Comparative Survival of Dialysis Patients in the United States After Coronary Angioplasty, Coronary Artery Stenting, and Coronary Artery Bypass Surgery and Impact of Diabetes

Charles A. Herzog, MD; Jennie Z. Ma, PhD; Allan J. Collins, MD

Background—The optimal method of coronary revascularization in dialysis patients is controversial. The purpose of this study was to compare the long-term survival of dialysis patients in the United States after PTCA, coronary stenting, or CABG.

Methods and Results—Dialysis patients hospitalized from 1995 to 1998 for first coronary revascularization procedures after renal replacement therapy initiation were identified from the US Renal Data System database. All-cause and cardiac survival was estimated by the life-table method and compared by the log-rank test. The impact of independent predictors on survival was examined in a Cox regression model. The in-hospital mortality was 8.6% for 6668 CABG patients, 6.4% for 4836 PTCA patients, and 4.1% for 4280 stent patients. The 2-year all-cause survival (mean±SEM) was 56.4±1.4% for CABG patients, 48.2±1.5% for PTCA patients, and 48.4±2.0% for stent patients (P<0.0001). After comorbidity adjustment, the relative risk (RR) for CABG (versus PTCA) patients was 0.80 (95% CI 0.76 to 0.84, P<0.0001) for all-cause death and 0.72 (95% CI 0.67 to 0.77, P<0.0001) for cardiac death. For stent (versus PTCA) patients, the RR was 0.94 (95% CI 0.88 to 0.99, P=0.03) for all-cause death and 0.92 (95% CI 0.85 to 0.99, P=0.04) for cardiac death. In diabetic (versus PTCA) patients, the RR for CABG surgery was 0.81 (95% CI 0.75 to 0.88, P<0.0001) for all-cause death and 0.71 (95% CI 0.64 to 0.78, P<0.0001) for cardiac death, and the RR for the stent procedure was 0.99 (95% CI 0.91 to 1.08, P=NS) for all-cause death and 0.99 (95% CI 0.89 to 1.11, P=NS) for cardiac death.

Conclusions—in this retrospective study, dialysis patients in the United States had better long-term survival after CABG surgery than after percutaneous coronary intervention. Stent outcomes were relatively worse in diabetic patients. Our data support the need for large clinical registries and prospective trials of surgical and percutaneous coronary revascularization procedures in dialysis patients. (Circulation. 2002;106:2207-2211.)

Key Words: bypass ■ angioplasty ■ stents ■ kidney ■ survival

Dialysis patients are a high-risk group for all-cause death. The death rate for all US dialysis patients from 1996 to 1998 was 231 per 1000 patient-years. The major cause of death in dialysis patients is cardiac disease, accounting for 44% of all-cause mortality, with ≈20% of cardiac deaths attributed to acute myocardial infarction (AMI). Dialysis patients sustaining AMI suffer poor long-term survival. The 2-year mortality for AMI occurring from 1990 to 1995 was 74%.2 The risk of cardiac and all-cause death is considerably higher in older patients and in patients with end-stage renal disease (ESRD) due to diabetic nephropathy. The greatest increase of treated ESRD has occurred in these patient groups. In 2000, there were ≈281 000 dialysis patients in the United States, and current projections forecast ≈520 000 dialysis patients in 2010.1 With increases in the number of older and diabetic ESRD patients, it is likely that the volume of coronary revascularization procedures will expand over time.

Previous studies have suggested more favorable results for patients with ESRD after CABG surgery compared with PTCA, but the optimal method of coronary revascularization remains controversial. Unfavorable outcomes in dialysis patients after PTCA compared with CABG surgery include increased risk of coronary artery restenosis3–11 and increased cardiac events,3,4,10,11 Agirbasli et al12 reported no significant...
difference in 1-year mortality after PTCA versus CABG surgery. Using the US Renal Data System (USRDS) database, we reported that the long-term survival of dialysis patients was more favorable after CABG surgery than after PTCA, with a 2-year survival (mean ± SEM) of 56.9 ± 0.6% after CABG surgery versus 52.9 ± 0.7% after PTCA. Szczech et al have independently confirmed the relative survival advantage of surgical coronary revascularization compared with PTCA in dialysis patients.

Coronary artery stenting is associated with lower rates of restenosis compared with PTCA in the general population and in dialysis patients. Le Feuvre and colleagues reported an increased 1-year cardiac death rate in 27 dialysis patients compared with 250 nondialysis patients receiving coronary stents but similar rates of restenosis after coronary stenting in dialysis patients compared with nonrenal control subjects. Rubenstein et al found that compared with mortality in patients with normal renal function, there was an increased mortality in patients with dialysis-dependent and non–dialysis-dependent renal failure after percutaneous coronary intervention (PCI) performed from 1994 to 1997. Azar compared the outcome of 34 dialysis patients receiving coronary stents in 40 lesions with the outcome of nonrenal control patients with 80 lesions matched for treatment site, diabetic status, lesion length, and reference vessel diameter. At the 9-month follow-up, repeat target lesion revascularization was 35% and mortality was 18% in the ESRD group versus 16% and 2%, respectively, in the control group.

The purpose of the present study was to compare the long-term survival of dialysis patients in the United States after PTCA, coronary artery stenting, or CABG surgery. Using the USRDS database, we analyzed the outcome of 15,784 chronic dialysis patients undergoing revascularization procedures.

Methods
All data were derived from the USRDS, which contains data on 1.2 million patients. Most data sets used by USRDS are provided by the Centers for Medicare and Medicaid Services. Administrative data come from Medicare claims, parts A (hospitalization) and B (physician/provider). The accuracy of these data has been previously validated.

The present study was a retrospective analysis of dialysis patients hospitalized for the first coronary revascularization procedure occurring after initiation of renal replacement therapy. Eligible patients were receiving renal replacement therapy for ≥90 days and were on dialysis for ≥60 days before revascularization. The time frame is from January 1995 to December 1998, with follow-up through June 1999.

Patients were identified from the USRDS by International Classification of Disease codes (ICD-9-CM) for CABG surgery (code 36.1X), PTCA (codes 36.01, 36.02, and 36.05), or coronary artery stenting (code 36.06). Patients receiving both PTCA and stenting were included in the stent group. Patient demographic data included age, sex, race (Hispanic patients were not identified separately), duration of ESRD, and primary renal diagnosis. A total of 300 patients having surgical and percutaneous coronary revascularization procedures on the same admission were excluded after a preliminary survival analysis indicated no difference with their inclusion. An exploratory survival analysis performed on patients identified from part B claims as receiving PTCA or stent compared with the patients identified from part A revealed no difference in outcome.

### Results
Coronary revascularization procedures were identified in 15,784 dialysis patients (6668 CABG surgery, 4836 PTCA, and 4280 stent patients). The mean ± SD follow-up time was 18.3 ± 14.4 months after PTCA (25th to 75th percentile range 5.9 to 28.6 months), 17.6 ± 13.7 months after CABG (25th to 75th percentile range 6.5 to 26.8 months), and 13.3 ± 9.8 months after stent (25th to 75th percentile range 6.2 to 19.1 months). There were 66 PTCA patients, 81 CABG patients, and 47 patients in the stent group lost to follow-up. Table 1 summarizes the demographic data.
In-hospital death was 8.6% for CABG surgery, 6.4% for PTCA, and 4.1% for stent. Table 2 summarizes estimated survival. Despite greater in-hospital death, the 2-year all-cause survival was ≈56% in the CABG surgery group versus 48% in the PTCA and stent groups. Figures 1 and 2 display the life-table survival estimates for all-cause and cardiac death. Although there is an initial early hazard of increased in-hospital mortality for the CABG surgery patients, 6 to 9 months after coronary revascularization, survival curves cross with a more favorable outcome for CABG surgery versus PTCA or stent.

The effects of independent predictors of overall mortality were examined by using the Cox proportional hazards model (Table 3). The most powerful predictors of death were an age of ≥75 years, liver disease, diabetic ESRD, and CHF. Other cardiovascular comorbid conditions (prior myocardial infarction, peripheral vascular disease, cerebrovascular accident/transient ischemic attack, and other cardiac disorders, except for other ASHD) were associated with a 21% to 31% increased risk of death. Surprisingly, other ASHD was associated with a 32% reduced death risk. Race was also a powerful predictor of survival. Compared with white patients, black patients had a 23% decreased death risk. Female sex was associated with a 12% increased death risk. There was a 6% reduction in death risk for stent compared with PTCA (relative risk [RR] 0.94, 95% CI 0.88 to 0.99) versus a 20% reduction in death risk for CABG surgery compared with PTCA (RR 0.80, 95% CI 0.76 to 0.84).

The independent predictors of cardiac death (not shown) and all-cause death were similar. Older age, CHF, other cardiac conditions, and diabetic ESRD were the most powerful predictors of cardiac death. There was an 8% reduction in cardiac death risk for stent compared with PTCA (RR 0.92, 95% CI 0.85 to 0.99) versus a 28% reduction in cardiac death risk for CABG surgery compared with PTCA (RR 0.72, 95% CI 0.67 to 0.77).

To assess the possible effect of advances in PCI on outcome, we compared PTCA and stent outcomes for all-cause death in 1995 to 1996 versus 1997 to 1998. The all-cause death RR for PTCA in 1997 to 1998 versus PTCA in 1995 to 1996 was 1.03 (95% CI 0.95 to 1.12), and the all-cause death RR for stent in 1997 to 1998 versus stent in 1995 to 1996 was 0.93 (95% CI 0.85 to 1.01, P=0.09).

The risk of all-cause and cardiac death by diabetic versus nondiabetic ESRD was also analyzed in a Cox model. Compared with PTCA, the risk of all-cause death was 10% lower for stent (RR 0.90, 95% CI 0.83 to 0.97) and 21% lower for CABG surgery (RR 0.79, 95% CI 0.73 to 0.85) in nondiabetic ESRD. In diabetic ESRD, there was no significant difference in all-cause death risk for stent (RR 0.99, 95% CI 0.91 to 1.08) but a 19% reduction for CABG surgery (RR 0.81, 95% CI 0.75 to 0.88) compared with PTCA. The RR of cardiac death was 13% lower for stent compared with PTCA (RR 0.87, 95% CI 0.78 to 0.96) and 29% lower for CABG surgery compared with PTCA (RR 0.71, 95% CI 0.64 to 0.78) in nondiabetic ESRD. In diabetic ESRD, there was no significant reduction in cardiac death risk for stent (RR 0.99, 95% CI 0.89 to 1.11) but a 27% reduction for CABG surgery (RR 0.73, 95% CI 0.66 to 0.81) compared with PTCA.

**Discussion**

We have previously reported a survival advantage in dialysis patients for CABG surgery compared with PTCA. Although recent data suggest an improvement in the outcome of patients with renal failure in the “new device era,” the estimated survival of dialysis patients in the United States after PCI has not improved over time. In 6887 dialysis patients undergoing PTCA from 1986 to 1995, 2-year survival was 52.9±0.7%. In the present study, 2-year survival was 48.4±2.0% in the stent group and 48.2±1.5% after PTCA. In addition, we found a reduction of ≈20% in
TABLE 3. Cox Model for Prediction of All-Cause Death

<table>
<thead>
<tr>
<th>Factor</th>
<th>RR (95% CI)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45–64</td>
<td>1.24 (1.12–1.37)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>65–74</td>
<td>1.49 (1.34–1.65)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>≥75</td>
<td>1.90 (1.70–2.13)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Female sex</td>
<td>1.12 (1.07–1.17)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Native American</td>
<td>0.99 (0.83–1.18)</td>
<td>0.9005</td>
</tr>
<tr>
<td>Black</td>
<td>0.77 (0.72–0.81)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Other</td>
<td>0.91 (0.81–1.02)</td>
<td>0.1152</td>
</tr>
<tr>
<td>Prior ESRD duration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1–&lt;2 y</td>
<td>1.07 (1.00–1.14)</td>
<td>0.0386</td>
</tr>
<tr>
<td>2–5 y</td>
<td>1.14 (1.07–1.21)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>&gt;5 y</td>
<td>1.11 (1.03–1.20)</td>
<td>0.0078</td>
</tr>
<tr>
<td>ESRD pathogenesis</td>
<td></td>
<td></td>
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<tr>
<td>Diabetes</td>
<td>1.35 (1.27–1.43)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Hypertension</td>
<td>1.18 (1.10–1.25)</td>
<td>&lt;0.0001</td>
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<tr>
<td>Comorbidity</td>
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<tr>
<td>Prior AMI</td>
<td>1.21 (1.15–1.26)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>ASHD (other)</td>
<td>0.68 (0.62–0.75)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>CHF</td>
<td>1.35 (1.29–1.42)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Cardiac (other)</td>
<td>1.31 (1.25–1.38)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Cancer</td>
<td>1.12 (1.04–1.20)</td>
<td>0.0026</td>
</tr>
<tr>
<td>COPD</td>
<td>1.16 (1.10–1.22)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>CVA/TIA</td>
<td>1.25 (1.18–1.32)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>PVD</td>
<td>1.28 (1.23–1.35)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>GI</td>
<td>1.06 (0.99–1.14)</td>
<td>0.1062</td>
</tr>
<tr>
<td>Liver</td>
<td>1.37 (1.14–1.65)</td>
<td>0.0010</td>
</tr>
<tr>
<td>Gall bladder</td>
<td>1.02 (0.91–1.14)</td>
<td>0.7755</td>
</tr>
<tr>
<td>Prior coronary revascularization</td>
<td>1.00 (0.92–1.10)</td>
<td>0.9222</td>
</tr>
<tr>
<td>CABG</td>
<td>0.80 (0.76–0.84)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Stent</td>
<td>0.94 (0.88–0.99)</td>
<td>0.0283</td>
</tr>
</tbody>
</table>

COPD indicates chronic obstructive pulmonary disease; CVA, cerebrovascular accident; TIA, transient ischemic attack; PVD, peripheral vascular disease; and GI, gastrointestinal disease. Reference group was as follows: age <45 y, male, white, prior ESRD duration <1 year, other-cause ESRD, and no comorbidity.

All-cause death risk after CABG surgery in nondiabetic and diabetic ESRD.

However, this relative survival advantage of surgical versus percutaneous revascularization is not present in the first 6 months after coronary revascularization because of the higher early periprocedural mortality associated with surgery. Although the 8.6% in-hospital mortality is lower than earlier reports of 12.9% for 1990 to 199511 and 12.2% for 1992 to 1997,22 the 2-year survival of 56.4±1.4% after surgery in the present study is nearly identical to the 56.9±0.6% reported previously.11 This lack of improvement in long-term survival after all types of coronary revascularization is in part attributable to increasing proportions of high-risk older and diabetic ESRD patients over time.

Diabetic status has an important impact on outcome after PCI. In diabetic patients, there was no difference between stents and PTCA for all-cause or cardiac death risk. However, diabetic patients receiving CABG surgery fared better than those receiving stents or PTCA. In nondiabetic ESRD patients, the results differed. We found that stents were better than PTCA, with a 10% and 13% lower risk of all-cause death and cardiac death, respectively, and that the relative advantage of CABG surgery (21% lower risk versus PTCA) over stents (10% lower risk versus PTCA) decreased for the nondiabetic ESRD group. Our finding of improved survival after CABG surgery compared with PTCA in patients with diabetic ESRD is reminiscent of the Bypass Angioplasty Revascularization Investigation (BARI) study.23,24 The BARI study compared CABG surgery with PTCA, and the findings were similar; specifically, the advantage of CABG surgery over PCI is greater for diabetic patients than it is for nondiabetic patients.

In studies of the nonrenal population, randomized trials comparing CABG surgery and stenting indicate no difference in survival25 or improved survival26 after stenting at the 1-year follow-up, although more repeat coronary revascularization procedures occur after stenting. However, there may be special high-risk patient subsets, including diabetes and ESRD, which derive relative benefit from surgical coronary revascularization.

One paradoxical finding is the relative survival advantage (32% reduction in death risk) present with the comorbid condition of other ASHD. It is possible that the identification and clinical diagnosis of other ASHD (ischemic heart disease, ICD-9-CM codes 411 to 414) is also associated with other medical therapy (eg, β-blockers), which has a favorable impact on long-term survival. We are unable to analyze this finding in greater detail because the USRDS database does not provide detailed information on medication use.

There are several limitations to the present study. The USRDS database provides few clinical data. Potentially important prognostic factors, such as left ventricular ejection fraction, the presence of left main coronary artery disease, overall severity of coronary artery disease, vessel size, and coronary artery lesion characteristics, are not identified in the USRDS database. The present study does not include the potentially important impact of left internal mammary artery grafting on improving outcome after surgical coronary revascularization. The present study also ignores the potential favorable impact of adjunctive pharmacologic agents, such as glycoprotein IIb/IIIa platelet inhibitors, on improving survival after PCI in dialysis patients.

In addition, the survival analysis is based on a retrospective study design, and selection bias for choice of revascularization procedure could have occurred, potentially confounding our findings. Szczech al11 published an analysis of survival outcome in dialysis patients after PTCA and CABG surgery in New York State by using a clinical database, and they found that the survival advantage of CABG surgery compared with PTCA is even greater than we previously reported11; this finding was due, in part, to a higher proportion of patients with high cardiac risk that were treated with surgery.

Our final limitation is that survival analysis was restricted to hospitalized patients undergoing their first coronary revascularization procedure after the initiation of renal replacement therapy, but our data should apply to all dialysis patients undergoing their first revascularization procedure. Although our data on survival after intervention are restricted to dialysis patients, the
survival of patients with non–dialysis-dependent renal failure after PCI may be comparable to that of ESRD patients.\textsuperscript{18,27,28} The rapid advance of coronary interventional techniques will continue to complicate the assessment of comparative outcomes of coronary revascularization procedures in dialysis patients. The nonsignificant trend of mortality reduction (7\%) after newer stents in the present study may reflect the early impact of procedural improvement. Coronary artery brachytherapy\textsuperscript{29–31} and drug-eluting stents\textsuperscript{12} are promising (but currently untested) approaches in this high-risk population.

We encourage future studies to address the issue of “competing death” and restenosis. Because of the increased mortality risk that some patients, especially dialysis patients, have for death after PCI, it is difficult to assess restenosis rates, inasmuch as patients who die shortly after PCI are eliminated from any further evaluation of this outcome. To address the issue of competing death, we would argue that the composite end point of target vessel revascularization or death should be included in the future evaluation of procedural outcomes in dialysis patients.

We conclude that dialysis patients in the United States have improved survival after CABG surgery compared with PTCA or stenting. Although it would be technically challenging, our data support the need for a randomized prospective trial comparing the most promising PCI techniques with CABG surgery. The initial planning of such a trial would include the creation of a clinical outcome registry of candidate techniques (eg, drug-eluting stents) in dialysis patients and, importantly, in the larger population of patients with non–dialysis-dependent renal failure. As a group at particularly high risk for all-cause and cardiac mortality, patients with renal failure potentially may reap the greatest absolute benefit from successful coronary revascularization strategies.

References
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