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CLINICAL RESEARCH

Percutaneous Coronary Intervention in Native Arteries Versus Bypass Grafts in Prior Coronary Artery Bypass Grafting Patients

A Report From the National Cardiovascular Data Registry

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Objectives This study examined a large registry to determine the frequency, predictors, and outcomes of native coronary artery versus bypass graft percutaneous coronary intervention (PCI) in patients with prior coronary artery bypass graft surgery (CABG).

Background The PCI target vessel and corresponding outcomes in prior CABG patients are poorly studied.

Methods We analyzed the frequency and factors associated with native versus bypass graft PCI in prior CABG patients undergoing PCI between January 1, 2004, and June 30, 2009, in the National Cardiovascular Data Registry (NCDR) CathPCI Registry. Generalized estimating equations logistic regression modeling was used to generate independent variables associated with native versus bypass graft PCI and in-hospital mortality.

Results During the study period, PCI in prior CABG patients represented 17.5% of the total PCI volume (300,902 of 1,721,046). The PCI target was a native coronary artery in 62.5% and a bypass graft in 37.5%: saphenous vein graft (SVG) (104,678 [34.9%]), arterial graft (7,517 [2.5%]), or both arterial graft and SVG (718 [0.2%]). Compared with patients undergoing native coronary artery PCI, those undergoing bypass graft PCI had higher-risk characteristics and more procedural complications. On multivariable analysis, several parameters (including graft stenosis and longer interval from CABG) were associated with performing native coronary PCI, and bypass graft PCI was associated with higher in-hospital mortality (adjusted odds ratio: 1.22, 95% confidence interval: 1.12 to 1.32).

Conclusions Most PCIs performed in prior CABG patients are done in native coronary artery lesions. Compared with native coronary PCI, bypass graft PCI is independently associated with higher in-hospital mortality. (J Am Coll Cardiol Intv 2011;4:844–50) © 2011 by the American College of Cardiology Foundation

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After coronary artery bypass graft surgery (CABG), bypass graft failure often develops, especially several years post-surgery (1). Since redo CABG carries higher risk than initial CABG, PCI is the most common revascularization procedure after CABG (2). Although PCI in patients with prior CABG carries higher procedural risk (3) and worse outcomes compared with PCI in patients without prior CABG (4), there are few reports on the specific target vessel (i.e., native coronary artery vs. bypass graft) and outcomes of PCI in such patients (5–8). We used the National Cardiovascular Data Registry (NCDR) CathPCI Registry to evaluate the contemporary patterns of PCI in prior CABG patients, to identify factors associated with PCI in native coronary arteries versus bypass grafts, and to examine their in-hospital clinical outcomes.

Methods

Patient population. The NCDR CathPCI Registry is an initiative of the American College of Cardiology Foundation and the Society for Cardiovascular Angiography and Interventions. The registry receives data from over 1,000 participating U.S. hospitals, and catalogs in-hospital stay data regarding patient characteristics, clinical features, angiographic and procedural details, and in-hospital outcomes for patients undergoing diagnostic catheterizations and PCI. The CathPCI Registry includes in-hospital data collected on patients undergoing cardiac catheterization and PCI procedures. This is a standard dataset with pre-specified definitions, uniform data entry and transmission requirements, and data quality checks. There is no core laboratory adjudication of the angiographic parameters. Details on the data collection process and the variable definitions have been published previously (9). For the purpose of this study, we examined CathPCI Registry patients with prior CABG undergoing stenting from January 1, 2004, through June 30, 2009.

Statistical analysis. Continuous variables were presented as medians and interquartile ranges. Categorical variables were reported as percentages. The baseline characteristics, PCI procedural findings, and in-hospital outcomes were compared between patients who underwent PCI of a native coronary artery versus a bypass graft. Comparisons between groups were performed using Pearson chi-square tests for all categorical variables and Wilcoxon tests for all continuous variables.

Multivariable logistic regression analyses were performed to determine variables associated with PCI of a native coronary artery among all prior CABG patients undergoing PCI. The following parameters were entered into the model: age, gender, Caucasian race, body mass index, prior myocardial infarction, diabetes, glomerular filtration rate, congestive heart failure, cardiogenic shock, presentation with ST-segment elevation acute myocardial infarction, transfer for primary PCI, thrombolytic administration, presence of graft stenosis >70%, multivessel disease, prior PCI, pre-procedure Thrombolysis In Myocardial Infarction (TIMI) flow grade, presence of high-risk coronary lesions, extent of native coronary artery disease, previously treated lesion, lesion length, time interval from prior CABG, and year of PCI.

Similarly, multivariable logistic regression analyses were performed to determine whether bypass graft PCI was independently associated with in-hospital mortality. The following parameters were entered in the model: age, Caucasian race, body mass index, glomerular filtration rate, New York Heart Association functional class, dialysis, ST-segment elevation, cardiogenic shock, prior congestive heart failure, prior valve surgery, prior cerebrovascular disease, peripheral arterial disease, chronic lung disease, prior PCI, insertion of intra-aortic balloon pump pre-PCI, ejection fraction, subacute thrombosis, TIMI flow grade pre-stenting, diabetes, lesion class, lesion segment, PCI status, and gender (10). Because patients within a hospital are more likely to be treated in a similar way, generalized estimating equations models were used to adjust for within-hospital correlation.

All tests were 2-sided, and a $p < 0.05$ was considered statistically significant. All analyses were performed using SAS software (version 9.2, SAS Institute, Cary, North Carolina) by the Duke Clinical Research Institute (Durham, North Carolina). The authors had full access to the data and take responsibility for its integrity. All authors have read and agree to the manuscript as written.

Abbreviations and Acronyms

CABG = coronary artery bypass graft surgery
CI = confidence interval
CTO = chronic total occlusion
NCDR = National Cardiovascular Data Registry
PCI = percutaneous coronary intervention
STEMI = ST-segment elevation (acute) myocardial infarction
SVG = saphenous vein graft
TIMI = Thrombolysis In Myocardial Infarction

Results

PCI target vessel in prior CABG patients. During the study period, PCI in prior CABG patients represented 17.5% of the total PCI volume (300,902 of 1,721,046). The PCI target vessel in prior CABG patients was only a native coronary artery in 62.5% and at least 1 bypass graft in 37.5% (Fig. 1). Most of the target grafts were saphenous vein grafts (SVGs) (n = 104,678 [34.9%]), and less frequently arterial grafts (n = 7,517 [2.5%]) or both arterial grafts and SVGs (n = 718 [0.2%]). The proportion of SVGs as PCI target vessels increased after 5 years and even more so after 10 years from CABG (Table 1). Overall, the PCI target vessel was a native coronary artery in 61.6% in 2004, 61.1% in 2005, 62.6% in 2006, 62.1% in 2007, 63.2% in 2008, and 63.5% in 2009.

Comparison of native coronary artery versus bypass graft PCI patients. The patients' baseline and treatment characteristics are summarized in Tables 2 and 3. Compared with patients undergoing native coronary artery PCI, those undergoing bypass graft PCI were more likely to be men and

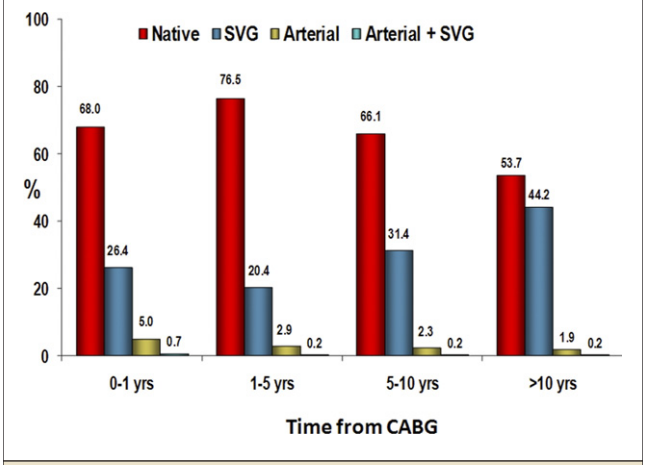

Figure 1. Target Vessel in Patients With Prior CABG

Comparison of the percutaneous coronary intervention target vessel in patients with prior coronary artery bypass graft surgery (CABG) surgery during different time intervals from CABG. $p < 0.001$. SVG = saphenous vein graft.

to have higher risk characteristics, and presented more commonly with an acute myocardial infarction. On multivariable analysis, several parameters (including the presence of graft stenosis >70%, longer time from previous CABG, lack of multivessel disease, lower baseline TIMI flow grade, male gender, high-risk lesions, and diabetes) were associated with higher likelihood of graft versus native coronary artery PCI (Table 4).

Outcomes. Compared with patients undergoing native coronary artery PCI, patients undergoing bypass graft PCI more frequently required intra-aortic balloon pump counterpulsation, required longer fluoroscopy time and larger amount of contrast, less frequently achieved TIMI flow grade 3 post-stenting, were more likely to receive blood transfusions, and had higher rates of post-procedural complications and in-hospital mortality (Table 3). On multivariable analysis, treatment of a bypass graft was independently associated with higher in-hospital mortality: adjusted odds ratio for SVG was 1.20 (95% confidence interval [CI]: 1.10 to 1.30), $p < 0.001$; for arterial grafts was 1.50 (95% CI: 1.18 to 1.90), $p < 0.001$; for both arterial graft and SVGs was 1.28 (95% CI: 0.70 to 2.37), $p = 0.426$; and for any bypass graft intervention was 1.22 (95% CI: 1.12 to 1.32), $p < 0.001$.

Treatment of chronic total occlusions. PCI to a chronic total occlusion (CTO) in a native coronary was attempted in 16,376 of 300,902 (5.44%) patients. PCI was successful in 76.6% of the procedures, and in-hospital mortality for this group of patients was 3.4%. In prior CABG patients undergoing native CTO PCI, in-hospital mortality was 8.4% in unsuccessful procedures, 5.2% in partially successful procedures, and 2.6% in successful procedures.

Discussion

Data from the CathPCI Registry demonstrate that: 1) most PCIs performed in prior CABG patients are done in native coronary arteries; 2) most bypass graft PCIs are done in saphenous vein grafts; and 3) patients undergoing bypass graft PCI have higher-risk clinical characteristics and higher in-hospital mortality.

PCI target vessel in prior CABG patients. Our study demonstrates that in prior CABG patients, most PCIs (62.5%) are performed in native coronary arteries. Previous studies were much smaller and have shown variable results: native coronary artery PCI was performed in 56% of 142 patients reported by Varghese et al. (7) versus 44% of 95 patients reported by Chen et al. (11). Chen et al. first showed that SVG PCI accounted for the majority of PCI after >10 years post-CABG, whereas Cole et al. (12) showed that SVG PCI accounted for 43% of PCI among 1,123 diabetic post-CABG patients undergoing PCI. In our study, the most common PCI target vessel in prior CABG patients was a native coronary artery both early and late post-CABG, although SVG PCI constituted an increasing proportion of PCI >5 years and even more so >10 years from CABG. Apart from progressive SVG failure late post-CABG, another explanation for this finding is that progression of native coronary artery atherosclerosis may render native coronary arteries progressively less likely to be amenable to PCI.

Coronary computed tomography has been advocated as an accurate method to measure bypass graft patency (13), but it has significant limitations for determining native coronary artery patency, especially in the presence of

Table 1. Target Vessel for PCI Among Patients Classified According to the Interval From CABG*

	0–1 Yr Post CABG	1–5 Yrs Post CABG	5–10 Yrs Post CABG	>10 Yrs Post CABG
Native coronary artery PCI	14,189 (68.0)	45,088 (76.5)	57,743 (66.1)	69,674 (53.7)
SVG PCI	5,500 (26.4)	12,047 (20.4)	27,397 (31.4)	57,413 (44.2)
Arterial graft PCI	1,041 (5.0)	1,702 (2.9)	2,000 (2.3)	2,434 (1.9)
Arterial graft and SVG PCI	141 (0.7)	122 (0.2)	158 (0.2)	277 (0.2)

Values are n (%). *Data on the interval from CABG were missing from 3,976 patients.
CABG = coronary artery bypass graft surgery; PCI = percutaneous coronary intervention; SVG = saphenous vein graft.

Table 2. Comparison of Baseline Patient Characteristics in CathPCI Registry Patients With Prior CABG Undergoing PCI Classified According to the Treated Vessel

Variable	Native Only (n = 187,989)	SVGs (n = 104,678)	Arterial Grafts (n = 7,517)	SVGs and Arterial Grafts (n = 718)	p Value
Demographics					
Age, yrs	68 (60–76)	70 (62–77)	67 (58–75)	68 (59–75)	<0.001
Male	72%	77%	72%	73%	<0.001
White race	86%	88%	81%	85%	<0.001
Comorbidities					
Hypertension	86%	87%	86%	89%	<0.001
Hyperlipidemia	88%	88%	88%	88%	0.769
Diabetes mellitus	43%	44%	45%	50%	<0.001
Noninsulin dependent	26%	28%	26%	29%	<0.001
Insulin dependent	17%	16%	19%	21%	<0.001
Smoking					
Current	16%	17%	17%	16%	<0.001
Former	44%	45%	46%	46%	<0.001
Prior MI	45%	48%	45%	43%	<0.001
Prior PCI	42%	45%	41%	41%	<0.001
Cerebrovascular disease	17%	20%	18%	19%	<0.001
Peripheral arterial disease	19%	23%	22%	25%	<0.001
History of renal failure	8%	9%	10%	11%	<0.001
Chronic lung disease	18%	18%	18%	18%	0.048
Warfarin use	6%	6%	5%	5%	0.368
Body mass index, kg/m^2	28.9 (25.7–32.9)	28.6 (25.5–32.4)	28.7 (25.5–32.7)	28.7 (25.5–32.7)	<0.001
Presentation					
Symptoms					<0.001
No angina	14%	11%	15%	12%	
Atypical chest pain	7%	6%	8%	7%	
Stable angina	21%	16%	20%	19%	
ACS: unstable angina	42%	40%	39%	40%	
ACS: NSTEMI	12%	20%	13%	19%	
ACS: STEMI	4%	7%	4%	3%	
Congestive heart failure	12%	14%	15%	17%	<0.001
Cardiogenic shock	1.3%	1.8%	1.9%	2.0%	<0.001
Days from CABG to PCI, median	2,859 (1,431–4,539)	3,949 (2,492–5,501)	2,572 (941–4,395)	2,998 (602–4,672)	<0.001

Values are % or n (interquartile range).

ACS = acute coronary syndrome(s); MI = myocardial infarction; NSTEMI = non–ST-segment elevation (acute) myocardial infarction; STEMI = ST-segment elevation (acute) myocardial infarction; other abbreviations as in Table 1.

calcification (14). Based on our finding that most PCIs in prior CABG patients are performed in native coronary arteries, coronary computed tomography may have significant limitations in assessing coronary anatomy and guiding angiography and revascularization decisions in these patients, who frequently have accelerated native coronary atherosclerosis and calcification. Moreover, complete native and graft angiography is important, even when engagement of the native coronary artery and/or grafts is challenging in the presence of proximal complete occlusions and calcification (15).

Choice of target PCI vessel in prior CABG patients. Traditionally PCI of a native coronary artery is preferred to SVG PCI that supplies the same territory, if feasible, since SVG PCI carries higher acute and long-term risk (7,16). Although the exact factors behind target vessel choice in the CathPCI Registry are not available, the main factors associated with PCI target vessel selection included: 1) the severity of SVG disease (which progressively worsens with longer interval from CABG); and 2) the severity of native coronary artery disease. Native coronary artery PCI may be preferred with diffusely degenerated SVGs, whereas SVG PCI may be preferred in the presence of long, tortuous, and calcified native coronary artery lesions or in the presence of CTOs. Drug-eluting stents are less commonly used in SVGs compared with native coronary arteries, as was recently reported from the CathPCI Registry (17).

Most of the bypass graft interventions in prior CABG patients were performed in SVGs (93%), with much fewer (7%) performed in arterial bypass grafts. This is consistent

Table 3. Comparison of Lesion Characteristics, Treatments, and Immediate Procedural Outcomes in the CathPCI Registry Patients With Prior CABG Undergoing PCI Classified According to the Type of Vessel That Was Treated

Variable	Native Only (n = 187,989)	SVGs (n = 104,678)	Arterial Grafts (n = 7,517)	SVGs and Arterial Grafts (n = 718)	p Value
Lesion characteristics					
Restenotic lesion	6.7%	8.7%	9.0%	8.9%	<0.001
Lesion location					<0.001
Aortic anastomosis	—	20.4%	18.5%	20.0%	
Body	—	62.2%	41.3%	47.2%	
Distal anastomosis	—	17.3%	40.2%	32.8%	
Lesion length, mm	15 (10–20)	16 (12–22)	13 (10–20)	14 (10–20)	<0.001
Treatment					
Unfractionated heparin	48.0%	53.4%	51.6%	49.2%	<0.001
Enoxaparin	14.0%	17.1%	12.9%	17.0%	<0.001
Bivalirudin	47.2%	41.9%	43.2%	44.2%	<0.001
Glycoprotein IIb/IIIa inhibitor	30.5%	39.1%	29.9%	37.6%	<0.001
Multivessel PCI	18.9%	14.6%	14.2%	70.9%	<0.001
Number of stents implanted	1 (1–2)	1 (1–2)	1 (1–2)	2 (2–3)	<0.001
Drug-eluting stents	71.7%	61.2%	69.0%	79.0%	<0.001
1	44.1%	37.0%	43.0%	18.8%	<0.001
2 or more	27.6%	24.3%	26.0%	60.2%	<0.001
Pre-procedure TIMI flow grade					<0.001
3	61.6%	51.2%	56.4%	56.7%	
2	21.2%	24.2%	23.1%	23.7%	
1	10.0%	13.0%	11.5%	11.6%	
0	6.5%	10.8%	8.2%	7.2%	
Post-procedure TIMI flow grade					<0.001
3	96.0%	94.3%	94.3%	96.4%	
2	1.7%	2.5%	2.3%	1.4%	
1	0.5%	0.9%	0.9%	0.7%	
0	1.5%	2.1%	2.2%	1.4%	
Intra-aortic balloon pump	1.3%	2.2%	2.6%	3.3%	<0.001
Fluoroscopy time, min	15.0 (9.5–23.5)	16.0 (10.5–23.8)	17.3 (11.2–25.9)	22.6 (15.8–32.3)	<0.001
Contrast use, ml	210 (150–285)	205 (150–279)	225 (160–300)	270 (200–350)	<0.001
Outcomes					
Transfusion	3.3%	4.3%	4.9%	4.3%	<0.001
Vascular complications	0.65%	0.67%	1.07%	1.54%	<0.001
Procedural complications	4.7%	6.6%	6.3%	7.1%	<0.001
In-hospital mortality	0.9%	1.5%	1.6%	1.4%	<0.001

Values are % or n (interquartile range).
TIMI = Thrombolysis In Myocardial Infarction; other abbreviations as in Table 1.

with the lower failure rates of arterial grafts, especially left internal mammary artery bypass grafts (1). However, arterial grafts were more likely to develop lesions at the distal anastomosis compared with SVGs (Table 3).

Impact of CTOs. Post-CABG patients in whom PCI of a native coronary artery CTO was attempted in the present series had a relatively good success rate (77%) but high in-hospital mortality (3.4%). As has been demonstrated with any CTO intervention (18), patients in whom CTO PCI was successful had better outcomes compared with those in whom CTO PCI failed. The presence of a CTO may adversely affect outcomes in patients who develop an acute coronary syndrome, as this may affect an even larger myocardial area than the target vessel distribution (19). Treatment of a native coronary artery CTO has been described for acutely thrombosed SVGs that could not be recanalized, but it can be a very challenging procedure requiring specialized equipment and expertise (20,21).

Outcomes after SVG versus native coronary PCI. Patients undergoing bypass graft interventions (in either arterial grafts or SVGs) had higher in-hospital mortality compared with patients who underwent native coronary artery interventions. Several factors may contribute to these worse outcomes, such as the higher-risk profile of the bypass graft

Table 4. Variables Associated With Treatment of Native Coronary Artery Lesion in CathPCI Registry Patients With Prior CABG

Variable	Odds Ratio	Lower 95% CI	Upper 95% CI	Chi-Square	p Value
Graft stenosis >70%	0.11	0.11	0.12	4,628	<0.001
Years from prior CABG (odds ratio for 1 yr)	0.92	0.92	0.93	3,743	<0.001
Multivessel disease	2.30	2.19	2.42	1,151	<0.001
Pre-procedure TIMI flow grade	1.15	1.13	1.16	332	<0.001
Male	0.82	0.81	0.84	282	<0.001
High-risk lesion	0.64	0.61	0.68	233	<0.001
Diabetes	0.93	0.92	0.94	168	<0.001
Right coronary artery stenosis >70%	0.83	0.80	0.85	162	<0.001
STEMI	0.75	0.72	0.79	137	<0.001
Glomerular filtration rate (odds ratio for 5 U)	1.01	1.01	1.02	115	<0.001
Left main stenosis >50%	0.87	0.85	0.89	114	<0.001

Only the 11 strongest predictors of the multivariable model are presented in this table.
CI = confidence interval; other abbreviations as in Tables 1 and 3.

PCI patients (Table 1), and the more complex lesion morphology (Table 2). SVG interventions are known to have higher risk for both acute complications, such as no-reflow and for subsequent in-stent restenosis (22,23), whereas PCI of arterial grafts can be complicated by long distance to the target lesion and excessive tortuosity (24).

These findings agree with previous studies: Varghese et al. (7) reported higher risk of no-reflow among SVG PCI patients. In the APEX-MI (Assessment of Pexelizumab in Acute Myocardial Infarction) trial prior CABG patients who presented with ST-segment elevation (acute) myocardial infarction (STEMI) underwent PCI of the infarct-related artery, which was a bypass graft in 63 patients or a native vessel in 55 patients. TIMI flow grade 3 was achieved less often in bypass grafts (67% vs. 88%), and bypass graft PCI patients had higher 90-day mortality (19% vs. 5.7%) compared with native artery PCI patients (8). Similar findings were seen in a study of 128 prior CABG patients presenting with STEMI from the Mayo Clinic (5) and in a study of 169 prior CABG patients with STEMI that were included in the PAMI-2 (Primary Angioplasty in Myocardial Infarction-2), Stent-PAMI-Pilot, Stent-PAMI, PAMI No SOS (Primary Angioplasty in Myocardial Infarction No Surgery-on-Site), and Local Med Pilot trials (6).

A novel finding of our study was that in-hospital mortality after arterial graft PCI was similar to SVG PCI and significantly higher than native coronary interventions. This could have occurred because arterial graft failure may be a sign of advanced atherosclerosis or because arterial graft failure (usually left internal mammary artery to the left anterior descending artery) can result in a large area of ischemic myocardium.

Study limitations. Not all U.S. facilities that perform cardiac catheterization and coronary PCI participate in the CathPCI Registry, and therefore, the results may not be representative of the entire U.S. stenting population, although the number of participating sites is large. In the CathPCI Registry, there is no core laboratory assessment of the patients' angiograms and composite assessments of the coronary anatomy, such as the SYNTAX (Synergy Between PCI With Taxus and Cardiac Surgery) score, were not available. CathPCI Registry data are collected for in-hospital stay only; as such, differences in long-term outcomes of patients who underwent PCI of native coronary artery or a bypass graft could not be assessed. It is not known what drove the decision to intervene on a native coronary artery versus a bypass graft; therefore, unmeasured unknown variables could be responsible for some of the variability in in-hospital outcomes post-native coronary artery or bypass graft PCI.

Conclusions

Most PCIs performed in prior CABG patients are done in native coronary artery lesions, although SVG PCI becomes more prevalent with longer time intervals from CABG. Compared with native coronary PCI, bypass graft PCI is independently associated with higher in-hospital mortality.

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