

# Trends in Coronary Revascularization 1989 to 1997: The Bypass Angioplasty Revascularization Investigation (BARI) Survey of Procedures

Richard Holubkov, PhD, Katherine M. Detre, MD, DrPH, George Sopko, MD, Kim Sutton-Tyrrell, DrPH, Sheryl F. Kelsey, PhD, and Robert L. Frye, MD, for the BARI Investigators

Use of catheter-based and surgical coronary revascularization has steadily increased in North America. Introduction of catheter-based "new devices," including intracoronary stents, has expanded the range of patients who can be treated with percutaneous approaches. We sought to address trends in the practice of catheter-based and surgical coronary revascularization during 1989 to 1997. The 17 North American institutions participating in the NHLBI Bypass Angioplasty Revascularization Investigation (BARI) periodically completed a 5-working day survey of all surgical and catheter-based coronary revascularizations. Data collected included patient demographics, vessel disease, prior interventions, and use of new devices or minimally invasive surgical techniques. The proportion of all procedures that were catheter based (vs surgical) increased from 52.1% in 1989/1990 to 62.0% in 1997 ( $p < 0.001$ ). Among surgically treated patients, prevalence of prior bypass surgery decreased from 13.4% in 1989/1990 to 7.5% in

1997 ( $p < 0.001$ ). In 1997, 3% of surgical procedures used minimal incisions or were performed without cardiopulmonary bypass. Among patients undergoing catheter-based intervention, prevalence of left main disease increased from 2.2% to 5.7% ( $p < 0.001$ ), myocardial infarction within 24 hours increased from 2.4% to 9.7% ( $p < 0.001$ ), and prior bypass surgery increased from 16.2% to 20.8% ( $p = 0.056$ ). Use of new devices increased from 11.6% of catheter-based procedures in 1990 to 67.0% in 1997 ( $p < 0.001$ ). Compared with the early 1990s, catheter-based revascularization is currently more commonly used for patients with acute myocardial infarction, prior bypass surgery, or severe left main narrowing. These trends are likely due to the proliferation of new devices, especially intracoronary stents, since the mid 1990s. ©1999 by Excerpta Medica, Inc.

(Am J Cardiol 1999;84:157-161)

The National Heart, Lung, and Blood Institute (NHLBI) funded Bypass Angioplasty Revascularization Investigation (BARI)<sup>1</sup> is the largest ongoing trial comparing percutaneous transluminal coronary angioplasty (PTCA) and coronary artery bypass graft surgery (CABG). In 1988, BARI began enrolling patients at 17 clinical centers. In late 1989, BARI began a periodic 5-weekday Survey of Procedures to characterize all revascularizations performed at participating institutions. The purpose of the initial surveys was to assess the relevance of BARI in the perspective of all coronary revascularization practice at these institutions, by monitoring the volume of cases at each center, the basic angiographic characteristics of patients, and the proportion of patients subsequently

enrolled in BARI. Although BARI patient recruitment was completed in August 1991, periodic surveys have continued during the BARI follow-up phase. The survey data provide uniform assessment of coronary revascularization at prominent cardiovascular North American institutions over a period of 8 years. This study examines the survey data over this time, pointing out trends in the patient population treated with each revascularization approach, and shifts in the use of catheter-based versus surgical revascularization in various angiographically defined patient subgroups.

## METHODS

**Study population:** The 17 North American clinical centers participating in BARI (listed in Appendix) completed 14 surveys during 5-weekday periods from 1989 to 1997 (Table I). Surveys were performed semi-annually from 1989 to 1993 and annually starting in 1994, with the most recent survey completed in May 1997.

All surgical or catheter-based coronary revascularization procedures were recorded with the single exception of combined surgical procedures that involved aortic and/or mitral valve replacement or resection of ventricular aneurysm. With the exception of planned, staged, catheter-based interventions, multiple interventions on the same patient during a survey week

From the Department of Epidemiology, Graduate School of Public Health, University of Pittsburgh, Pittsburgh, Pennsylvania; Division of Heart and Vascular Diseases, National Heart, Lung, and Blood Institute (NHLBI), National Institutes of Health, Bethesda, Maryland; and Mayo Clinic, Mayo Foundation, Rochester, Minnesota. This work was supported by NHLBI grants HL38493, HL38504, HL38509, HL38512, HL38514-6, HL38518, HL38524-5, HL38529, HL38532, HL38556, HL38610, HL38642, and HL42145. Manuscript received December 15, 1998; revised manuscript received and accepted February 23, 1999.

Address for reprints: Richard Holubkov, PhD, Epidemiology Data Coordinating Center, University of Pittsburgh, 127 Parran Hall, 130 Desoto Street, Pittsburgh, Pennsylvania 15261. E-mail: holubkov@edc.gsph.pitt.edu.

**TABLE I** Characteristics of BARI Surveys of Procedures

Survey	Survey Week	No. of Procedures		
		Catheter Based	Surgical	Total
1	December 4–8, 1989	211	194	405
2	March 12–16, 1990	266	225	491
3	July 9–13, 1990	219	240	459
4	December 10–14, 1990	276	234	510
5	April 15–19, 1991	253	207	460
6	October 7–11, 1991	293	208	501
7	April 27–May 1, 1992	284	202	486
8	November 2–6, 1992	302	228	530
9	May 21–25, 1993	282	219	501
10	December 6–10, 1993	289	216	505
11	June 13–17, 1994	338	228	566
12	January 23–27, 1995	334	243	577
13	February 19–23, 1996	302	202	504
14	May 12–16, 1997	370	227	597

were recorded as separate procedures. For example, a patient receiving PTCA followed by CABG during the same week would have both procedures entered into the survey.

**Data collection:** Interventions were logged daily to ensure completeness of data. Nurse coordinators obtained angiographic and demographic data from catheterization laboratory and surgical records, as well as from other hospital sources.

Patient characteristics collected in all surveys included number of diseased vessels, presence of significant stenosis in the left main coronary artery, and prior CABG or percutaneous intervention. Additional patient characteristics collected included myocardial infarction within 24 hours before procedure (surveys 2 to 14), age and gender (surveys 3 to 14), and race (surveys 4 to 14). Use of “new devices” other than standard balloon angioplasty during percutaneous intervention was collected in surveys 3 to 14. The specific device was not recorded, with the exception of intracoronary stent use collected in surveys 13 and 14. To document the emerging use of new surgical techniques, type of incision (full sternotomy or minimal access) and use of cardiopulmonary bypass were recorded in survey 14.

**Definitions:** Vessel disease was defined as the number of arteries with narrowing  $\geq 50\%$  in diameter. Patients with left dominant circulation and lesions in the proximal trunk of the left circumflex coronary artery were classified as having 2-vessel disease. Significant left main lesions were treated as 3-vessel disease in patients with left dominant circulation and 2-vessel disease in others. Left main disease, recorded separately from vessel disease, was defined as a lesion  $\geq 50\%$  in diameter in the left main artery.

**Statistical analysis:** For clarity of presentation, several surveys were combined into the following categories: 1989 to 1990 (4 surveys), 1991 (2 surveys), 1992 (2 surveys), and 1993 (2 surveys). All percentages reflect a denominator of patients with known information.

For dichotomous variables, statistical significance

of trends over time in proportion was assessed by the Cochran-Armitage test.<sup>2</sup> Significance of time trends with respect to age and vessel disease was assessed using the Jonckheere-Terpstra test.<sup>3</sup> All testing was performed using StaXact 3 (Cytel Software Corporation, version 3.0.1, Cambridge, Massachusetts), with a significance level of 0.05.

## RESULTS

There was an increase over time in total number of procedures performed at BARI centers, primarily due to an increase in the number of catheter-based interventions (Table I).

**Patient characteristics:** Among all patients undergoing revascularization, mean age, gender, and proportion

with significant left main stenosis and with prior CABG remained stable over time (Table II). Relatively small but statistically significant increases occurred over time in the proportion of patients who were nonwhite and who underwent revascularization within 24 hours of myocardial infarction. Although there was a statistically significant time trend with respect to severity of vessel disease, the pattern of change over time with respect to this factor was not consistent. The prevalence of prior PTCA increased in 1991 and remained stable thereafter.

Among patients undergoing surgical intervention, there was a sharp increase during the 1997 survey in the proportion of patients with 3-vessel disease (Table III). The proportion of surgical operations that were repeat surgical interventions decreased markedly over time. Additional information from the 1997 survey shows that 220 of 227 surgical interventions (97%) involved full sternotomy and cardiopulmonary bypass, 3 used full sternotomy without cardiopulmonary bypass, 1 involved a (presumably “less invasive”) incision other than full sternotomy with cardiopulmonary bypass, and 3 used an alternative incision without cardiopulmonary bypass. The 7 “nontraditional” surgical interventions were performed at 5 different centers.

Among patients undergoing catheter-based intervention, the proportion who were nonwhite doubled from 1991 to 1997 (Table IV). Although severity of angiographic disease in these patients did not show a time trend, the proportion of treated patients who had left main disease and prior bypass surgery increased, most notably in 1996 and 1997. In 1997, a higher proportion of patients were treated in the setting of acute myocardial infarction.

The most notable trend was the increased proportion of catheter-based interventions using stents and/or other new devices. In the 1997 survey, this proportion was 67% overall, and ranged from 42% to 100% at the separate BARI clinical centers. Additional information from recent surveys shows that 31% of 1996 catheter-based interventions and 57% of 1997 inter-

Characteristics	Year of Survey							
	1989–1990 (n = 1,865)	1991 (n = 961)	1992 (n = 1,016)	1993 (n = 1,006)	1994 (n = 566)	1995 (n = 577)	1996 (n = 504)	1997 (n = 597)
Mean age (yrs)	61.9	62.2	62.2	62.1	62.2	62.4	61.8	62.8
Women (%)	28.2	28.4	28.7	28.5	28.8	26.9	31.2	30.0
Non-White (%) <sup>†</sup>	—	6.7	7.8	8.0	8.5	10.9	10.9	11.1
No. of coronary arteries narrowed ≥50% in diameter <sup>‡</sup>								
1 (%)	27.9	27.4	25.8	27.4	31.4	27.7	28.0	29.1
2 (%)	27.2	28.1	30.9	30.4	31.1	33.3	30.8	26.8
3 (%)	44.9	44.5	43.3	42.1	37.5	39.0	41.3	44.1
Left main disease (%)	10.2	10.5	11.6	10.9	11.3	11.8	12.1	10.6
Prior PTCA (%) <sup>*</sup>	20.6	23.8	23.5	24.3	25.1	23.2	24.0	24.3
Prior CABG (%)	14.9	15.3	14.8	15.4	12.7	14.4	14.1	15.7
Myocardial infarction within 24 hrs before procedure (%) <sup>†</sup>	2.0	3.6	2.7	3.6	4.6	4.2	4.2	7.0
Catheter-based intervention (%) <sup>†</sup>	52.1	56.8	57.7	56.8	59.7	57.9	59.9	62.0

\*p < 0.05; †p < 0.001 for Cochran-Armitage test of trend; ‡p < 0.05 for trend over time by Jonckheere-Terpstra test.

Characteristics	Year of Survey							
	1989–1990 (n = 893)	1991 (n = 415)	1992 (n = 430)	1993 (n = 435)	1994 (n = 228)	1995 (n = 243)	1996 (n = 202)	1997 (n = 227)
Mean age (yrs)	63.6	62.9	63.6	63.9	64.5	64.9	62.5	63.0
Women (%)	28.2	25.8	24.4	28.3	27.2	23.0	27.7	27.8
Nonwhite (%) <sup>*</sup>	—	8.7	5.3	6.7	9.6	11.5	11.9	10.1
No. of coronary arteries narrowed ≥50% in diameter								
1 (%)	6.0	4.6	4.7	5.5	5.7	2.9	5.9	2.2
2 (%)	25.8	26.0	24.2	25.1	25.0	28.4	26.2	20.3
3 (%)	68.2	69.4	71.2	69.4	69.3	68.7	67.8	77.5
Left main disease (%)	19.0	20.7	21.9	18.9	25.9	21.4	21.8	18.5
Prior PTCA (%)	13.3	14.7	12.3	14.9	17.1	14.0	14.4	17.2
Prior CABG (%) <sup>†</sup>	13.4	14.5	10.7	12.0	8.8	10.3	6.9	7.5
Myocardial infarction within 24 hrs before procedure (%)	1.6	1.7	1.6	2.3	1.8	2.9	2.0	2.6

\*p < 0.05; †p < 0.001 for Cochran-Armitage test of trend.

ventions employed stents, whereas other new devices were used 12% of the time in 1996 and 14% of the time in 1997.

**Use of catheter-based versus surgical intervention in various subgroups:** The shifts in angiographic characteristics of populations treated with each approach over time are shown in Table V, which shows the percentage of all procedures for each year that were catheter based (vs surgical) according to extent of vessel disease and history of procedures. Revascularizations in the setting of acute myocardial infarction (where choice of treatment may be restricted) were excluded from this analysis. Patients with significant left main disease were categorized separately from patients with 2- and 3-vessel disease.

For patients with 1-vessel disease, catheter-based intervention was the dominant form of intervention from 1989 to 1990, and used almost exclusively at the time of the 1997 survey. (This group of patients accounted for

28% of all patients revascularized outside of the acute myocardial infarction setting in the 1997 survey.) For patients with 2-vessel disease without left main stenosis (who accounted for 26% of this 1997 population), the use of catheter-based intervention increased over time, regardless of revascularization history.

For patients with 3-vessel disease without prior CABG (28% of this population as of 1997), surgical intervention was the most common approach throughout the surveys, and was particularly prevalent in 1997. However, for such patients with prior CABG (8% of this 1997 population), the use of catheter-based interventions increased from 57% in 1989 to 1991 to 79% in 1997. Similarly, patients with left main disease and no prior intervention were treated predominantly with CABG, whereas those with left main stenosis and prior CABG were significantly more likely to receive catheter-based reintervention in more recent years. (These 2 left main disease sub-

**TABLE IV** Patient and Procedure Characteristics by Year of Survey for Patients Undergoing Catheter-based Intervention

Characteristics	Year of Survey							
	1989-1990 (n = 972)	1991 (n = 546)	1992 (n = 586)	1993 (n = 571)	1994 (n = 338)	1995 (n = 334)	1996 (n = 302)	1997 (n = 370)
Mean age (yrs)	60.5	61.7	61.2	60.8	60.6	60.7	61.2	62.7
Women (%)	28.3	30.4	31.9	28.7	29.9	29.6	33.4	31.4
Nonwhite (%) <sup>†</sup>	—	5.1	9.6	8.9	7.7	10.5	10.3	11.6
No. of coronary arteries narrowed ≥50% in diameter								
1 (%)	48.0	44.7	41.3	44.1	48.8	45.8	42.7	45.7
2 (%)	28.5	29.7	35.8	34.5	35.2	36.8	33.8	30.8
3 (%)	23.5	25.6	22.9	21.4	16.0	17.4	23.5	23.5
Left main disease <sup>‡</sup>	2.2	2.7	4.1	4.9	1.5	4.8	5.6	5.7
Prior PTCA	27.4	30.8	31.7	31.3	30.5	29.9	30.5	28.6
Prior CABG*	16.2	15.9	17.7	18.0	15.4	17.4	18.9	20.8
Myocardial infarction within 24 h before procedure (%) <sup>‡</sup>	2.4	5.1	3.4	4.6	6.5	5.1	5.6	9.7
Use of new devices (%) <sup>‡</sup>	11.6	11.0	13.8	14.0	19.8	28.7	39.1	67.0

\*p = 0.056; †p < 0.01; ‡p < 0.001 for Cochran-Armitage test of trend.

**TABLE V** Percentage of Interventions That Were Catheter-based by Vessel Disease and Prior Procedures for Patients Undergoing Revascularization Outside of the Setting of Acute Myocardial Infarction

Characteristics	Year of Survey							
	1989-1990	1991	1992	1993	1994	1995	1996	1997
1-Vessel disease								
No prior procedures	92%	94%	93%	93%	95%	97%	92%	96%
Prior PTCA only*	84%	90%	89%	85%	90%	93%	89%	100%
Prior CABG <sup>†</sup>	70%	— <sup>‡</sup>	95%	100%	100%	94%	— <sup>‡</sup>	100%
2-Vessel disease (without left main)								
No prior procedures <sup>‡</sup>	53%	60%	67%	63%	64%	65%	61%	71%
Prior PTCA only	67%	74%	81%	77%	79%	67%	77%	72%
Prior CABG	74%	70%	62%	74%	72%	59%	81%	81%
3-Vessel disease (without left main)								
No prior procedures	17%	21%	21%	18%	18%	17%	24%	14%
Prior PTCA only	52%	49%	47%	38%	45%	38%	53%	28%
Prior CABG <sup>†</sup>	57%	57%	68%	57%	67%	63%	75%	79%
Left main disease <sup>§</sup>								
No prior procedures	3%	3%	5%	3%	0%	7%	8%	9%
Prior CABG <sup>†</sup>	34%	45%	60%	66%	42%	75%	75%	75%

\*p < 0.05; †p < 0.01; ‡p < 0.001 for Cochran-Armitage test of trend; §within this category, prior PTCA only had < 10 patients for each year; †< 10 patients.

groups accounted for 7% and 4%, respectively, of all patients revascularized outside of the acute myocardial infarction setting as of 1997.)

## DISCUSSION

Baseline characteristics of patients undergoing revascularization at BARI hospitals remained stable over 8 years in terms of age, angiographic severity of disease, and history of CABG. There was a slight increase in the prevalence of prior catheter-based intervention. The proportion of revascularized patients who were nonwhite increased significantly over the time of the survey, whereas the proportion who were women did not change appreciably.

The proportion of all revascularizations that were catheter based increased due to higher catheterization laboratory volume, whereas the (absolute) number of surgical interventions increased only slightly. An increasing proportion of catheter-based revascularizations were performed in the setting of acute myocar-

dial infarction, particularly during the most recent 1997 survey. Outside of the acute infarction setting, the likelihood of patients with de novo 2-vessel disease receiving catheter-based intervention increased over time, with an even more striking increase in the catheter-based treatment of patients with prior CABG. Although our survey did not collect information about specific lesions treated, we hypothesize that this increase in patients with prior CABG is related to the emergence of new catheter-based devices that have made the treatment of lesions in bypass grafts possible. This trend would be consistent with a recent comparison of patients undergoing de novo revascularization in the NHLBI's PTCA and New Approaches to Coronary Intervention (NACI) Registries, which found 29% of lesions treated with new devices were bypass graft stenoses compared with 3% of lesions treated with PTCA in 1985 to 1986.<sup>4</sup> The proliferation in the use of new catheter-based devices,

particularly stents, in recent years is clearly reflected in our survey data.

Surgery remained the more common revascularization approach in patients with 3-vessel disease, who did not have previous CABG. Use of the internal mammary artery, which has been demonstrated to benefit long-term survival,<sup>5</sup> was not collected in our survey; other studies have found internal mammary artery use to have increased substantially in the last decade.<sup>6,7</sup> Although the role of newly emerging minimally invasive surgical procedures is not yet clear,<sup>8,9</sup> use of this procedure was noted in 5 of the 17 BARI centers during the 1997 survey.

The BARI randomized trial had as major clinical exclusion criteria 1-vessel or left main disease, prior CABG, prior PTCA, and acute myocardial infarction. Among the survey patients, prevalences of the last 2 criteria increased slightly over time, whereas the others remained stable. Despite this relative stability, it is not clear whether the proportion of patients undergoing revascularization today who would be eligible for BARI is close to the 12% estimated in a prior study using 1993 survey data.<sup>10</sup> The availability of more detailed information might have indicated more dramatic changes in recent revascularization practice, particularly increased eligibility for catheter-based intervention based on lesion-specific angiographic criteria.

**Acknowledgment:** We are most grateful to the Nurse Coordinators at the BARI clinical centers for their hard work in the collection of the survey data.

## APPENDIX

**BARI Clinical Centers:** Bellevue Hospital/New York University Medical Center New York, NY; Boston University Medical Center, Boston, MA; Brown University/Rhode Island Hospital, Providence, RI; Cleveland Clinic Foundation, Cleveland, OH; Duke University Medical Center, Durham, NC; Harvard University/Beth Israel Hospital, Boston, MA; Jewish Hospital, St. Louis, MO; Maine Medical Center, Portland, ME; Mayo Clinic, Rochester, MN; Medical College of Virginia, Richmond, VA; Montreal Heart Institute, Montreal, Quebec, Canada; New York Medical College, Valhalla, NY; Saint Louis University Hospital, Saint Louis, MO; The Toronto Hospital, Toronto, Ontario, Canada; University of Alabama Medical Center, Birmingham, AL; University of Massachusetts, Worcester, MA; University of Michigan, Ann Arbor, MI.

1. Protocol for the Bypass Angioplasty Revascularization Investigation. *Circulation* 1991;84(suppl V):V1-V27.
2. Armitage P. Test for linear trend in proportions and frequencies. *Biometrics* 1955;11:375-386.
3. Jonckheere AR. A distribution-free k-sample test against ordered alternatives. *Biometrika* 1954;41:133-145.
4. King SB III, Yeh W, Holubkov R, Baim DS, Sopko G, Desvigne-Nickens P, Holmes DR Jr, Cowley MJ, Bourassa MG, Margolis J, Detre KM. Balloon angioplasty vs. new device intervention, clinical outcomes: a comparison of the NHLBI PTCA and NACI registries. *J Am Coll Cardiol* 1998;31:558-566.
5. Loop FD. Internal-thoracic-artery grafts. Biologically better coronary arteries. *N Engl J Med* 1996;334:263-265.
6. Harris WO, Mock MB, Orszulak TA, Schaff HV, Holmes DR Jr. Use of coronary artery bypass surgical procedure and coronary angioplasty in treatment of coronary artery disease: changes during a 10-year period at Mayo Clinic Rochester. *Mayo Clin Proc* 1996;71:927-935.
7. Leavitt BJ, Olmstead EM, Plume SK, Charlesworth DC, Maislen EL, James TW, Baribeau YR, Quinn R, O'Connor GT. Use of the internal mammary graft in Northern New England. Northern New England Cardiovascular Disease Study Group. *Circulation* 1997;96(suppl II):II-32-36.
8. Acuff TE, Landreneau RJ, Griffith BP, Mack MJ. Minimally invasive coronary artery bypass grafting. *Ann Thorac Surg* 1996;61:135-137.
9. Holubkov R, Zenati M, Akin JJ, Erb L, Courcoulas A. MIDCAB characteristics and results: the CardioThoracic Systems (CTS) Registry. *Eur J Cardiothorac Surg* 1998;14(suppl 1):S25-S30.
10. Detre KM, Rosen AD, Bost JE, Cooper ME, Sutton-Tyrrell K, Holubkov R, Shemin RJ, Frye RL. Contemporary practice of coronary revascularization in US hospitals and hospitals participating in the Bypass Angioplasty Revascularization Investigation (BARI). *J Am Coll Cardiol* 1996;28:609-615.