PCI and CABG for patients with remote prior PCI (≥14 days).
### Table 1. Patient Characteristics in CABG Patients With Remote Prior PCI (≥14 Days) or With No Prior PCI

<table>
<thead>
<tr>
<th></th>
<th>All CABG Patients</th>
<th>CABG Patients Matched 1:3</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Prior PCI</td>
<td>No PCI</td>
<td>Prior PCI</td>
</tr>
<tr>
<td></td>
<td>(n=823)</td>
<td>(n=8819)</td>
<td>(n=809)</td>
</tr>
<tr>
<td><strong>Age, y</strong></td>
<td>63±11</td>
<td>67±11</td>
<td>63±11</td>
</tr>
<tr>
<td>&lt;65</td>
<td>455 (55%)</td>
<td>3324 (38%)</td>
<td>441 (55%)</td>
</tr>
<tr>
<td>65–74</td>
<td>229 (28%)</td>
<td>2939 (33%)</td>
<td>229 (28%)</td>
</tr>
<tr>
<td>&gt;74</td>
<td>139 (17%)</td>
<td>2556 (29%)</td>
<td>139 (17%)</td>
</tr>
<tr>
<td><strong>Sex, female, n (%)</strong></td>
<td>255 (31%)</td>
<td>2305 (26%)</td>
<td>245 (30%)</td>
</tr>
<tr>
<td><strong>Race/ethnicity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Hispanic white, n (%)</td>
<td>757 (92%)</td>
<td>8037 (91%)</td>
<td>745 (92%)</td>
</tr>
<tr>
<td>Non-Hispanic black, n (%)</td>
<td>18 (2%)</td>
<td>172 (2%)</td>
<td>17 (2%)</td>
</tr>
<tr>
<td>Hispanic, n (%)</td>
<td>25 (3%)</td>
<td>272 (3%)</td>
<td>24 (3%)</td>
</tr>
<tr>
<td>Other, n (%)</td>
<td>23 (3%)</td>
<td>338 (4%)</td>
<td>23 (3%)</td>
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<tr>
<td>Diabetes, n (%)</td>
<td>355 (43%)</td>
<td>3297 (37%)</td>
<td>347 (43%)</td>
</tr>
<tr>
<td>Hypertension, n (%)</td>
<td>679 (83%)</td>
<td>6981 (79%)</td>
<td>666 (82%)</td>
</tr>
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<td>Dyslipidemia, n (%)</td>
<td>741 (90%)</td>
<td>6937 (79%)</td>
<td>727 (90%)</td>
</tr>
<tr>
<td>Body surface area, m²</td>
<td>2.0±0.2</td>
<td>2.0±0.2</td>
<td>2.0±0.2</td>
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<tr>
<td>&lt;1.86 m², n (%)</td>
<td>232 (28%)</td>
<td>2979 (34%)</td>
<td>232 (29%)</td>
</tr>
<tr>
<td>1.86–2.05 m², n (%)</td>
<td>281 (34%)</td>
<td>3004 (34%)</td>
<td>273 (34%)</td>
</tr>
<tr>
<td>&gt;2.05 m², n (%)</td>
<td>301 (38%)</td>
<td>2836 (32%)</td>
<td>304 (38%)</td>
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<tr>
<td>Angina, n (%)</td>
<td>771 (94%)</td>
<td>7664 (87%)</td>
<td>758 (94%)</td>
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<td><strong>Prior myocardial infarction</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>None, n (%)</td>
<td>400 (49%)</td>
<td>4614 (53%)</td>
<td>395 (49%)</td>
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<tr>
<td>≥24 h before CABG, n (%)</td>
<td>11 (1%)</td>
<td>261 (3%)</td>
<td>11 (1%)</td>
</tr>
<tr>
<td>&gt;24 h before CABG, n (%)</td>
<td>412 (50%)</td>
<td>3917 (44%)</td>
<td>403 (50%)</td>
</tr>
<tr>
<td><strong>NYHA Functional Class III–IV, n (%)</strong></td>
<td>575 (70%)</td>
<td>5906 (67%)</td>
<td>567 (70%)</td>
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<tr>
<td>Left ventricular ejection fraction, %</td>
<td>52±12</td>
<td>49±14</td>
<td>52±12</td>
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<tr>
<td>&lt;30%, n (%)</td>
<td>31 (4%)</td>
<td>749 (8%)</td>
<td>31 (4%)</td>
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<tr>
<td>30%–39%, n (%)</td>
<td>77 (9%)</td>
<td>1025 (12%)</td>
<td>76 (9%)</td>
</tr>
<tr>
<td>&gt;39%, n (%)</td>
<td>683 (83%)</td>
<td>6664 (76%)</td>
<td>671 (83%)</td>
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<td>Missing, n (%)</td>
<td>32 (4%)</td>
<td>381 (4%)</td>
<td>31 (4%)</td>
</tr>
<tr>
<td>Arrhythmia,* n (%)</td>
<td>39 (5%)</td>
<td>843 (10%)</td>
<td>39 (5%)</td>
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<tr>
<td>Peripheral vascular disease, n (%)</td>
<td>122 (15%)</td>
<td>1574 (18%)</td>
<td>119 (15%)</td>
</tr>
<tr>
<td>Renal failure, n (%)</td>
<td>59 (7%)</td>
<td>586 (7%)</td>
<td>57 (7%)</td>
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<tr>
<td>Dialysis, n (%)</td>
<td>22 (3%)</td>
<td>108 (1%)</td>
<td>20 (2%)</td>
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<tr>
<td>Chronic lung disease, n (%)</td>
<td>107 (13%)</td>
<td>1159 (13%)</td>
<td>104 (13%)</td>
</tr>
<tr>
<td>Current smoker, n (%)</td>
<td>116 (14%)</td>
<td>1495 (17%)</td>
<td>116 (14%)</td>
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<tr>
<td><strong>Status of surgery</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elective, n (%)</td>
<td>313 (38%)</td>
<td>2833 (32%)</td>
<td>306 (38%)</td>
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<tr>
<td>Urgent, n (%)</td>
<td>496 (60%)</td>
<td>5730 (65%)</td>
<td>489 (60%)</td>
</tr>
<tr>
<td>Emergent/salvage, n (%)</td>
<td>14 (2%)</td>
<td>256 (3%)</td>
<td>14 (2%)</td>
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<tr>
<td>Cardiogenic shock, n (%)</td>
<td>6 (1%)</td>
<td>118 (1%)</td>
<td>6 (1%)</td>
</tr>
<tr>
<td>Preoperative intraaortic balloon pump need, n (%)</td>
<td>53 (6%)</td>
<td>902 (10%)</td>
<td>52 (6%)</td>
</tr>
<tr>
<td>Left main stenosis (≥50%), n (%)</td>
<td>216 (26%)</td>
<td>3132 (36%)</td>
<td>215 (27%)</td>
</tr>
<tr>
<td>No. of diseased vessels, n</td>
<td>2.6±0.6</td>
<td>2.8±0.5</td>
<td>2.6±0.6</td>
</tr>
<tr>
<td>One, n (%)</td>
<td>63 (8%)</td>
<td>260 (3%)</td>
<td>58 (7%)</td>
</tr>
<tr>
<td>Two, n (%)</td>
<td>221 (27%)</td>
<td>1534 (17%)</td>
<td>213 (26%)</td>
</tr>
<tr>
<td>Three, n (%)</td>
<td>539 (65%)</td>
<td>7025 (80%)</td>
<td>538 (67%)</td>
</tr>
<tr>
<td><strong>Year of surgery</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2002, n (%)</td>
<td>293 (36%)</td>
<td>3108 (35%)</td>
<td>287 (35%)</td>
</tr>
<tr>
<td>2003, n (%)</td>
<td>308 (37%)</td>
<td>3008 (34%)</td>
<td>302 (37%)</td>
</tr>
<tr>
<td>2004, n (%)</td>
<td>222 (27%)</td>
<td>2703 (31%)</td>
<td>220 (27%)</td>
</tr>
<tr>
<td><strong>Primary health insurance</strong></td>
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<td></td>
<td></td>
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<tr>
<td>Private-HMO, n (%)</td>
<td>462 (56%)</td>
<td>4161 (47%)</td>
<td>451 (56%)</td>
</tr>
<tr>
<td>Medicare, n (%)</td>
<td>303 (37%)</td>
<td>4117 (47%)</td>
<td>302 (37%)</td>
</tr>
<tr>
<td>Welfare/Medicaid, n (%)</td>
<td>39 (5%)</td>
<td>234 (3%)</td>
<td>37 (5%)</td>
</tr>
<tr>
<td>Uninsured, n (%)</td>
<td>14 (2%)</td>
<td>204 (2%)</td>
<td>14 (2%)</td>
</tr>
</tbody>
</table>

*Arrhythmia indicates atrial fibrillation, heart block, or cardiac arrest; and SD, standardized difference.
balloon pump before surgery. In the 809 CABBG patients with remote prior PCI who were successfully matched to 2427 control subjects, no differences in patient characteristics were noted, except for a higher prevalence of angina, NYHA functional class III-IV and myocardial infarction not identified as a risk factor for 30-day mortality in univariate analyses.

Operative data and postoperative outcomes for the matched groups with remote prior PCI are shown in Table 2. Patients with remote prior PCI received fewer coronary grafts, less frequently had a left internal thoracic artery graft, and had lower cross-clamp times. There was no clustering for lower use of left internal thoracic artery graft, and had lower cross-clamp times. Overall hospital morbidity was also no different for nonmatched CABG patients with or without remote prior PCI. Matched CABG patients with or without remote prior PCI received more blood product transfusions, without a difference in rate of reoperation for bleeding. The median length of stay was similar for CABG patients with or without remote prior PCI.

Among nonmatched patients, remote prior PCI was identified as a predictor of improved long-term survival in univariable (HR, 0.74 [0.60 to 0.91]; P=0.004) but not multivariable regression models (supplemental Table 1). As portrayed in Figure 2A, survival was better for nonmatched CABG patients with remote prior PCI compared with CABG patients with no prior PCI. However, no difference in survival was noted for matched groups (Figure 2B).

### CABG Patients With Recent Prior PCI (<14 Days)

In the recent prior PCI group, 131 patients (45%) had a myocardial infarction at the time of PCI or after the procedure. The indication for CABBG was unstable angina with referral to CABBG within 6 hours of PCI (n=86; 29%), 6 to 24 hours after PCI (n=111; 38%), or greater than 24 hours after PCI (n=24; 8%); stable angina after PCI (n=55; 19%); or no...
documented angina but either 2- or 3-vessel disease (n = 18; 6%). Ninety-seven patients with recent prior PCI (33%) required an intraaortic balloon pump before CABG, including 23 patients (8%) who did not have unstable angina. Compared with nonmatched patients with no prior PCI, nonmatched patients with recent prior PCI were younger (standardized difference, SD = 20%) and more likely to be female (SD = 12%), have a prior myocardial infarction (SD = 34%), angina (SD = 15%), cardiogenic shock (SD = 39%), require an intraaortic balloon pump preoperatively (SD = 58%), and present in an emergent/salvage status (SD = 59%) (supplemental Table 2). They were less likely to present with left main (SD = −25%) or 3-vessel disease (SD = −44%). In the 260 CABG patients with recent prior PCI that were successfully matched to 780 CABG patients with no prior PCI, no differences in patient characteristics were noted except for a higher prevalence of prior myocardial infarction (SD = 25%) and intraaortic balloon pump use before surgery (SD = 12%).

Fewer grafts were received and the left internal thoracic artery and radial artery grafts were less frequently used by matched patients with recent prior PCI. The 30-day mortality was higher in nonmatched patients with recent prior PCI (4.1% versus 1.9%; P = 0.033) but no different in matched patients with or without prior PCI (3.5% versus 3.1%; P = 0.754). Overall hospital morbidity was higher for both the nonmatched (58% versus 43%; P < 0.001) and matched (59% versus 45%; P < 0.001) CABG patients with prior PCI. Matched CABG patients with recent prior PCI received more blood product transfusions (69% versus 54%; P < 0.001), had a higher rate of reoperation for bleeding (4.2% versus 1.4%; P = 0.010) or graft revision (2.3% versus 0.1%; P = 0.007), perioperative myocardial infarction (13% versus 4%; P < 0.001), and prolonged ventilation greater than 24 hours (25% versus 13%; P < 0.001). The incidence of postoperative neurological deficit, renal failure, atrial fibrillation, or gastrointestinal complication was similar for the 2 matched groups. Matched patients with recent prior PCI had longer length of stay (median of 10 days versus 9 days; P < 0.001) and higher readmission rate at 30 days (15% versus 10%; P = 0.021).

Survival was no different in nonmatched CABG patients with recent prior PCI and in matched CABG patients with or without prior PCI (Figure 3A and 3B).

Figure 2. Survival after CABG surgery for A, patients with remote (≥14 days) prior PCI versus patients with no prior PCI, and B, propensity score–matched patients with remote prior PCI versus patients with no prior PCI. Yearly survival estimates and number at risk are provided in the embedded table. Groups were compared using a stratified proportional hazards model accounting A, for clustering among hospitals, or B, for matching. We report the death hazard ratio from the stratified proportional hazards model, with 95% confidence interval and probability value, for remote prior PCI (a HR < 1 indicates a lower risk for death for patients with remote prior PCI versus those with no prior PCI).

![Figure 2](image)

Figure 3. Survival after CABG surgery for A, patients with recent (<14 days) prior PCI versus patients with no prior PCI, and B, propensity score–matched patients with recent prior PCI versus patients with no prior PCI. See Figure 2 legend.

![Figure 3](image)
Discussion

In this large contemporary real world multiinstitutional study, we present long-term results of CABG patients with prior PCI and contrast them with a matched group of patients with no prior PCI. To avoid bias resulting from poorer outcomes in patients requiring CABG on an urgent basis after incomplete or complicated PCI revascularization, we excluded patients requiring primary PCI for acute myocardial infarction and analyzed separately patients with recent (<14 days) or remote (≥14 days) prior PCI. Our matched analyses based on a propensity score revealed higher overall morbidity for patients with recent PCI but no difference in early and long-term survival among CABG patients with and without a prior PCI.

Prior studies have addressed outcomes of CABG patients with prior successful/uneventful PCI. However, these studies (1) differed in their design: retrospective cohort or case-control, with different control groups: CABG patients with no prior PCI or PCI patients with no subsequent CABB; (2) did not take into consideration the PCI to CABG interval, pooling all patients with a history of prior PCI together; (3) included patients with prior PCI in the setting of acute myocardial infarction and shock where the PCI goal may have been to treat the culprit lesion expeditiously instead of providing complete revascularization; and (4) with few exceptions, these studies were limited to short-term outcomes.

In a substudy of the IMAGINE trial, of 2489 patients with a median follow-up of 2.95 years, CABG patients with prior PCI had a worse outcome than those with no prior PCI (HR = 1.55 [1.17 to 1.98]), with a higher occurrence of the composite outcome of cardiovascular death or resuscitated cardiac arrest, nonfatal myocardial infarction (MI), coronary revascularization, unstable angina requiring hospitalization, documented angina not requiring hospitalization, stroke, or congestive heart failure requiring hospitalization. Taken individually, only coronary revascularization (HR = 1.80 [1.13 to 2.87]) and unstable angina requiring hospitalization (HR = 2.43 [1.52 to 3.89]) were significantly higher in patients with prior PCI, whereas cardiovascular death was not (HR = 1.91 [0.88 to 4.13]). Similar to our study, fewer distal anastomosis were performed in CABG patients with prior PCI (3.0±1.1 versus 3.3±1.1; P<0.001). However, completeness of revascularization appeared to be equivalent between groups. Kalaycioglu et al compared the outcome of 40 CABG patients with prior successful PTCA to 40 case-matched CABG patients with no prior PCI and reported decreased freedom from angina (82.5% versus 87.5% at 3 years) and survival (92.5% versus 95.0% at 3 years) in CABG patients with prior PCI.

Using both multivariable and propensity score matching techniques in 6032 CABG patients, Hassan et al showed that prior PCI was an independent predictor of in-hospital mortality after CABG (OR = 1.93 [1.26 to 2.96]). Thielmann et al compared short-term outcomes of 2,626 CABG patients with no prior PCI to CABG patients with single (n = 360) or multiple (n = 289) prior PCI sessions. Their analyses revealed that multiple but not single prior PCI sessions were associated with increased in-hospital mortality (OR = 2.24 [1.52 to 3.21]) and major adverse cardiac events (OR = 2.28 [1.38 to 3.59]). They suggested that the worse postoperative outcomes may be a consequence of increased endothelial injury with multiple stenting attempts and coronary side-branch obstruction due to overlapping stents. In a study of 749 diabetic patients, the same group demonstrated that prior PCI was an independent predictor of in-hospital mortality (OR = 2.87 [1.29 to 6.37]) and major adverse cardiac events (OR = 2.34 [1.39 to 5.46]) in patients with triple vessel disease.

In patients treated between 1981 and 1997, Barakate et al demonstrated similar 30-day mortality in 361 CABG patients with prior PCI (median time from initial PCI to CABG of 4 months) compared with 11,909 CABG patients with no prior PCI. They excluded patients requiring emergent CABG within 24 hours of PCI or those with unsuccessful PCI, defined by residual luminal narrowing >40% or a PCI complication. Patients with prior PCI were less likely to present with triple-vessel or left main disease and received fewer distal anastomoses (2.9 versus 4.1; P = 0.05). After adjusting for the number of diseased coronary vessels and left main disease, we have shown that patients with prior PCI received, on average, less grafts and the left internal thoracic artery graft was used less frequently. Lesser use of the left internal thoracic artery is of some concern and may reflect (1) absence of significant left anterior descending artery (LAD) disease, or other suitable coronary artery with large runoff, at the time of CABG, (2) successful PCI or borderline restenosis (<70%) with adequate flow in the LAD where a graft would be subject to competition of flow, or (3) the need to graft the LAD at a more distal site with a smaller luminal diameter and suboptimal runoff, or at a point where the left internal thoracic artery would not reach in situ or as a free graft. The left internal thoracic artery is associated with better long-term patency and survival at 10 and 20 years after CABG compared with saphenous vein grafts, and this may translate to lower late survival in CABG patients with prior PCI.

What Is the Impact of the Time Interval Between PCI and CABG?

The time interval between PCI and CABG is rarely reported, and no prior study has reported how varying intervals may affect outcomes after CABG. In matched CABG patients with versus without prior PCI within 14 days of their CABG, we found a significant increase in hospital morbidity, but no difference in 30-day mortality or long-term survival. Such patients are more likely to have a history of myocardial infarction or angina and present in cardiogenic shock or in an emergent/salvage status compared with patients with no prior PCI or PCI more than 14 days before CABG. Some characteristics may be a consequence of the PCI, such as early restenosis, thrombosis or coronary dissection with unstable angina. If this were the case in a sizeable proportion of patients, propensity score matching based on these characteristics would lead to the selection of a sicker control group and bias the results toward no difference between groups. Ideally, propensity score matching is best performed using patient characteristics before PCI, or by identifying characteristics that are a consequence of PCI, for example, whether cardiogenic shock developed before or after PCI. Nevertheless, we found an increase in hospital morbidity in this higher risk
subgroup compared with their propensity score matched control subjects, as they were more likely to receive blood product transfusions, requiring reexploration for bleeding, present with perioperative myocardial infarction, or require prolonged ventilation. In the early period after PCI, patients may have received loading doses and/or combinations of antiplatelet and anticoagulant agents (eg, clopidogrel, aspirin, glycoprotein IIb/IIIa inhibitors, and/or heparin) associated with increased risk of bleeding.

“Recent” and “remote” prior PCI were arbitrarily defined a priori with a cutoff at 14 days. The objective was to assess separately patients who underwent PCI and CABG during the same hospitalization or a time frame equivalent to an average hospitalization. Analyses were repeated using a cutoff at 30 days and all the conclusions remained the same because there were fewer patients in the 14- to 30-day interval (n=34) compared with the 0- to 14-day interval (n=294).

Limitations
As a retrospective study using CABG as the mechanism for entry into analysis, this study does not directly address the question of treatment at the time of initial intervention (PCI versus CABG). Because we did not review the total PCI population but only the subgroup that came to surgery, we cannot account for the fact that some patients may have died in the time interval between PCI and CABG, and sicker patients with prior PCI may have declined CABG surgery. It is also possible that in some patients there was increase in risk between the PCI and CABG (for example, reduction in LVEF due to MI).

This study lacked detailed cardiac catheterization data at the time of PCI and subsequent CABG. Furthermore, it was not possible to determine precisely whether PCI was performed in the setting of single-vessel or multiple-vessel disease and whether balloon dilatation and/or stent(s) were used. In this study, we expected to capture mostly the patients with restenosis after PCI, as opposed to native disease progression, by including only patients who had undergone PCI less than 5 years before CABG. This study primarily focuses on the remote prior PCI group, as the recent prior PCI group is more likely to represent a heterogeneous group with acute PCI complications. In the available data bases, it was not possible to restrict analyses to patients with a single admission for PCI before CABG because some prior PCI could have been performed before 1997. However, our study found no difference in early results according to the number of prior admissions for PCI.

In conclusion, 30-day mortality, hospital morbidity, hospital length of stay, and survival of CABG patients with remote prior PCI are no different than a matched CABG population with no prior PCI. Patients presenting for CABG early (within 14 days) after PCI represent a sicker subgroup in whom hospital morbidity is significantly increased. Prospective follow-up of CABG patients with prior PCI is warranted because their late survival may be affected by the decreased use of the left internal thoracic artery and coronary grafting at distal sites with poor runoff.

Acknowledgments
The authors thank the MASSDAC team, and especially Dr Sharon-Lise T. Normand, Robert E. Wolf, Ann Lovett, and Katya Zelevinsky, for kindly providing the data and initial advice.

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Disclosures
None.

References
CLINICAL PERSPECTIVE

Although several clinical studies have reported worse outcomes for patients undergoing coronary artery bypass grafting (CABG) after percutaneous coronary intervention (PCI) associated with acute complications, few studies have assessed outcomes after CABG procedures after initially successful and uneventful PCI. Moreover, no study has explicitly excluded primary PCI for acute myocardial infarction before CABG, where patients are more likely to be treated solely for their culprit lesion, with resultant incomplete revascularization. In this study, we sought to describe patient characteristics and outcomes of real world patients who underwent primary isolated CABG after remote (>14 days) PCI and contrast them to CABG patients with no prior PCI. In subsequent analyses, we also explored the results of CABG patients after recent (<14 days) PCI. We demonstrate that in patients undergoing CABG, remote prior PCI (>14 days) was not associated with adverse outcomes at 30 days or during long-term follow-up. Hospital morbidity was increased for CABG patients with recent prior PCI (<14 days), but there was no difference in early or long-term survival compared with matched patients without prior PCI. Prospective follow-up of CABG patients with prior PCI is warranted, as their later survival may be affected by the decreased use of the left internal thoracic artery and coronary grafting at distal sites with poor runoff.
Coronary Artery Bypass Grafting After Recent or Remote Percutaneous Coronary Intervention in the Commonwealth of Massachusetts
Louis-Mathieu Stevens, Paul Khairy and Arvind K. Agnihotri

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Supplemental Methods

Prior to obtaining data, the following covariates were identified and later used in the propensity score: age (<65 years, 65-74 years, >74 years), female gender, body surface area (<1.86 m², 1.86-2.05 m², >2.05 m²), diabetes, hypertension, dyslipidemia, peripheral vascular disease, left ventricular ejection fraction (<30%, 30-39%, >39%), renal failure (none, with dialysis, without dialysis), chronic lung disease, current smoking, arrhythmia, status of surgery (elective, urgent, emergent/salvage), cardiogenic shock, preoperative intra-aortic balloon pump need, left main disease, number of diseased vessels, primary health insurance (private-HMO, Medicare, welfare/Medicaid, uninsured, missing), and year of CABG surgery (Table 1). Angina and prior myocardial infarction were not used in the propensity score since they could have been a consequence of the PCI.
## Supplemental Table 1. Independent Predictors of Long-Term Mortality*

<table>
<thead>
<tr>
<th></th>
<th>Hazard Ratio [95% CI]</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td>&lt; .001</td>
</tr>
<tr>
<td>&lt; 65 y</td>
<td>0.63 [0.53-0.74]</td>
<td></td>
</tr>
<tr>
<td>65-74 y (ref.)</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>&gt; 74 y</td>
<td>1.63 [1.45-1.84]</td>
<td></td>
</tr>
<tr>
<td><strong>Sex (female)</strong></td>
<td>1.15 [1.03-1.29]</td>
<td>0.013</td>
</tr>
<tr>
<td><strong>Diabetes</strong></td>
<td>1.40 [1.25-1.55]</td>
<td>&lt; .001</td>
</tr>
<tr>
<td><strong>Hypertension</strong></td>
<td>1.20 [1.03-1.40]</td>
<td>0.017</td>
</tr>
<tr>
<td><strong>Dyslipidemia</strong></td>
<td>0.80 [0.71-0.90]</td>
<td>&lt; .001</td>
</tr>
<tr>
<td><strong>NYHA Functional Class III-IV</strong></td>
<td>1.31 [1.14-1.50]</td>
<td>&lt; .001</td>
</tr>
<tr>
<td><strong>Left ventricular ejection fraction</strong></td>
<td></td>
<td>&lt; .001</td>
</tr>
<tr>
<td>&lt; 30%</td>
<td>2.04 [1.76-2.37]</td>
<td></td>
</tr>
<tr>
<td>30%-39%</td>
<td>1.34 [1.16-1.55]</td>
<td></td>
</tr>
<tr>
<td>&gt; 39% (ref.)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>Arrhythmia</strong></td>
<td>1.41 [1.22-1.62]</td>
<td>&lt; .001</td>
</tr>
<tr>
<td><strong>Cerebrovascular disease</strong></td>
<td>1.39 [1.22-1.58]</td>
<td>&lt; .001</td>
</tr>
<tr>
<td><strong>Peripheral vascular disease</strong></td>
<td>1.64 [1.46-1.84]</td>
<td>&lt; .001</td>
</tr>
<tr>
<td><strong>Renal failure</strong></td>
<td></td>
<td>&lt; .001</td>
</tr>
<tr>
<td>With dialysis</td>
<td>5.06 [3.98-6.43]</td>
<td></td>
</tr>
<tr>
<td>Without dialysis</td>
<td>2.35 [2.02-2.74]</td>
<td></td>
</tr>
<tr>
<td>None (ref.)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>Chronic lung disease,</strong></td>
<td>1.81 [1.59-2.05]</td>
<td>&lt; .001</td>
</tr>
<tr>
<td><strong>Cardiogenic shock,</strong></td>
<td>1.54 [1.14-2.10]</td>
<td>0.005</td>
</tr>
<tr>
<td><strong>Left main stenosis (≥ 50%)</strong></td>
<td>1.13 [1.02-1.26]</td>
<td>0.023</td>
</tr>
<tr>
<td><strong>Health Insurance</strong></td>
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<td>0.030</td>
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<tr>
<td>Private-HMO (ref.)</td>
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</tr>
<tr>
<td>Medicare</td>
<td>1.17 [1.03-1.33]</td>
<td></td>
</tr>
<tr>
<td>Welfare/Medicaid</td>
<td>1.36 [0.99-1.89]</td>
<td></td>
</tr>
<tr>
<td>Uninsured</td>
<td>0.70 [0.40-1.23]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hazard Ratio [95% CI]</td>
<td>P</td>
</tr>
<tr>
<td>------------------------------------</td>
<td>-----------------------</td>
<td>-----</td>
</tr>
<tr>
<td>Internal thoracic artery graft(s) used</td>
<td>0.63 [0.52-0.75]</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Radial artery graft(s) used</td>
<td>0.57 [0.46-0.71]</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Remote Prior PCI (≥14 days)</td>
<td>0.93 [0.76-1.15]</td>
<td>0.517</td>
</tr>
</tbody>
</table>

*Hazard ratio and p-value obtained from stratified proportional hazard multivariable model.

Missing data were handled by dummy coding for multicategory covariates (hazard ratios for dummy variables are not shown – 4% missing data for left ventricular ejection fraction and 1% missing data for primary health insurance).
## Supplemental Table 2. Patient Characteristics in CABG Patients With Recent Prior PCI (<14 days) or With No Prior PCI

<table>
<thead>
<tr>
<th></th>
<th>All CABG patients</th>
<th>CABG patients matched 1:3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Prior-PCI (n=294)</td>
<td>No-PCI (n=8819)</td>
</tr>
<tr>
<td>Age, y</td>
<td>65±11</td>
<td>67±11</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• &lt; 65</td>
<td>140 (48%)</td>
<td>3324 (38%)</td>
</tr>
<tr>
<td></td>
<td>123 (47%)</td>
<td>345 (44%)</td>
</tr>
<tr>
<td>• 65-74</td>
<td>87 (30%)</td>
<td>2939 (33%)</td>
</tr>
<tr>
<td></td>
<td>75 (29%)</td>
<td>252 (32%)</td>
</tr>
<tr>
<td>• &gt; 74</td>
<td>67 (23%)</td>
<td>2556 (29%)</td>
</tr>
<tr>
<td></td>
<td>62 (24%)</td>
<td>183 (23%)</td>
</tr>
<tr>
<td>Sex (female), n(%)</td>
<td>93 (32%)</td>
<td>2305 (26%)</td>
</tr>
<tr>
<td></td>
<td>98 (30%)</td>
<td>203 (26%)</td>
</tr>
<tr>
<td>Race/ethnicity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Non-hispanic white, n(%)</td>
<td>268 (91%)</td>
<td>8037 (91%)</td>
</tr>
<tr>
<td></td>
<td>236 (91%)</td>
<td>712 (91%)</td>
</tr>
<tr>
<td>• Non-hispanic black, n(%)</td>
<td>4 (1%)</td>
<td>172 (2%)</td>
</tr>
<tr>
<td></td>
<td>4 (2%)</td>
<td>14 (2%)</td>
</tr>
<tr>
<td>• Hispanic, n(%)</td>
<td>12 (4%)</td>
<td>272 (3%)</td>
</tr>
<tr>
<td></td>
<td>12 (5%)</td>
<td>29 (4%)</td>
</tr>
<tr>
<td>• Other, n(%)</td>
<td>10 (3%)</td>
<td>338 (4%)</td>
</tr>
<tr>
<td></td>
<td>8 (3%)</td>
<td>25 (3%)</td>
</tr>
<tr>
<td>Diabetes, n(%)</td>
<td>103 (35%)</td>
<td>3297 (37%)</td>
</tr>
<tr>
<td></td>
<td>97 (37%)</td>
<td>256 (33%)</td>
</tr>
<tr>
<td>Hypertension, n(%)</td>
<td>236 (80%)</td>
<td>6981 (79%)</td>
</tr>
<tr>
<td></td>
<td>212 (82%)</td>
<td>625 (80%)</td>
</tr>
<tr>
<td>Dyslipidemia, n(%)</td>
<td>243 (83%)</td>
<td>6937 (79%)</td>
</tr>
<tr>
<td></td>
<td>213 (82%)</td>
<td>653 (84%)</td>
</tr>
<tr>
<td>Body surface area, m²</td>
<td>1.9±0.2</td>
<td>2.0±0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• &lt; 1.86 m², n(%)</td>
<td>111 (38%)</td>
<td>2979 (34%)</td>
</tr>
<tr>
<td></td>
<td>95 (37%)</td>
<td>280 (36%)</td>
</tr>
<tr>
<td>• 1.86-2.05 m², n(%)</td>
<td>96 (33%)</td>
<td>3004 (34%)</td>
</tr>
<tr>
<td></td>
<td>84 (32%)</td>
<td>277 (36%)</td>
</tr>
<tr>
<td>• &gt; 2.05 m², n(%)</td>
<td>87 (29%)</td>
<td>2836 (32%)</td>
</tr>
<tr>
<td></td>
<td>81 (31%)</td>
<td>223 (29%)</td>
</tr>
<tr>
<td>Condition</td>
<td>All CABG patients</td>
<td>CABG patients matched 1:3</td>
</tr>
<tr>
<td>---------------------------------------</td>
<td>-------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td></td>
<td>Prior-PCI (n=294)</td>
<td>No-PCI (n=8819)</td>
</tr>
<tr>
<td>Angina, n(%)</td>
<td>269 (91%)</td>
<td>7664 (87%)</td>
</tr>
<tr>
<td>Prior myocardial infarction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• None, n(%)</td>
<td>106 (36%)</td>
<td>4641 (53%)</td>
</tr>
<tr>
<td>• ≤ 24 hours prior to CABG, n(%)</td>
<td>35 (12%)</td>
<td>261 (3%)</td>
</tr>
<tr>
<td>• &gt; 24 hours prior to CABG, n(%)</td>
<td>153 (52%)</td>
<td>3917 (44%)</td>
</tr>
<tr>
<td>NYHA Functional Class III-IV, n(%)</td>
<td>208 (71%)</td>
<td>5906 (67%)</td>
</tr>
<tr>
<td>Left ventricular ejection fraction, %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• &lt; 30%, n(%)</td>
<td>19 (6%)</td>
<td>749 (8%)</td>
</tr>
<tr>
<td>• 30%-39%, n(%)</td>
<td>32 (11%)</td>
<td>1025 (12%)</td>
</tr>
<tr>
<td>• &gt; 39%, n(%)</td>
<td>271 (74%)</td>
<td>6664 (76%)</td>
</tr>
<tr>
<td>• Missing, n(%)</td>
<td>26 (9%)</td>
<td>381 (4%)</td>
</tr>
<tr>
<td>Arrhythmia*, n(%)</td>
<td>28 (10%)</td>
<td>843 (10%)</td>
</tr>
<tr>
<td>Peripheral vascular disease, n(%)</td>
<td>54 (18%)</td>
<td>1574 (18%)</td>
</tr>
<tr>
<td>Renal failure, n(%)</td>
<td>18 (6%)</td>
<td>586 (7%)</td>
</tr>
<tr>
<td>Dialysis, n(%)</td>
<td>8 (3%)</td>
<td>108 (1%)</td>
</tr>
<tr>
<td>Chronic lung disease, n(%)</td>
<td>38 (13%)</td>
<td>1159 (13%)</td>
</tr>
<tr>
<td>Current smoker, n(%)</td>
<td>61 (21%)</td>
<td>1495 (17%)</td>
</tr>
</tbody>
</table>
### Status of surgery

<table>
<thead>
<tr>
<th>Status</th>
<th>Prior-PCI (n=294)</th>
<th>No-PCI (n=8819)</th>
<th>SD</th>
<th>Prior-PCI (n=260)</th>
<th>No-PCI (n=780)</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elective, n(%)</td>
<td>48 (16%)</td>
<td>2833 (32%)</td>
<td>-37.5</td>
<td>48 (18%)</td>
<td>141 (18%)</td>
<td>1.0</td>
</tr>
<tr>
<td>Urgent, n(%)</td>
<td>183 (62%)</td>
<td>5730 (65%)</td>
<td>-5.7</td>
<td>182 (70%)</td>
<td>543 (70%)</td>
<td>0.8</td>
</tr>
<tr>
<td>Emergent/salvage, n(%)</td>
<td>63 (21%)</td>
<td>256 (3%)</td>
<td>59.1</td>
<td>30 (12%)</td>
<td>96 (12%)</td>
<td>-2.4</td>
</tr>
<tr>
<td>Cardiogenic shock, n(%)</td>
<td>30 (10%)</td>
<td>118 (1%)</td>
<td>38.7</td>
<td>14 (5%)</td>
<td>42 (5%)</td>
<td>0</td>
</tr>
<tr>
<td>Preoperative intra-aortic balloon pump need, n(%)</td>
<td>97 (33%)</td>
<td>902 (10%)</td>
<td>57.6</td>
<td>71 (27%)</td>
<td>202 (26%)</td>
<td>3.2</td>
</tr>
<tr>
<td>Left main stenosis ((\geq 50%))</td>
<td>71 (24%)</td>
<td>3132 (36%)</td>
<td>-25.0</td>
<td>69 (27%)</td>
<td>227 (29%)</td>
<td>-5.7</td>
</tr>
<tr>
<td>Number of diseased vessels, n</td>
<td>2.5±0.7</td>
<td>2.8±0.5</td>
<td>2.6±0.6</td>
<td>2.5±0.7</td>
<td>2.8±0.5</td>
<td>2.6±0.6</td>
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<tr>
<td>One, n(%)</td>
<td>30 (10%)</td>
<td>260 (3%)</td>
<td>29.6</td>
<td>17 (7%)</td>
<td>73 (9%)</td>
<td>-10.4</td>
</tr>
<tr>
<td>Two, n(%)</td>
<td>88 (30%)</td>
<td>1534 (17%)</td>
<td>29.8</td>
<td>75 (29%)</td>
<td>227 (29%)</td>
<td>-0.6</td>
</tr>
<tr>
<td>Three, n(%)</td>
<td>176 (60%)</td>
<td>7025 (80%)</td>
<td>-44.1</td>
<td>168 (65%)</td>
<td>480 (62%)</td>
<td>6.4</td>
</tr>
<tr>
<td>Year of surgery</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2002, n(%)</td>
<td>88 (30%)</td>
<td>3108 (35%)</td>
<td>-11.3</td>
<td>73 (28%)</td>
<td>232 (30%)</td>
<td>-3.7</td>
</tr>
<tr>
<td>2003, n(%)</td>
<td>100 (34%)</td>
<td>3008 (34%)</td>
<td>-0.2</td>
<td>90 (35%)</td>
<td>270 (35%)</td>
<td>0</td>
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<tr>
<td>2004, n(%)</td>
<td>106 (36%)</td>
<td>2703 (31%)</td>
<td>11.5</td>
<td>97 (37%)</td>
<td>278 (36%)</td>
<td>3.5</td>
</tr>
</tbody>
</table>
All CABG patients
CABG patients matched 1:3

<table>
<thead>
<tr>
<th></th>
<th>Prior-PCI (n=294)</th>
<th>No-PCI (n=8819)</th>
<th>SD</th>
<th>Prior-PCI (n=260)</th>
<th>No-PCI (n=780)</th>
<th>SD</th>
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</thead>
<tbody>
<tr>
<td><strong>Primary health insurance</strong></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Private-HMO, n(%)</td>
<td>158 (54%)</td>
<td>4161 (47%)</td>
<td>13.1</td>
<td>139 (53%)</td>
<td>406 (52%)</td>
<td>2.8</td>
</tr>
<tr>
<td>Medicare, n(%)</td>
<td>126 (43%)</td>
<td>4117 (47%)</td>
<td>-7.7</td>
<td>112 (43%)</td>
<td>343 (44%)</td>
<td>-1.8</td>
</tr>
<tr>
<td>Welfare/Medicaid, n(%)</td>
<td>4 (1%)</td>
<td>234 (3%)</td>
<td>-9.2</td>
<td>4 (2%)</td>
<td>7 (1%)</td>
<td>5.8</td>
</tr>
<tr>
<td>Uninsured, n(%)</td>
<td>4 (1%)</td>
<td>204 (2%)</td>
<td>-7.1</td>
<td>4 (2%)</td>
<td>13 (2%)</td>
<td>-1.0</td>
</tr>
</tbody>
</table>

* Arrhythmia: atrial fibrillation, heart block, cardiac arrest. SD: Standardized Difference.