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# Survival of Patients With Diabetes and Multivessel Coronary Artery Disease After Surgical or Percutaneous Coronary Revascularization: Results of a Large Regional Prospective Study

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**OBJECTIVES** We sought to assess survival among patients with diabetes and multivessel coronary artery disease (MVD) after percutaneous coronary intervention (PCI) and after coronary artery bypass grafting surgery (CABG).

**BACKGROUND** The Bypass Angioplasty Revascularization Investigation (BARI) demonstrated that diabetics with MVD survive longer after initial CABG than after initial PCI. Other randomized trials or observational databases have not conclusively reproduced this result.

**METHODS** A large, regional database was linked to the National Death Index to assess five-year mortality. Of 7,159 consecutive patients with diabetes who underwent coronary revascularization in northern New England during 1992 to 1996, 2,766 (38.6%) were similar to those randomized in the BARI trial. Percutaneous coronary intervention was the initial revascularization strategy in 736 patients and CABG in 2,030. Cox proportional hazards regression was used to calculate risk-adjusted hazard ratios (HR) and 95% confidence intervals (CI 95%).

**RESULTS** Patients who underwent PCI were younger, had higher ejection fractions and less extensive coronary disease. After adjusting for differences in baseline clinical characteristics, patients with diabetes treated with PCI had significantly greater mortality relative to those undergoing CABG (HR = 1.49; CI 95%: 1.02 to 2.17; p = 0.037). Mortality risk tended to increase more among 1,251 patients with 3VD (HR = 2.02; CI 95%: 1.04 to 3.91; p = 0.038) than among 1,515 patients with 2VD (HR = 1.33; CI 95%: 0.84 to 2.1; p = 0.21).

**CONCLUSIONS** In this analysis of a large regional contemporary database of patients with diabetes selected to be similar to those enrolled in the BARI trial, five-year mortality was significantly increased after initial PCI. This supports the BARI conclusion on initial revascularization of patients with diabetes and MVD. (J Am Coll Cardiol 2001;37:1008–15) © 2001 by the American College of Cardiology

Patients with diabetes mellitus have a higher risk of cardiovascular mortality than the general population (1,2). This increase in risk is believed to be related to accelerated coronary atherosclerosis, a higher frequency of complications of coronary disease, including myocardial infarction (MI), as well as a higher likelihood of mortality resulting from those complications (3).

Although only 5% of the population have diabetes; 13% to 25% of the patients undergoing coronary revascularization procedures have diabetes (4–8). Patients with diabetes experience higher perioperative as well as midterm mortality rates compared with nondiabetics undergoing coronary artery bypass grafting (CABG) (9,10). However, patients with diabetes have also been shown to have less favorable long-term survival after percutaneous coronary intervention (PCI) (4,11). Thus, for patients with diabetes requiring

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**Abbreviations and Acronyms**

BARI = Bypass Angioplasty Revascularization Investigation
CABG = coronary artery bypass grafting
CABRI = Coronary Angioplasty versus Bypass Revascularization Investigation
CHF = congestive heart failure
CI 95% = 95% confidence interval
COPD = chronic obstructive pulmonary disease
EAST = Emory Angioplasty versus Surgery Trial
HR = hazard ratio
MAHI = Mid America Heart Institute
MI = myocardial infarction
MVD = multivessel coronary artery disease
NHLBI = National Heart, Lung and Blood Institute
PCI = percutaneous coronary intervention
PTCA = percutaneous transluminal coronary angioplasty
PVD = peripheral vascular disease
RITA = Randomized Intervention Treatment of Angina
2VD = two-vessel coronary artery disease
3VD = three-vessel coronary artery disease

revascularization, the choice of procedure has provoked much controversy.

The Bypass Angioplasty Revascularization Investigation (BARI) trial demonstrated that, for patients with treated diabetes mellitus and multivessel coronary artery disease (MVD) who were candidates for either CABG or PCI, initial CABG was associated with a markedly lower five-year mortality rate relative to initial PCI (19.4% vs. 34.5%, respectively, $p = 0.003$) (6). This result triggered a National Heart, Lung and Blood Institute (NHLBI) clinical alert recommending bypass surgery in this patient group. However, this recommendation has not been fully accepted (12,13) in part because the results of other randomized trials have not been completely consistent with BARI.

Although the Coronary Angioplasty versus Bypass Revascularization Investigation (CABRI) demonstrated greater survival at two years in 122 patients with diabetes undergoing CABG (14), the combined results of the Emory Angioplasty versus Surgery Trial (EAST) (15), CABRI (16) and the Randomized Intervention Treatment of Angina (RITA) trial (17), which included 233 randomized patients with diabetes, demonstrated similar five-year mortalities in the patients treated with PCI (15%) and CABG (12%) (13). Moreover, some have doubted that the BARI result can be generalized to "real world" medical practice because diabetes was not a prespecified subgroup for analysis (18), and the BARI population with diabetes was relatively small and highly selected (6).

The purpose of this analysis was to evaluate revascularization strategies in patients with diabetes treated in our region. A large regional registry of consecutive coronary revascularization procedures was used to identify all patients with diabetes and MVD requiring revascularization and to compare their long-term survival after CABG versus PCI procedures.

## METHODS

**Data collection.** Data were collected by the Northern New England Cardiovascular Diseases Study Group—a voluntary, regional consortium of physicians, allied health professionals, administrators and scientists from the five institutions in Maine, New Hampshire and Vermont, who are the sole providers of CABG and PCI in the region, and one Massachusetts-based hospital, who have banded together to study the process and outcomes of their cardiovascular care. Since 1987 this group has collected data prospectively on all coronary revascularizations in the region. Details of the data collection have previously been described (7,8). Briefly, information was collected in the following categories: demographics, past medical history, primary indication for procedure, priority of procedure, therapy, cardiac anatomy and function, procedural details and outcomes. Demographics included name, date of birth, gender and other unique patient identifiers. Past medical history included information on previous CABG, PCI and MI, the dates of these events, cardiac risk factors and comorbid conditions, including diabetes mellitus documented in the medical record or by patient history, congestive heart failure (CHF), chronic obstructive pulmonary disease (COPD), peripheral vascular disease (PVD) and renal disease requiring dialysis. Priority of the revascularization procedure was classified as nonurgent, urgent and emergent. Priority was assessed by the operator in the following fashion: emergent signified that medical factors relating to the patient's cardiac disease dictated that the procedure be performed within hours to prevent morbidity or death. Urgent signified that medical factors required the patient to stay in the hospital for the procedure before discharge. Nonurgent signified that medical factors indicated the need for the procedure, but the clinical situation allowed discharge from the hospital with readmission at a later date. Cardiac catheterizations were performed at the participating or referring institutions using their own standard methods during the course of regular clinical care. Coronary anatomy was assessed using local standards. Patients were classified into those with two-vessel coronary artery disease (2VD) and those with three-vessel coronary artery disease (3VD) using methods adapted from the NHBLI Coronary Artery Surgery study (19). Data collection methods of the Northern New England Cardiovascular Disease Study Group have been approved by the human subjects committees of each of the participating institutions.

**Patient population.** A total of 7,159 patients with diabetes underwent coronary revascularization procedures at the member institutions of the Northern New England Cardiovascular Disease Study Group between January 1, 1992 and December 31, 1996. This study examined the outcomes of patients within this population with characteristics making

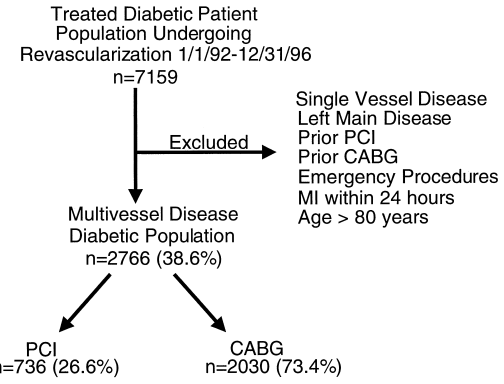


**Figure 1.** A total of 7,159 diabetic patients underwent coronary revascularization procedures between January 1, 1992 and December 31, 1996. Patients were excluded if they: were ≥80 years of age, had less than two-vessel disease, had undergone prior PCI or CABG, had left main disease (≥50% stenosis), had emergency procedures or had experienced an acute MI within 24 h before the procedure. The final study population consisted of 2,766 patients with diabetes and MVD and clinical indications for revascularization. Percutaneous intervention was performed on 736 of these patients, and 2,030 patients underwent CABG procedures. CABG = coronary artery bypass grafting; MI = myocardial infarction; MVD = multivesssel coronary artery disease; PCI = percutaneous coronary intervention.

them similar to patients randomized in the BARI trial (Fig. 1). Patients were excluded if they: were ≥80 years of age, had less than 2VD, had prior revascularization procedures, had left main disease (>50% stenosis), had emergency procedures or had experienced an acute MI within 24 h before the procedure. The final study population consisted of 2,766 patients with diabetes and MVD and clinical indications for revascularization. Percutaneous coronary intervention was performed on 736 of these patients, and 2,030 patients underwent CABG procedures.

**Follow-up.** The outcome measure of the study was all-cause mortality over a five-year interval. Median follow-up among 2,766 patients with diabetes was 1.8 years with 13.1% reaching four-year follow-up. Mortality through December 31, 1996 was determined by a probabilistic match of the regional registry to the National Death Index (US Department of Health and Human Services) (20,21) using some combination of name, social security number, date of birth, gender, date last known alive and state of last known residence. The accuracy of the National Death Index is between 92% and 99%, depending on which identifiers are available (22,23).

**Procedures.** Patients undergoing initial bypass surgery received an average of 3.8 distal anastomoses. Ninety-one percent of patients had an internal mammary graft placed. Among patients undergoing initial PCI, a culprit lesion strategy predominated with intended incomplete revascularization (a greater number of vessels with significant disease than were intervened upon) in at least 74% of patients. Only 14% of PCI patients received stents starting in 1994. Stent procedures accounted for <5% of total patient-years of follow-up. Abciximab was used in only four patients, all in 1996.

**Statistical analysis.** Baseline characteristics were summarized with mean values for continuous variables and percentages for discrete variables. Patients were assigned a treatment variable according to their initial revascularization procedure (either PCI or CABG). Comparisons of characteristics between the PCI and CABG groups were made using the *t* test for continuous variables and the chi-square test for categorical variables. Prior analyses of the CABG and PCI database indicate that the most important comorbid conditions affecting outcome were COPD, renal failure requiring dialysis, PVD and diabetes. Other comorbid conditions including dementia, chronic liver disease/cirrhosis, peptic ulcer disease and cancer either did not importantly influence outcome or occurred too infrequently in the population to have an important effect (24,25). Kaplan-Meier techniques were used to display the survivorship function. A proportional hazard regression model was used to assess the influence of initial procedure on long-term outcome, while adjusting for baseline characteristics. Hazard ratios (HR) and 95% confidence intervals (CI 95%) were calculated. The covariates included age, gender, left ventricular ejection fraction, priority of procedure, presence of renal failure, COPD and PVD. A combined analysis for patients with MVD, adjusted for the proportion of 3VD, was performed. Analyses were also conducted separately for patients with 2VD and 3VD.

A history of prior CHF has been demonstrated to be a predictor of in-hospital mortality among patients undergoing PCI (24) as well as a predictor of 30-day mortality after CABG (25). Reliable collection of this information among northern New England patients undergoing CABG began in 1994 and, therefore, was not available for use in the combined PCI-CABG dataset from 1992 to 1996, upon which this study is based. In order to assess the potential confounding impact of prior CHF on the results, a separate analysis of 1,849 patients undergoing procedures from 1994 to 1996 was performed with CHF included as an adjustment variable.

**Table 1.** Baseline Characteristics of Diabetic Patients

| | PCI n = 736 | CABG n = 2,030 |
|---|---|---|
| Age (mean) | 62.9 | 64.4* |
| Female (%) | 45.2 | 35.7* |
| PVD (%) | 18.1 | 20.7 |
| COPD (%) | 9.8 | 12.5† |
| Renal failure (%) | 4.8 | 3.2 |
| Nonurgent (mean %) | 35.4 | 40.6† |
| Ejection fraction (%) | 52.0 | 50.3† |
| Three-vessel disease (%) | 15.9 | 55.9* |

*$p < 0.001$ and †$p < 0.05$ (PCI compared with CABG).
CABG = coronary artery bypass grafting; COPD = chronic obstructive pulmonary disease; PCI = percutaneous coronary intervention; PVD = peripheral vascular disease.

## RESULTS

**Baseline characteristics.** Clinical, angiographic, hemodynamic and procedural variables for patients with diabetes undergoing initial CABG and PCI are compared in Table

**Table 2.** Crude Five-year Mortality

| | Overall | PCI | CABG |
|---|---|---|---|
| Patient-years of follow-up | 5,659 | 1,593 | 4,066 |
| Number of deaths (total) | 288 | 94 | 194 |
| Death rate per 100 patient-years | 5.1 | 5.9 | 4.8 |

CABG = coronary artery bypass grafting; PCI = percutaneous coronary intervention.

1. Patients with diabetes undergoing PCI procedures were younger and more likely to be women compared with those undergoing CABG. Patients undergoing PCI were less likely to have COPD. There was no statistically significant difference in the proportion having PVD or renal failure. Although PCI procedures were less likely to be nonurgent compared with CABG procedures, PCI patients had better left ventricular function as measured by ejection fraction. The most conspicuous difference between the PCI and CABG treated patients was in the extent of coronary artery disease. Fifty-six percent of CABG treated patients had 3VD compared with 16% of PCI treated patients.

**Adjusted survival outcomes.** During 5,659 patient-years of follow-up, 288 patients in the cohort died, 94 in the PCI group died, and 194 in the bypass surgery group died. Death rates per 100 patient-years were: 5.1 overall, 5.9 for the PCI group and 4.8 for the bypass surgery group (Table 2). Adjusted in-hospital mortality was similar for PCI and bypass surgery patients: 2.1% and 2.6%, respectively. The five-year Kaplan-Meyer survival was examined according to revascularization strategy after adjusting for differences in baseline characteristics (age, gender, ejection fraction, left ventricular end-diastolic pressure, procedural priority and comorbid conditions: COPD on bronchodilator therapy, renal failure on dialysis or PVD). Survival in the two groups was similar through the first three to four months (Fig. 2). Thereafter, the curves separate and remain so throughout the five-year follow-up period. After adjustment, patients with diabetes undergoing initial PCI were 49% more likely to die during follow-up compared with patients undergoing initial bypass surgery (HR = 1.49; CI 95%: 1.02 to 2.17; p = 0.037). When the analysis was repeated on the subgroup of patients undergoing procedures from 1994 to 1996 and CHF was included as an adjustment variable, the results did not change (HR for initial PCI = 1.68; CI 95%: 1.08 to 2.62; p = 0.02).

The five-year adjusted survival for patients with diabetes with 2VD and 3VD revascularized initially with CABG or PCI is shown in Figure 3. Among the 1,251 patients with diabetes and 3VD, mortality risk more than doubled after initial PCI compared with initial surgery, with an HR of 2.02 (CI 95%: 1.04 to 3.91; p = 0.038). Mortality was also higher after PCI among 1,515 patients with diabetes with 2VD with an HR of 1.33 (CI 95%: 0.84 to 2.1; p = 0.2). Although patients with 2VD appeared to benefit less from initial PCI than those with 3VD, there was no statistically significant interaction between the number of diseased vessels and procedure that predicted survival.

## DISCUSSION

This study used a large regional database to compare five-year, all-cause mortality among patients with diabetes

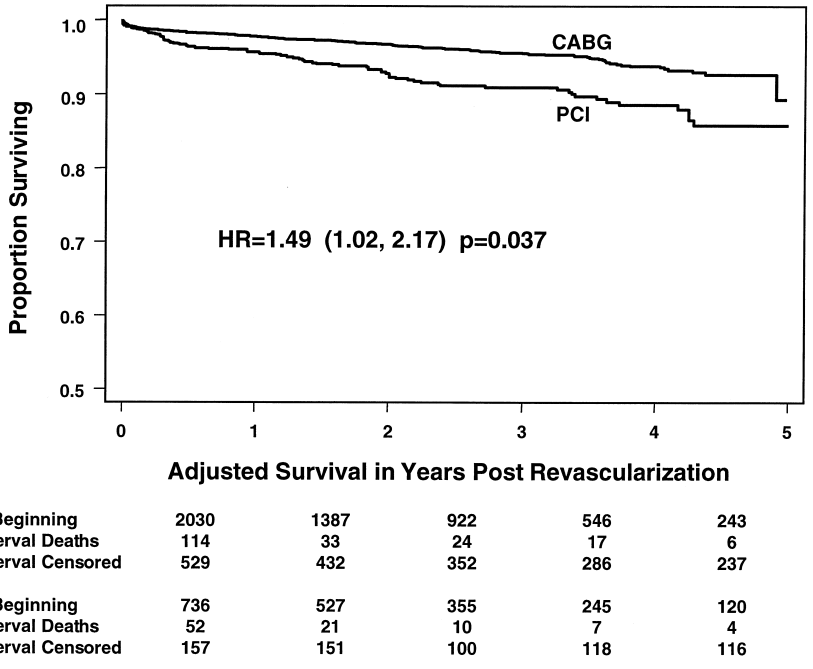


**Figure 2.** Five-year Kaplan-Meyer survival according to revascularization strategy after adjusting for differences in baseline characteristics: age, gender, ejection fraction, left ventricular end-diastolic pressure, procedural priority, comorbid conditions (chronic obstructive pulmonary disease requiring bronchodilator therapy, renal failure on dialysis or peripheral vascular disease) and the proportion of patients with three-vessel disease. CABG = coronary artery bypass grafting; HR = hazard ratio; PCI = percutaneous coronary intervention.

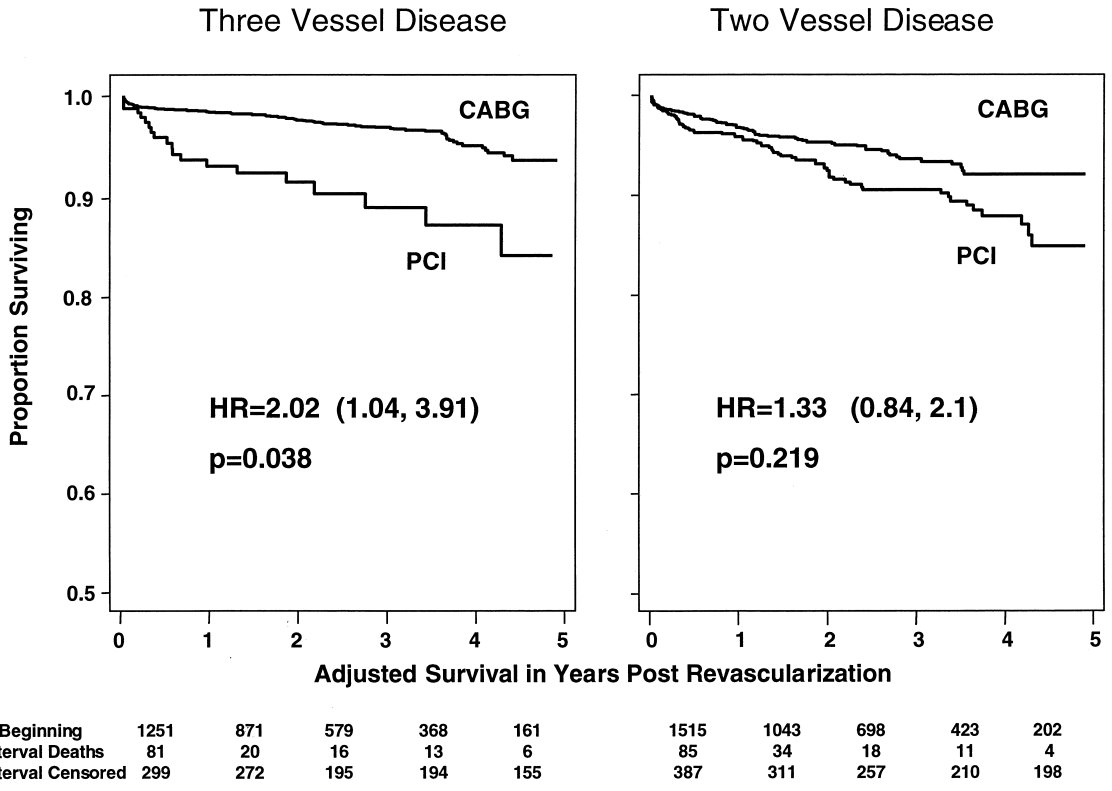


**Figure 3.** Five-year Kaplan-Meyer survival for 1,251 patients with diabetes and three-vessel disease and 1,515 with diabetes and two-vessel disease revascularized initially with CABG or PCI after adjusting for differences in baseline characteristics (age, gender, ejection fraction, left ventricular end-diastolic pressure, procedural priority and comorbid conditions: chronic obstructive pulmonary disease requiring bronchodilator therapy, renal failure on dialysis or peripheral vascular disease). CABG = coronary artery bypass grafting; HR = hazard ratio; PCI = percutaneous coronary intervention.

and MVD undergoing initial PCI or CABG in northern New England. After considering BARI entry requirements, the analysis revealed that patients with diabetes undergoing PCI are younger, more often women, have fewer comorbid conditions, better left ventricular function and significantly less extensive coronary artery disease. After adjustment for these differences in baseline characteristics, initial PCI was associated with a substantially worse five-year survival.

**Comparison with previous studies.** The BARI trial demonstrated that the subgroup of patients with diabetes and MVD had better long-term survival after initial CABG compared with initial PCI (6,26). However, analyses of other randomized trials (14–17) have not uniformly confirmed this result. Disparate findings among randomized trials may relate to differences in patient populations. Such differences may be magnified when the relatively smaller diabetic groups are considered. In the absence of additional prospective randomized trial data, investigators have turned to analyses of diabetic cohorts within large registry databases to confirm the BARI results.

Results from three single-institution databases (Duke [5], Emory [27] and the Mid America Heart Institute [MAHI] [28]), as well as the BARI registry analysis of "randomizable" but "nonrandomized" patients (29), have previously been reported. Hazard ratios (and CI 95%) for PCI treatment compared with CABG among patients with diabetes and MVD estimated from these reports are presented in Figure 4. In all of these studies, patients similar to the population with diabetes in BARI were selected, and multivariate adjustment techniques were used to control for confounding. In the Duke analysis, diabetes was associated with a worse long-term outcome regardless of treatment strategy; however, outcomes for patients with diabetes treated with PCI versus CABG were not significantly different. In the MAHI study, unadjusted survival tended to be better in patients treated with CABG. However, after adjustment for completeness of revascularization, the revascularization method did not influence late mortality. Analysis of all patients with diabetes in the Emory database showed no significant difference in five-year survival among patients with diabetes after PCI or CABG, except in the insulin-requiring patients whose outcomes were significantly improved after CABG. In the BARI registry, adjusted five-year survival among 299 treated patients with diabetes tended to be better after initial CABG; however, this difference did not reach statistical significance. Although none of the single-institution studies nor the BARI registry showed a clear difference in survival for CABG compared with PCI, this study demonstrated a significant improvement in survival with initial CABG with an HR approaching that seen in the BARI randomized trial (Northern New England = 1.49; BARI trial = 1.78). What should not be overlooked, however, is that the direction of

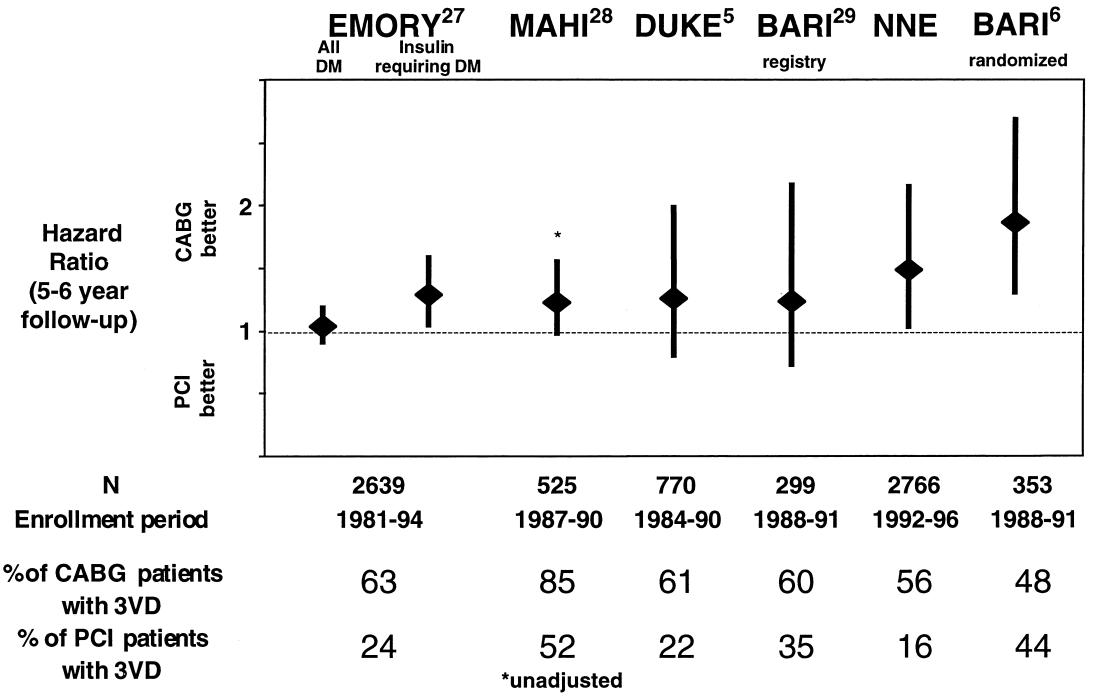


**Figure 4.** Hazard ratios (and 95% confidence intervals) at five- to six-year follow-up for initial PCI compared with CABG among patients with diabetes and multivessel disease estimated from three single-institution database studies, the BARI registry, the current NNE and the BARI randomized trial. All hazard ratios are adjusted except where indicated by asterisks. BARI = Bypass-Angioplasty Revascularization Investigation; CABG = coronary artery bypass grafting; DM = diabetes mellitus; HR = hazard ratio; MAHI = Mid America Heart Institute; NNE = Northern New England database study; PCI = percutaneous coronary intervention; 3VD = three-vessel disease.

the benefit in all studies favors CABG over PCI with overlapping confidence intervals (Fig. 4).

**Severity of coronary disease.** The severity of coronary artery disease may be a particularly important determinant of long-term survival in patients with diabetes depending upon the revascularization approach. It has been suggested that, unlike CABG, long-term outcome after PCI in patients with diabetes is particularly unfavorable when extensive disease is present at the time of the initial procedure (30). Indeed, as shown in the table accompanying Figure 4, when selection of the revascularization procedure is based on physician/patient choice rather than random assignment, there is a strong tendency to refer those with more extensive disease (i.e., 3VD) to CABG. This practice is supported by data from NHLBI Percutaneous Transluminal Coronary Angioplasty (PTCA) Registry (4) as well as the Emory PTCA database (11), which demonstrate more favorable survival after PTCA among patients with relatively less extensive disease. The results of this analysis also lend support to this practice. Among patients with 3VD, the HR was 2.02 favoring CABG, and the survival curves separated early, suggesting that even in the short term PCI does not palliate extensive coronary disease as effectively as bypass surgery. However, among patients with less extensive disease (i.e., 2VD), PCI is nearly as effective as surgery in the short term, and the difference between the five-year survivals does not reach statistical significance.

**Completeness of revascularization.** Long-term survival may also be effected by completeness of revascularization. Others have shown that complete revascularization is accomplished more often with CABG than it is with PCI (27), and, indeed, when incomplete revascularization is accounted for, mode of revascularization does not correlate with late mortality (11). Although in this study completeness of revascularization could not be examined rigorously, the data are consistent with previous reports in that at least 74% of PCI patients were incompletely revascularized, reflecting a predominant strategy of "culprit lesion angioplasty," whereas CABG procedures in this population averaged 3.8 grafts per patient. From a practical standpoint, the goal of this analysis was to compare revascularization approaches in multivessel patients with diabetes as they are practiced in northern New England. To accomplish this, adjustment for completeness of revascularization was not necessary. From a methodological standpoint, it may be futile to attempt to separate the influence of "completeness of revascularization" and "revascularization method" using standard adjustment techniques if, indeed, there is strong covariance between initial PCI and incompleteness of revascularization.

**Study limitations.** This study has several limitations. First, this is an observational study, and it is possible that one or more unmeasured factors exist that effect outcome for which we could not adjust. However, with respect to baseline characteristics that are likely to predict long-term survival after revascularization (age, number of diseased vessels, ejection fraction and comorbid conditions), CABG treated patients were generally sicker than PCI treated patients.

Thus, it is likely that more complete adjustment would tend to further widen the difference between the CABG and PCI survival curves. Second, unlike the BARI trial, there is no certainty that all patients who underwent CABG were also candidates for PCI and vice-versa. In fact, a substantial bias toward CABG in patients with more extensive (3VD) disease was apparent. Although it is possible that some patients were, in fact, determined to be noncandidates for either PCI or CABG, the extent to which such determinations were based on differences in age, gender, left ventricular function or comorbid conditions (PVD, COPD or renal disease) was adjusted for in this analysis and, therefore, should not confound the result. Third, 61% of the population with diabetes was excluded from this analysis. Although these exclusions might appear to limit the generalizability of the findings, in fact, only patients in whom clinical circumstances had an overriding influence on the choice of revascularization approach were excluded. Presumably, in these patients the relative long-term benefits of CABG versus PCI are less relevant. Fourth, we did not collect data on treatment of diabetes, which also appears to be an important determinant of mortality outcome after revascularization. This information is now part of our data collection. Although it is possible that our PCI patients had more severe diabetes, this seems unlikely since they clearly tended to have less severe coronary artery disease.

**Further studies.** While they cannot be examined in these data, there are other areas of investigation which may provide better understanding of the observed effect. For example, more detailed assessment of coronary anatomy and myocardial jeopardy by a core angiographic laboratory could reveal anatomic substrates with less favorable outcomes after PCI. Conversely, postprocedural protocols or patient compliance may result in more successful cardiac risk factor control after CABG. Examination of these issues must await further studies.

Major technical advances in the field of percutaneous coronary revascularization have occurred over the last several years that may be particularly useful in improving outcomes and restenosis rates in patients with diabetes, including coronary stents (31), glycoprotein IIB/IIIA antiplatelet agents (32) and gamma source radiation (33). Although encouraging, proof that these modalities improve survival, or indeed yield outcomes comparable with CABG surgery in patients with diabetes, is lacking. Unfortunately, this study cannot consider the impact of such novel technologies on survival since patients treated with them accounted for <5% of the total patient-years of follow-up. Further studies must clarify this important issue. However, the results of this analysis do support the contention that, for the patient with diabetes and MVD who is a candidate for either method of revascularization, "stand-alone" balloon angioplasty should not be considered an acceptable alternative to CABG.

**Conclusions.** In summary, this large, regional prospective study, which includes data on 2,766 patients with diabetes undergoing their first coronary revascularization procedure, indicates improved survival when CABG is the initial revascularization approach. The analysis supports the recommendation of the initial NHLBI clinical alert that bypass surgery is preferable to coronary angioplasty for the revascularization of patients with diabetes with both 2VD- and 3VD.

### *Addendum*

The participants in the Northern New England Cardiovascular Disease Study Group are listed in a previous publication (34).

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## REFERENCES

1. Kannel WB, McGee DL. Diabetes and cardiovascular disease: the Framingham study. JAMA 1979;241:2035–8.
2. Wingard DL, Barrett-Connor E. Heart disease and diabetes. In: Harris MI, editor. Diabetes in America. 2nd ed. Washington, DC: National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases, 1995:429–48.
3. Jacoby RM, Nesto RW. Acute myocardial infarction in the diabetic patient: pathophysiology, clinical course and prognosis. J Am Coll Cardiol 1992;20:736–44.
4. Kip KE, Faxon DP, Detre KM, Yeh W, Kelsey SF, Currier JW. Coronary angioplasty in diabetic patients: the National Heart, Lung and Blood Institute percutaneous transluminal coronary angioplasty registry. Circulation 1996;94:1818–25.
5. Barsness GW, Peterson ED, Ohman EM, et al. Relationship between diabetes mellitus and long-term survival after coronary bypass and angioplasty. Circulation 1997;96:2551–6.
6. The BARI Investigators. Comparison of coronary bypass surgery with angioplasty in patients with multivessel disease. N Engl J Med 1996;335:217–25.
7. Malenka DJ, O'Connor GT, Quinton H, et al. Differences in outcomes between women and men associated with percutaneous transluminal coronary angioplasty. Circulation 1996;94 Suppl II:II99–104.
8. O'Connor GT, Plume SK, Olmstead EM, et al. Multivariate prediction of in-hospital mortality associated with coronary artery bypass graft surgery. Circulation 1992;85:2110–8.
9. Thourani VH, Weintraub WS, Stein B, Gebhart SS, Craver JM, Jones EL. Influence of diabetes mellitus on early and late outcome after coronary artery bypass grafting. Ann Thorac Surg 1999;67:1045–52.
10. Smith LR, Harrell FE, Jr, Rankin JS, et al. Determinants of early versus late cardiac death in patients undergoing coronary artery bypass graft surgery. Circulation 1991;84 Suppl III:III245–53.
11. Stein B, Weintraub WS, Gebhart SSP, et al. Influence of diabetes mellitus on early and late outcome after percutaneous transluminal coronary angioplasty. Circulation 1995;91:979–89.
12. King SB. Trying to understand BARI. J Am Coll Cardiol 1997;30:1426–7.
13. Ellis SG, Narins CR. Problem of angioplasty in diabetics. Circulation 1997;96:1707–10.
14. Bertrand M. Long-term follow-up of European revascularization trials. Presented at 68th Scientific Sessions, Plenary Session XII, American Heart Association, Anaheim, CA, November 16, 1995.
15. King SB, Lembo NJ, Weintraub WS, et al. A randomized trial comparing coronary angioplasty with coronary bypass surgery. N Engl J Med 1994;331:1044–50.
16. CABRI Trial Participants. First-year results of CABRI (Coronary Angioplasty versus Bypass Revascularization Investigation). Lancet 1995;346:1179–84.

17. Henderson RA, Pocock SJ, Sharp SJ, Nanchahal K, Schulpher MJ, Buxton MJ. Long-term Results of RITA-1 trial: clinical and cost comparison of coronary angioplasty and coronary-artery bypass grafting. Lancet 1998;352:1419–25.
18. The BARI Investigators. Protocol for the Bypass Angioplasty Revascularization Investigation (BARI). Circulation 1991;84 Suppl V:V1–27.
19. The Principal Investigators of CASS and their Associates. The National Heart, Lung and Blood Institute Coronary Artery Surgery Study (CASS). Circulation 1981;63 Suppl I:I1–81.
20. Wentworth DN, Neaton JD, Rasmussen WL. An evaluation of the Social Security Administration master beneficiary record and the national death index in the ascertainment of vital status. Am J Pub Health 1983;73:1270–4.
21. National Death Index Plus: Coded Causes of Death. National Death Index User's Manual. Hyattsville, MD: US Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Center for Health Statistics, 1997.
22. Williams BC, Demitrack LB, Fries BE. The accuracy of the national death index when personal identifiers other than social security number are used. Am J Pub Health 1992;82:1145–7.
23. Rich-Edwards JW, Corsano KA, Stampfer MJ. Test of the national death index and Equifax nationwide death search. Am J Epidemiol 1994;140:1016–9.
24. Block PC, Peterson EC, Krone R, et al. Identification of variables needed to risk adjust outcomes of coronary interventions: evidence-based guidelines for efficient data collection. J Am Coll Cardiol 1998;32:275–82.
25. Jones RH, Hannan EL, Hammermeister KE, et al., for the Working Group Panel on the Cooperative CABG Database Project. Identification of preoperative variables needed for risk adjustment of short-term mortality after coronary artery bypass graft surgery. J Am Coll Cardiol 1996;28:1478–87.
26. The BARI Investigators. Influence of diabetes on five-year mortality and morbidity in a randomized trial comparing CABG and PTCA in patients with multivessel disease: the Bypass Angioplasty Revascularization Investigation (BARI). Circulation 1997;96:1761–9.
27. Weintraub WS, Stein B, Kosinski A, et al. Outcome of coronary bypass surgery versus coronary angioplasty in diabetic patients with multivessel coronary artery disease. J Am Coll Cardiol 1998;31:10–9.
28. Gum PA, O'Keefe JH, Jr, Borkon AM, et al. Bypass surgery versus coronary angioplasty for revascularization of treated diabetic patients. Circulation 1997;96 Suppl II:II7–10.
29. Detre KM, Guo P, Holubkov R, et al. Coronary revascularization in diabetic patients: a comparison of the randomized and observational components of the Bypass Angioplasty Revascularization Investigation (BARI). Circulation 1999;99:633–40.
30. Kuntz RE. Importance of considering atherosclerosis progression when choosing a coronary revascularization strategy: the diabetes-percutaneous transluminal coronary angioplasty dilemma. Circulation 1999;99:847–51.
31. Van Belle E, Bauters C, Hubert E, et al. Restenosis rates in diabetic patients: a comparison of coronary stenting and balloon angioplasty in native coronary vessels. Circulation 1997;96:1454–60.
32. Marso SP, Lincoff AM, Ellis SG, et al. Optimizing the percutaneous interventional outcomes for patients with diabetes mellitus: results of the EPISTENT (Evaluation of Platelet IIb/IIIa Inhibitor for Stenting Trial) diabetic substudy. Circulation 1999;100:2477–84.
33. Teirstein PS, Massullo V, Jani S, et al. Catheter-based radiotherapy to inhibit restenosis after coronary stenting. N Engl J Med 1997;336:1697–703.
34. Malenka DJ, McGrath PD, Wennberg DE, et al., for the Northern New England Cardiovascular Disease Study Group. The relationship between operator volume and outcomes after percutaneous coronary interventions in high volume hospitals in 1994–1996: the Northern New England Experience. J Am Coll Cardiol 1999;34:1471–80.