Comparing Long-Term Survival of Patients With Multivessel Coronary Disease After CABG or PCI
Analysis of BARI-Like Patients in Northern New England

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Background—Randomized trials comparing coronary artery bypass graft surgery (CABG) with percutaneous coronary interventions (PCIs) for patients with multivessel coronary disease (MVD) report similar long-term survival for CABG and PCI. These studies used a highly selected population of patients and providers, and their results may not be generalizable to actual care. Our goal in this study was to compare long-term survival of MVD patients treated with CABG vs PCI in contemporary practice.

Methods and Results—From our northern New England registries of consecutive coronary revascularizations, we identified 10,198 CABG and 4295 PCI patients with MVD who may have been eligible for either procedure between 1994 and 2001. Vital status was obtained by linkage to the National Death Index. Proportional-hazards regression was used to calculate hazard ratios (HRs) for survival in CABG vs PCI patients after adjustment for comorbidities and disease characteristics. CABG patients were older; had more comorbidities, more 3-vessel disease, and lower ejection fractions; and were more completely revascularized. Adjusted long-term survival for patients with 3-vessel disease was better after CABG than PCI (HR, 0.60; \( P < 0.01 \)) but not for patients with 2-vessel disease (HR, 0.98; \( P = 0.77 \)). The survival advantage of CABG for 3-vessel disease patients was present in all patient populations, including women, diabetics, and the elderly and in the era of high stent utilization.

Conclusions—In contemporary practice, survival for patients with 3-vessel coronary disease is better after CABG than PCI, an observation that patients and physicians should carefully consider when deciding on a revascularization strategy.

Key Words: angioplasty, bypass, prognosis, revascularization, survival

Percutaneous coronary intervention (PCI) as an alternative to coronary artery bypass graft surgery (CABG) for revascularization of patients with multivessel coronary artery disease (CAD) has become an increasingly attractive option as the technology has advanced, the risk of complications has declined, and the success rate has improved. The downside of choosing PCI is the increased symptom-driven need for subsequent revascularization, and even this problem, with the advent of stents, has become less of a concern. Support for PCI in this patient population has always presupposed that long-term survival is comparable to that of CABG (except for diabetics), an assumption supported by a series of randomized trials. Those trials enrolled a select patient population, treated by select physicians, and at select institutions, and as would be expected in a clinical trial, patients were routinely seen in follow-up at regular intervals. Therefore, it is reasonable to consider whether the results of the rather idealized treatment in these trials can be generalized to everyday practice and support the fundamental premise that in an appropriate patient population, PCI and CABG result in similar survival.

Methods

The patient cohort used for this study was drawn from the PCI and CABG registries of the Northern New England Cardiovascular Disease Study Group, a voluntary research consortium composed of...
clinicians, research scientists, and hospital administrators at institutions in Maine, New Hampshire, and Vermont who are the sole providers of coronary revascularization in the region, and 1 Boston-based institution. The intent of this group is to foster continuous improvement in the quality of care of patients with cardiovascular disease in northern New England through the pooling of process and outcome data and its timely feedback to clinicians. As described more fully in prior publications,16,17 hospital-based data on all PCIs and CABGs in the region are prospectively collected and periodically validated. These data include patient demographics, comorbidities, past cardiac history, cardiac anatomy and function, procedural indication and priority, procedural details, and outcomes.

The study cohort was selected according to criteria similar to those of the Bypass Angioplasty Revascularization Investigation (BARI).4 Patients included were <80 old with 2- or 3-vessel CAD (≥70% stenosis), with no left main stenosis >50% or history of prior revascularization, who were not being treated within 24 hours of a myocardial infarction (MI), and who were not undergoing an emergent procedure.

Survival data were obtained by linkage to the National Death Index (NDI)18 by using a probabilistic match of some combination of name, social security number, date of birth, sex, date last known alive, and state of last known residence. The accuracy of the NDI is between 92% and 99%, depending on which patient identifiers are available.19,20

Comparisons of means and proportions were performed with standard statistical techniques. Crude survival was plotted according to the nonparametric Kaplan-Meier method. Cox proportional-hazards regression21 was used to determine the adjusted hazard ratio (HR) for survival in CABG vs PCI patients, with HR <1 indicating better survival for the CABG population and vice versa for PCI. We adjusted for the following patient characteristics: age, sex, diabetes mellitus, peripheral vascular disease, obstructive pulmonary disease, renal failure requiring dialysis or renal insufficiency (creatinine >2 mg/dL), cancer, congestive heart failure, history of an MI, ejection fraction, and, when appropriate, the presence of 3-vessel CAD. STATA statistical software22 was used for the analysis.

Between January 1, 1994, and December 31, 2001, we were able to identify 14,493 patients meeting the study criteria, of whom 10,198 (70.4%) underwent CABG and 4,295 (29.6%) underwent PCI. Survival data from the NDI were available through December 31, 2001, for this cohort. Among these patients, there were a total of 52,352 person-years of follow-up, with a mean follow-up of 3.61 years, and a total of 1,654 deaths.

**Results**

Table 1 shows the characteristics of the PCI and CABG populations. The PCI cohort had a higher percentage of women, whereas the CABG cohort was slightly older and had more patients >70 years old; more patients with diabetes, peripheral vascular disease, diabetes, cancer, and congestive heart failure; a comparable prevalence of obstructive pulmonary disease; and slightly fewer patients with renal failure or insufficiency. The PCI population was more likely to have a history of an MI but less likely to have 3-vessel CAD, more likely to have an ejection fraction <40%, and slightly less likely to require an urgent procedure. During the study period, 64.3% of PCI patients received at least 1 stent, whereas 93.4% of CABG patients had an internal mammary artery used as a bypass conduit. Adjusted in-hospital mortality was 0.51% for PCI and 1.66% for CABG.

Overall, long-term survival was slightly better in the CABG than the PCI cohort, with an adjusted HR of 0.86 (95% confidence interval [CI], 0.77 to 0.97; P<0.01, Figure 1). However, when the analysis was stratified by number of diseased vessels, adjusted survival for patients with 2-vessel CAD (Figure 2a) was comparable for the CABG and PCI cohorts (adjusted HR, 0.98; 95% CI, 0.85 to 1.13; P=0.77) but better after CABG than PCI for patients with 3-vessel CAD (Figure 2b), with a significant adjusted HR of 0.60 (95% CI, 0.48 to 0.74; P<0.01). There was no survival advantage to CABG in patients with 2-vessel CAD when there was a proximal lesion in the left anterior descending coronary artery (adjusted HR, 0.89; 95% CI, 0.60 to 1.31; P=0.546). The survival benefit of CABG over PCI for patients with 3-vessel disease was observed in women and men, across most age groups, in diabetics and nondiabetics, and in patients with a depressed (<40%) or more normal (≥40%) ejection fraction (Table 2).

**Discussion**

In our large, recent (1994–2001), regional experience with coronary revascularization of 14,493 BARI-like patients with multivessel CAD, we found that adjusted long-term survival was better after CABG than PCI. This result was driven by the superior survival after CABG in patients with 3-vessel CAD (Figure 2a) was comparable for the CABG and PCI cohorts (adjusted HR, 0.98; 95% CI, 0.85 to 1.13; P=0.77) but better after CABG than PCI for patients with 3-vessel CAD (Figure 2b), with a significant adjusted HR of 0.60 (95% CI, 0.48 to 0.74; P<0.01). There was no survival advantage to CABG in patients with 2-vessel CAD when there was a proximal lesion in the left anterior descending coronary artery (adjusted HR, 0.89; 95% CI, 0.60 to 1.31; P=0.546). The survival benefit of CABG over PCI for patients with 3-vessel disease was observed in women and men, across most age groups, in diabetics and nondiabetics, and in patients with a depressed (<40%) or more normal (≥40%) ejection fraction (Table 2).


<table>
<thead>
<tr>
<th>Characteristic</th>
<th>PCI</th>
<th>CABG</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex, %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>69.6</td>
<td>73.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Women</td>
<td>30.4</td>
<td>26.7</td>
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<tr>
<td>Age (mean), y</td>
<td>62.2</td>
<td>64.5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>≥70, %</td>
<td>29.8</td>
<td>34.0</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Body surface area mean, m²</td>
<td>1.95</td>
<td>1.96</td>
<td>0.490</td>
</tr>
<tr>
<td>Comorbidities, %</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Diabetes</td>
<td>26.3</td>
<td>34.4</td>
<td>&lt;0.001</td>
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<tr>
<td>Peripheral vascular disease</td>
<td>10.9</td>
<td>18.3</td>
<td>&lt;0.001</td>
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<td>Cancer</td>
<td>1.9</td>
<td>2.7</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>7.9</td>
<td>16.4</td>
<td>&lt;0.001</td>
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<tr>
<td>Obstructive pulmonary disease</td>
<td>9.9</td>
<td>9.0</td>
<td>0.066</td>
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<tr>
<td>Renal failure or creatinine &gt;2 mg/dL</td>
<td>4.8</td>
<td>2.9</td>
<td>&lt;0.001</td>
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<td>Cardiac history, %</td>
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<tr>
<td>Prior MI</td>
<td>48.5</td>
<td>44.7</td>
<td>&lt;0.001</td>
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<td>1–7 days after MI</td>
<td>16.8</td>
<td>11.4</td>
<td>&lt;0.001</td>
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<tr>
<td>Anatomy and function, %</td>
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<tr>
<td>Vessels diseased</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2</td>
<td>86.2</td>
<td>49.6</td>
<td>&lt;0.001</td>
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<tr>
<td>3</td>
<td>13.8</td>
<td>50.4</td>
<td></td>
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<tr>
<td>Ejection fraction &lt;40%</td>
<td>6.0</td>
<td>14.3</td>
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<td>Clinical presentation, %</td>
<td></td>
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<tr>
<td>Priority</td>
<td></td>
<td></td>
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<tr>
<td>Elective</td>
<td>39.8</td>
<td>36.9</td>
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<tr>
<td>Urgent</td>
<td>60.2</td>
<td>63.1</td>
<td></td>
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<tr>
<td>Procedural characteristics, %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥1 Stent</td>
<td>64.3</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>≥1 Internal mammary artery graft</td>
<td>...</td>
<td>93.4</td>
<td>...</td>
</tr>
<tr>
<td>Adjusted in-hospital mortality, %</td>
<td>0.51</td>
<td>1.66</td>
<td>&lt;0.001</td>
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</table>
CAD. Those patients with 2-vessel CAD had comparable survival regardless of how they were revascularized.

There is a general belief in the cardiology community that survival after coronary revascularization is similar for PCI and CABG, and at least in the short-term, this is the case. In a meta-analysis of 9 randomized trials, Hoffman et al reported an insignificant improvement in 3-year survival of 1.3% (P=0.19) for CABG versus PCI. However, when this same meta-analysis examined data from the 4 studies reporting on longer-term survival, it showed a small but significant absolute survival benefit associated with CABG of 2.3% at 5 years and of 3.4% at 8 years. Two of these trials, the Emory Angioplasty versus Surgery Trial (EAST) and BARI, stratified their analysis, as we did, by number of diseased vessels. In EAST, patients with 3-vessel CAD showed a nonsignificant trend toward improved survival with surgery compared with PCI at 8 years (81.6% vs 75.5%; P=0.35) but there was no survival advantage to surgery in patients with 2-vessel CAD. In BARI, there was a strong trend toward improved survival for CABG versus PCI patients with 3-vessel CAD at 7 years (84% vs 79%; P=0.06) but no difference in survival for patients with 2-vessel CAD.

There have been other registry studies comparing long-term survival after CABG and PCI. BARI maintained a registry of patients who were study-eligible but not randomized and reported comparable adjusted survival at 7 years. A province-wide revascularization registry in Alberta, Canada, that included data from 1995 to 1998 suggested there was no difference in 5-year survival between CABG and PCI, although there was a trend toward better CABG survival in patients with 3-vessel CAD and a proximal left anterior descending lesion (adjusted HR, 0.77; P=0.084).

Two institutions have compared long-term survival after revascularization in CABG and PCI. Using data from the Duke Cardiovascular Disease Databank from 1984 to 1990, Mark et al reported better adjusted 5-year survival after CABG than PCI for all patients with 3-vessel disease and those 2-vessel disease patients with a significant lesion in the proximal left anterior descending coronary artery (25% to 60% mortality reduction, depending on the severity of disease). Analysis of a series of 6033 consecutive patients with multivessel CAD revascularized at the Cleveland Clinic between 1995 and 1999 showed significantly better survival after CABG at a median follow-up of 5.2 years, with an adjusted HR of 0.48 (95% CI, 0.38 to 0.59; P<0.001).

The randomized studies reporting on longer-term outcomes predate the availability of stents, and none of the more recent trials comparing PCI plus stenting versus CABG have published results for survival beyond 3 years. Although stent use in our data set was 64.3%, it was low in 1994 to 1995 (2.0% and 10.3%, respectively). When we limited our analysis to 1996 to 2001, when the average stent use increased to 80.8% (range, 52.9% to 94.9%), our results did not change, and survival after CABG remained superior to PCI (adjusted HR, 0.76; 95% CI, 0.65 to 0.88; P<0.001). There have been other important temporal changes in the management of PCI patients that have been associated with improved outcomes, including the increasing use of glycoprotein IIb/IIIa receptor blockers and thienopyridines. Restricting our analysis to the most recent data that still allow for 5 year follow-up, 1996 to 2001, did not change our findings (adjusted HR, 0.74; 95% CI, 0.62 to 0.89; P=0.001).
Why might CABG survival be better than survival after PCI for patients with 3-vessel CAD? One possibility relates to completeness of revascularization. The surgical literature consistently reports an association between completeness of revascularization and survival.32 Surprisingly, the PCI literature tends to report comparable long-term survival regardless of completeness of revascularization but a higher rate of crossover to subsequent CABG during follow-up in those incompletely revascularized.33,34 Appropriate crossover to CABG is more complete. If PCI patients in northern New England are not appropriately crossing over to CABG during follow-up (data we do not yet have), this could explain their poorer survival.

Our study has several limitations. This was not a randomized trial, and choice of treatment was likely influenced by patient characteristics, patient preference, and provider preference. Although we controlled for differences in important patient and disease characteristics related to survival, unmeasured differences in case mix could have biased our results. However, if such data were randomly missed, our results would be biased toward the null hypothesis, and our result would be an underestimate of the true magnitude of the effect. In addition, it is important to keep in mind that much of the published data on long-term outcomes, including those from randomized trials, are consistent with our findings.

Survival after revascularization is multifactorial and relates to more than patients’ physical health and choice of procedure. Factors such as mental health, socioeconomic status, support system, and follow-up care all influence long-term survival, and this is information we do not have. As mentioned earlier, of particular interest would be the details of follow-up care, because other studies have suggested that reason completeness of revascularization for PCI is unrelated to long-term survival is the crossover to CABG. The influence of follow-up care on survival is also important because the details of such care can potentially be modified.

The practice of PCI has evolved during the last decade, with the ever-increasing use of coronary stents and other technology and new insights into the role of adjunctive medical therapy. In northern New England, these changing practices have improved hospital outcomes.1 It remains to be seen whether new technology and techniques will improve long-term survival after PCI. In our cohort, limiting the analysis to 1996 to 2001, when >80% of patients received at least 1 stent, did not eliminate the survival advantage associated with surgical revascularization. This might be expected if the incomplete revascularization associated with PCI is a function of anatomy (eg, total occlusions) that might not be amenable to percutaneous revascularization. We do not have a sufficiently detailed description of the coronary anatomy of the 10.4% of revascularized patients with 3-vessel CAD who underwent PCI to know what impact evolving practices might have on long-term outcomes.

The Stent or Surgery Trial32 reported a higher 1-year mortality for PCI than CABG. Because they were able to assess cause of death, they could attribute the increased PCI mortality to an unexpectedly large number of cancer deaths. Unlike that study, we have information only on total mortality and cannot comment on whether cardiac-specific mortality is better after CABG than PCI. However, it is unlikely such a chance event would explain our findings as well as those of all other studies with similar results.

The choice of CABG versus PCI is a complicated decision and requires understanding the details of a person’s coronary anatomy, what type of revascularization can be accomplished with each procedure, estimates of the increased short-term
mortality and morbidity of surgery that are patient-specific and account for comorbidities and severity of illness, patient-specific estimates of long-term survival, and other outcomes such as repeated revascularization. This information must then be considered in the context of a patient’s preference for trading off the up-front risks and benefits of CABG versus PCI against the long-term risks and benefits of these procedures. Sometimes the details of a patient’s anatomy or other medical conditions make the decision relatively straightforward. More often, the decision making is difficult, because patients and physicians try to weigh small differences in short-term risks and benefits against small differences in long-term risks and benefits. Although we had access to some of this information, some of it was unavailable, and we cannot comment on what actually finalized the choice of revascularization procedure.

In northern New England, survival for patients with 2-vessel CAD is comparable for CABG and PCI, whereas survival for patients with 3-vessel disease is better after CABG. Although the majority of patients with 3-vessel CAD undergo surgical revascularization, a substantial number of patients undergo PCI. Our data should help to better inform patients and physicians in their choice of procedure.

References


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