Narrowing the gap: Early and intermediate outcomes after percutaneous coronary intervention and coronary artery bypass graft procedures in California, 1997 to 2006

Joseph S. Carey, MD,^{a,b} Beate Danielsén, PhD,^c Jeffrey Milliken, MD,^{a,b} Zhongmin Li, PhD,^d and Bruce E. Stabile, MD^e

Objective: Percutaneous coronary intervention is increasingly used to treat multivessel coronary artery disease. Coronary artery bypass graft procedures have decreased, and as a result, percutaneous coronary intervention has increased. The overall impact of this treatment shift is uncertain. We examined the in-hospital mortality and complication rates for these procedures in California using a combined risk model.

Methods: The confidential dataset of the Office of Statewide Health Planning and Development patient discharge database was queried for 1997 to 2006. A risk model was developed using International Classification of Diseases, Ninth Revision, Clinical Modification procedures and diagnostic codes from the combined pool of isolated coronary artery bypass graft and percutaneous coronary intervention procedures performed during 2005 and 2006. In-hospital mortality was corrected for “same-day” transfers to another health care institution. Early failure rate was defined as in-hospital mortality rate plus reintervention for another percutaneous coronary intervention or cardiac surgery procedure within 90 days.

Results: Coronary artery bypass graft volume decreased from 28,495 (1997) to 15,520 (2006), whereas percutaneous coronary intervention volume increased from 38,098 to 53,703. Risk-adjusted mortality rate decreased from 4.7% to 2.1% for coronary artery bypass graft procedures and from 3.4% to 1.9% for percutaneous coronary intervention. Expected mortality rate increased for both procedures. Early failure rate decreased from 13.1% to 8.0% for percutaneous coronary intervention and from 6.5% to 5.4% for coronary artery bypass graft. For the years 2004 and 2005, the risk of recurrent myocardial infarction or need for coronary artery bypass graft during the first postoperative year was 12% for percutaneous coronary intervention and 6% for coronary artery bypass grafts.

Conclusion: This study shows that as volume shifted from coronary artery bypass grafts to percutaneous coronary intervention, expected mortality increased for both procedures. Risk-adjusted mortality rate decreased for both procedures, more so for coronary artery bypass grafts, so that corrected in-hospital mortality rates essentially equalized at approximately 2.0% in 2006. The post-procedural risk of reintervention, death, or myocardial infarction within the first year was twice as high for percutaneous coronary intervention as for coronary artery bypass grafts.

Two important events occurred in 2003 that influenced the practice of coronary artery revascularization in California: the introduction of drug-eluting stents and public reporting of outcomes of coronary artery bypass procedures. Concurrently, the California Society of Thoracic Surgeons introduced

a quality improvement program, known as the California Cardiac Surgery and Intervention Project. This project used the available reporting systems to study outcomes of cardiac surgery and interventions and evaluate best practices.

The public reporting system, the California CABG Outcomes Reporting Program, reported only on isolated coronary artery bypass graft (CABG) procedures. The California Cardiac Surgery and Intervention Project therefore used the patient discharge database maintained by the Office of Statewide Health Planning and Development (OSHPD-PDD) to collect outcome information on all cardiac surgery and percutaneous coronary intervention (PCI) procedures. Initial studies found that mortality rates for cardiac surgery and PCI procedures in the years before 2003 were higher in California compared with New York, a state with a public reporting system in place since 1991.¹ After the introduction of the California public reporting system in 2003, we found that the mortality rates for CABG and valve procedures declined.²

From the California Society of Thoracic Surgeons,^a Sacramento, Calif; University of California,^b Irvine, Calif; Health Information Solutions,^c Sacramento, Calif; University of California,^d Davis, California; and Harbor UCLA Medical Center,^e Torrance, Calif.

Disclosures: Supported by the California Society of Thoracic Surgeons and the Blue Shield of California Foundation.

Received for publication Dec 19, 2008; revisions received Feb 17, 2009; accepted for publication March 17, 2009.

Address for reprints: Joseph S. Carey, MD, UCLA School of Medical Thoracic Surgery, 3475 Torrance Blvd, Suite B-1, Torrance, CA 90503 (E-mail: careysj@earthlink.net).

J Thorac Cardiovasc Surg 2009;138:1100-7
0022-5223/\$36.00

Copyright © 2009 by The American Association for Thoracic Surgery
doi:10.1016/j.jtcvs.2009.03.069

Abbreviations and Acronyms	
CABG	= coronary artery bypass graft
MI	= myocardial infarction
OSHDP-PDD	= Office of Statewide Health Planning and Development
PCI	= percutaneous coronary intervention
RAMR	= risk-adjusted mortality rate

After the widespread introduction of drug-eluting stents for PCI, and the resulting decrease in restenosis, PCI has been increasingly used to treat multivessel coronary artery disease, and the number of CABG procedures has declined. The overall impact of this treatment shift is uncertain. We examined the in-hospital mortality rates and post-hospital outcomes for PCI and CABG in California using the OSHDP-PDD to collect data on all programs that performed both procedures during 1997 to 2006.

MATERIALS AND METHODS

The confidential dataset of the OSHDP-PDD was queried for 1997 to 2006. A risk model was developed using demographic variables and International Classification of Diseases, Ninth Revision, Clinical Modification procedure and diagnostic codes from the combined pool of isolated CABG and PCI procedures based on 2005 and 2006 only. In-hospital mortality was determined for the index hospitalization and corrected for deaths that occurred after “same-day” transfers to another healthcare facility. Ninety-day postdischarge outcomes were determined, including readmissions for death or re-intervention (any PCI or CABG). Out-of-hospital deaths were not included in the mortality rates. Because of loss in follow-up, for the entire time period from 1997 to 2006, we had to exclude 7,551 patients (1%) with a CABG or PCI because we were unable to determine their last nontransfer disposition. For patients with multiple admissions for the same procedure, the first admission was included in the study as the index hospitalization.

Multiple variable logistic regression was used to fit a model for the 2 outcomes. The model included the risk factors listed in Appendix A. Because the effect of a risk factor on mortality differs by surgery type, with the exception of the demographic variables, we fitted a term for each of the risk factors listed above separately for the patients with a CABG or PCI. For instance, cardiogenic shock increased the risk of mortality by a factor of 5 in those undergoing PCI and by a factor of 15 in those undergoing CABG.

In a previous report,³ one of the authors described the variation in incidence of risk factors between the CABG and PCI groups. In this study, propensity analysis was also used to study the influence of procedure choice on outcomes.

RESULTS

In-Hospital Mortality

We initially compared in-hospital mortality rates for CABG and PCI using a risk model obtained from a combined pool of procedures performed during 2005 and 2006. This analysis, using only the index hospitalization, showed that in-hospital mortality rates decreased markedly during the 10-year period for CABG but only slightly for PCI (Table 1).

When in-hospital mortality was corrected for deaths occurring after “same-day” transfers to another healthcare facility, the RAMR in 2006 was 2.09% for CABG and 1.90% for PCI

TABLE 1. Observed in-hospital mortality rates after coronary artery bypass graft surgery and percutaneous coronary intervention, California, 1997–2006 (not corrected for “same day” transfers)

Surgery year	CABGs			PCIs		
	N	Events	Event %	N	Events	Event %
1997	28,495	883	3.10	38,098	571	1.50
1998	28,403	846	2.98	42,449	588	1.39
1999	27,897	827	2.96	44,178	610	1.38
2000	28,091	801	2.85	45,329	641	1.41
2001	26,163	772	2.95	47,876	701	1.46
2002	24,676	660	2.67	49,162	701	1.43
2003	21,519	518	2.41	52,292	719	1.37
2004	19,305	525	2.72	54,339	807	1.49
2005	17,074	409	2.40	54,666	787	1.44
2006	15,520	268	1.73	53,703	758	1.41

CABG, Coronary artery bypass graft; PCI, percutaneous intervention.

(Table 2, Figure 1). CABG volume decreased from 28,249 (1997) to 14,782 (2006), and PCI volume increased from 37,964 to 52,764. The observed in-hospital mortality for CABG decreased from 3.63% (1997) to 2.05% (2006) and remained stable for PCI at 1.6%. Expected mortality, predicted from the 2005 to 2006 risk model, increased 27% from 1997 to 2006 for CABG and 71% for PCI. The risk-adjusted mortality rate (RAMR) decreased markedly over the entire period for CABG. The RAMR for PCI decreased from 1997 to 1999, but decreased only slightly thereafter.

Correction of in-hospital mortality for “same-day” transfers compares favorably with “operative mortality” as determined by the Society of Thoracic Surgeons’ definition. Operative mortality includes death during the index hospitalization plus any death within 30 days but does not include in-hospital deaths occurring beyond 30 days after transfer to another facility. The OSHPD California CABG Outcomes Reporting Program reports, using the “operative mortality” definition and validating deaths by linkage to the California death file (available at: http://www.oshpd.ca.gov/HID/Products/Clinical_Data/CABG/), counted 1766 deaths (3.08%) among 57,316 patients undergoing isolated CABG from 2003 to 2005. In the present report, without counting readmission or out-of-hospital deaths within 30 days but adding all deaths in transferred patients, 1723 deaths (3.05%) among 56,475 patients undergoing isolated CABG were counted during the same time period.

Early Failure Rate

The early failure rate for PCI and CABG was determined by combining mortality with reintervention for another revascularization procedure (PCI or CABG surgery) within 90 days after the index procedure (Table 3, Figure 2).

The early failure rate decreased for both procedures, more significantly for PCI. This decrease for PCI was observed despite the fact that the data included procedures performed for nontarget vessel revascularization.

TABLE 2. Observed and risk-adjusted corrected in-hospital mortality rates after isolated coronary artery bypass graft surgery or percutaneous coronary intervention, California, 1997–2006

Coronary Intervention, California, 1997-2006						RAMR	
Year	Surgeries	In-hospital deaths	% Mortality	% Expected mortality	RAMR	95% LCL	95% UCL
Isolated CABGs							
1997	25,830	938	3.63	1.66	4.71	4.41	5.02
1998	28,136	999	3.55	1.72	4.43	4.16	4.71
1999	27,623	977	3.54	1.75	4.35	4.08	4.63
2000	27,806	911	3.28	1.76	4.00	3.74	4.27
2001	25,864	917	3.55	1.82	4.18	3.91	4.46
2002	24,318	761	3.13	1.89	3.55	3.31	3.82
2003	21,124	630	2.98	1.95	3.29	3.03	3.55
2004	18,844	607	3.22	2.04	3.39	3.12	3.67
2005	16,507	486	2.94	2.06	3.06	2.80	3.35
2006	14,782	303	2.05	2.11	2.09	1.86	2.34
PCIs							
1997	34,487	567	1.64	1.04	3.39	3.11	3.68
1998	42,261	654	1.55	1.05	3.16	2.93	3.42
1999	43,921	701	1.60	1.48	2.32	2.15	2.50
2000	45,057	715	1.59	1.52	2.24	2.08	2.41
2001	47,605	781	1.64	1.56	2.25	2.10	2.42
2002	48,870	784	1.60	1.59	2.16	2.01	2.32
2003	51,931	806	1.55	1.64	2.04	1.90	2.18
2004	53,916	901	1.67	1.65	2.17	2.03	2.32
2005	54,125	883	1.63	1.69	2.08	1.94	2.22
2006	52,762	835	1.58	1.78	1.90	1.78	2.04

RAMR, Risk-adjusted mortality rate; *CABG*, coronary artery bypass graft; *LCL*, lower confidence limit; *UCL*, upper confidence limit; *PCI*, percutaneous coronary intervention. The corrected in-hospital mortality rate includes mortality after a same-day transfer. Approximately 1% of patients are lost to follow-up because it was not possible to determine their post-transfer disposition. The California corrected in-hospital mortality rate after isolated CABG surgery or PCI for 2005/2006 was 2.15 and is used as the reference level for the RAMR. The RAMR was computed on the basis of a multiple logistic regression model fit to the 2005/2006 data including isolated CABGs and PCIs.

Late Failure Rate

Patients undergoing PCI or CABG during 2004 and 2005 were followed to determine the incidence of readmission for acute myocardial infarction (MI) or need for another CABG (“late failure rate”) during the first year after the index procedure (Table 4). This risk of acute MI or readmission for CABG within the first year was approximately 12% for PCI and 6% for CABG.

Individual Hospital Variation

The number of hospitals performing both PCI and CABG each year varied between 118 and 122. As the gap narrowed in early mortality, the number of hospitals with higher mortality after PCI than after CABG surgery increased from 9 in 1997 to 58 in 2006. In 2006, 48% of California hospitals had higher unadjusted in-hospital mortality for PCI than CABG. In 2006, 41 hospitals (34%) had higher risk-adjusted mortality after PCI compared with CABG.

Hospitals performing a lower volume of CABG procedures in 2005 and 2006 tended to have higher mortality after CABG surgery, but not for PCI. Table 5 shows a comparison of hospitals performing fewer than 100 CABG surgeries per year during 2005 and 2006 with those performing at least 100. The CABG risk-adjusted in-hospital mortality rate was approximately 21% higher in low-volume hospitals,

whereas the PCI RAMR was only 12% higher. The difference in mortality for low-volume versus high-volume hospitals after CABG surgery or PCI is not statistically significant. The PCI to CABG volume ratio was 5:1 for low-volume hospitals and 3:1 for high-volume hospitals.

DISCUSSION

Several recent reviews have examined the comparative outcomes of PCI and CABG procedures. A meta-analysis

FIGURE 1. Risk-adjusted in-hospital mortality rate after isolated CABG surgery or percutaneous coronary intervention, California, 1997–2006. The dotted lines show the 95% confidence limits of the risk-adjusted mortality rate. *CABG*, Coronary artery bypass graft; *RAMR*, risk-adjusted mortality rate; *PCI*, percutaneous coronary intervention.

TABLE 3. Observed and risk-adjusted 90-day in-hospital mortality/reintervention rates after isolated coronary artery bypass graft surgery or percutaneous coronary intervention, California, 1997–2006

Year	Surgeries	INH/RE90	% INH/RE90	% INH/RE90	RAER	RAER	
						95% LCL	95% UCL
Isolated CABGs							
1997	25,507	1127	4.42	5.11	6.49	6.12	6.88
1998	27,774	1223	4.40	5.08	6.51	6.15	6.88
1999	27,270	1200	4.40	5.17	6.39	6.03	6.76
2000	27,452	1124	4.09	5.11	6.01	5.67	6.37
2001	25,578	1143	4.47	5.13	6.54	6.16	6.93
2002	24,091	1027	4.26	5.13	6.24	5.86	6.63
2003	21,076	846	4.01	5.15	5.85	5.46	6.26
2004	18,813	818	4.35	5.16	6.33	5.90	6.77
2005	16,589	635	3.83	5.18	5.55	5.13	6.00
2006	11,626	435	3.74	5.23	5.37	4.88	5.90
PCI							
1997	33,739	3718	11.02	6.32	13.08	12.67	13.51
1998	41,388	4165	10.06	6.35	11.90	11.55	12.27
1999	42,870	4155	9.69	7.53	9.67	9.38	9.97
2000	43,835	4090	9.33	7.61	9.21	8.93	9.50
2001	46,564	4272	9.17	7.68	8.97	8.70	9.24
2002	47,918	4393	9.17	7.76	8.87	8.61	9.14
2003	51,020	4430	8.68	7.82	8.34	8.09	8.59
2004	52,947	4297	8.12	7.87	7.74	7.51	7.98
2005	52,945	4402	8.31	7.96	7.84	7.61	8.08
2006	39,955	3480	8.71	8.19	7.99	7.72	8.26

RAER, Risk-adjusted event rate; CABG, coronary artery bypass graft; LCL, lower confidence limit; UCL, upper confidence limit; INH/RE90, 90-day in-hospital mortality/reintervention rate; PCI, percutaneous coronary intervention. The in-hospital mortality/reintervention rate includes mortality after a same-day transfer and any readmissions for reinterventions within 90 days. Approximately 5% of patients are lost to follow-up. The California in-hospital mortality/reintervention rate after isolated CABG surgery or PCI for 2005/2006 was 7.51 and is used as the reference level for the risk-adjusted event rate. The risk-adjusted event rate was computed on the basis of a multiple logistic regression model fit to the 2005/2006 data, including isolated CABGs and PCIs.

of long-term (up to 5 years) outcomes in 4 randomized controlled trials of PCI with stenting versus CABG for multivessel coronary artery disease found that PCI was associated with an increase in subsequent revascularization (PCI or CABG) and major adverse cardiovascular events relative to CABG.⁴

Taggart⁵ also reviewed meta-analyses and found that drug-eluting stents have not improved survival or freedom from MI compared with CABG. He concluded that CABG remains the best therapy in terms of improved survival and freedom from reintervention for most patients with proximal left anterior descending, multivessel, and left main-stem coronary artery disease. Other studies have pointed out that although early outcomes of PCI using drug-eluting stents and CABG were similar, PCI had the advantage of shorter hospital stays and fewer complications.⁶ Longer-term data have found CABG to be associated with fewer recurrences of angina and MI, and less need for intervention, than PCI.⁷

This study shows that over time in California, early outcomes of PCI and CABG have become comparable. Follow-up through 90 days to 1 year indicates a higher reintervention rate for PCI. Much of the reintervention rate is due to nontarget vessel reintervention, which we could not distinguish in the present data. Tables 2 and 3 suggest

that the introduction of stenting may have had an impact on early outcomes in the 1997 to 1999 period, whereas the introduction of drug-eluting stents in 2003 may have had a lesser effect.

The New York public reporting registry has been studied extensively. Hannan and colleagues⁸ reported that for patients with multivessel disease, CABG continues to be associated with lower mortality rates than does treatment with

FIGURE 2. Risk-adjusted in-hospital mortality/90-day readmission rate after isolated CABG surgery or percutaneous coronary intervention, California, 1997–2006. The dotted lines show the 95% confidence limits of the risk-adjusted mortality rate. CABG, Coronary artery bypass graft; RAMR, risk-adjusted mortality rate; PCI, percutaneous coronary intervention.

ACD

TABLE 4. Comparison of one-year outcomes between percutaneous coronary intervention and isolated coronary artery bypass graft, 2004–2005

	Year	PCI		CABG		P value
		N	Mean % (95% CI)	N	Mean % (95% CI)	
Post-procedural MI	2004	53,089	9.99 (9.93–10.04)	20,677	6.00 (5.91–6.09)	<.0001
	2005	52,535	9.88 (9.83–9.93)	19,128	5.73 (5.64–5.82)	<.0001
Readmission for CABG	2004	53,089	2.22 (2.21–2.23)	20,677	0.20 (0.19–0.21)	<.0001
	2005	52,535	2.16 (2.15–2.17)	19,128	0.21 (0.20–0.22)	<.0001
Operative mortality	2004	53,089	2.11 (2.07–2.15)	20,677	3.23 (3.17–3.29)	<.0001
	2005	52,535	1.97 (1.93–2.01)	19,128	3.00 (2.94–3.06)	<.0001
Length of stay	2004	53,089	3.12 (3.04–3.20)	20,677	9.91 (9.83–9.99)	<.0001
	2005	52,535	2.98 (2.91–3.05)	19,128	9.86 (9.80–9.93)	<.0001

PCI, Percutaneous coronary intervention; CABG, coronary artery bypass graft; CI, confidence interval; MI, myocardial infarction.

drug-eluting stents and is associated with lower rates of death or MI and repeat revascularization.⁸ Other studies noted that public reporting in New York was associated with reluctance to perform PCI in high-risk patients.⁹ Significant differences in case mix between patients undergoing PCI in Michigan and New York were found that result in marked differences in unadjusted mortality rates.¹⁰ It was believed that a propensity in New York toward not intervening on higher-risk patients because of fear of public reporting of high mortality rates was the cause of lower mortality for PCI in New York compared with Michigan.

The present study does not find evidence that the introduction of public reporting in California is associated with a reluctance to perform CABG procedures in high-risk patients. Outcomes reporting may have encouraged more attention to best practices, because CABG mortality decreased while expected mortality increased. PCI in-hospital mortality rates in California are similar to those in other states and in countries that do not have public reporting programs.^{2,9} Public reporting of PCI procedures in California might have a similar impact on outcomes as it apparently has had in New York.

Individual hospital data found a predominance of low-volume programs. Of 118 sites performing both PCI and CABG during 2005 and 2006, 62 performed less than 100 CABG procedures per year. As noted in our previous studies¹ and in public reports from California (available at: <http://www.osphd.ca.gov/HQAD/Outcomes/Studies/cabg>), no statistically significant relationship has been found between the volume of CABG procedures and risk-adjusted mortality for surgeons or hospitals. In the present study, lower-volume sites had higher mortality for CABG in 2005 and 2006 compared with higher-volume hospitals, whereas PCI mortality rates did not differ as much.

However, the difference by volume was not statistically significant. Lower-volume sites also performed a relatively higher number of PCI procedures compared with CABG procedures, suggesting that these programs may have a more aggressive approach to interventional procedures. In previous studies we found that a ratio of PCI to CABG more than 2:1 was associated with an increase in CABG mortality.¹ Further studies of surgeon and hospital volume may clarify the effect of more aggressive PCI strategies on CABG mortality.

This study shows the strengths and limitations of using an administrative hospital discharge database for outcomes studies. Strengths include the completeness (all patients included), consistency of coding, and ability to follow patients through subsequent admissions, thus collecting all deaths and complications except the few that occur out of hospital. Weaknesses include limited ability to subset patients and the absence of clinical data on organ system function, such as myocardial contractility and pulmonary disease. We therefore chose to look only at the total experience with PCI and isolated CABG procedures in California, with the assumption that the choice of procedure was random, although in many cases it was not. In previous studies we found that propensity analysis, for example, did not show major differences in outcomes when patients were analyzed in quintiles according to risk factors.³

Narrowing the in-hospital outcome gap between PCI and CABG should affect the decision about which procedure is appropriate for more complicated multivessel disease patients, because the post-hospital risk of repeat revascularization and MI is higher with PCI. However, the incentive to perform a less-invasive procedure is a powerful motivator for both patient and provider. Only a clear and robust body of evidence-based data are likely to change clinical practice.

TABLE 5. Risk-adjusted in-hospital mortality rate after isolated coronary artery bypass graft surgery and percutaneous coronary intervention for low- and high-volume hospitals, California, 2005–2006

Subgroup	No. of hospitals	PCI annual volume	CABG annual volume	PCI RAMR	CABG RAMR
Low volume (<100 CABGs/y)	62	282 ± 187	58 ± 27	2.07	2.96
High volume (≥100 CABGs/y)	58	579 ± 362	197 ± 139	1.94	2.50

PCI, Percutaneous coronary intervention; CABG, coronary artery bypass graft; RAMR, risk-adjusted mortality rate. The differences in the RAMRs for low- and high-volume hospitals are not statistically significant for the CABG or PCI group.

CONCLUSIONS

This study shows that as volume shifted from CABG to PCI from 1997 to 2006, expected mortality increased for both procedures. In-hospital mortality decreased markedly for CABG and remained stable for PCI, leading to a smaller mortality gap for the 2 interventions in 2006. The need for repeat revascularization decreased, but remained significantly higher for PCI compared with CABG. During the first year after the index procedure, the risk of acute MI or need for repeat CABG was also higher for PCI. Overall, RAMR decreased for patients undergoing coronary revascularization procedures in California from 1997 to 2006. However, late procedure failure has persisted, especially for PCI.

References

1. Carey JS, Danielsen B, Gold J, Rossiter S. Procedure rates and outcomes of coronary revascularization procedures in California and New York. *J Thorac Cardiovasc Surg.* 2005;129:1276-82.
2. Carey JS, Danielsen B, Junod FL, Rossiter SJ, Stabile B. The California cardiac surgery and intervention project: evolution of a public reporting system. *Am Surg.* 2006;72:978-83.
3. Li Z, Yeo KK, Mahendra G, Amsterdam E. Patient profiling of coronary artery bypass in comparison to percutaneous coronary intervention in California 2004. (Abstract) *J Am Coll Cardiol.* 2008;51(Suppl A):A233.
4. Takagi H, Kawai N, Umemoto T. Meta-analysis of four randomized controlled trials on long-term outcomes of coronary artery bypass grafting versus percutaneous coronary intervention with stenting for multivessel coronary artery disease. *Am J Cardiol.* 2008;101:1259-62.
5. Taggart DP. Coronary artery bypass graft vs. percutaneous coronary angioplasty: CABG on the rebound? *Curr Opin Cardiol.* 2007;22:517-23.
6. Varani E, Balducci M, Vecchi G, Aquilina M, Maresta A. Comparison of multiple drug-eluting stent percutaneous coronary intervention and surgical revascularization in patients with multivessel coronary artery disease: one-year clinical results and total treatment costs. *J Invasive Cardiol.* 2007;19:476-7.
7. Bair TL, Muhlestein JB, May HT, Meredith KG, Horne BD, Pearson RR, et al. Surgical revascularization is associated with improved long-term outcomes compared with percutaneous stenting in most subgroups of patients with multivessel coronary artery disease: results from the Intermountain Heart Registry. *Circulation.* 2007;115:1226-31.
8. Hannan EL, Wu C, Walford G, Culliford AT, Gold JP, Smith CR, et al. Drug-eluting stents vs. coronary-artery bypass grafting in multivessel coronary disease. *N Engl J Med.* 2008;358:405-7.
9. Apolito RA, Greenberg MA, Menegus MA, Lowe AM, Sleeper LA, Goldberger MH, et al. Impact of the New York State Cardiac Surgery and Percutaneous Coronary Intervention Reporting System on the management of patients with acute myocardial infarction complicated by cardiogenic shock. *Am Heart J.* 2008;155:267-73.
10. Moscucci M, Eagle KA, Share D, Smith D, De Franco AC, O'Donnell M, et al. Public reporting and case selection for percutaneous coronary interventions: an analysis from 2 large multicenter percutaneous coronary intervention databases. *J Am Coll Cardiol.* 2005;45:1766-8.

Discussion

Dr Gabriel Aldea (*Seattle, Wash*). Decreased CABG mortality despite increased patient acuity and complexity over the past decades is indisputable and laudable. These findings were previously published by the authors. Parallel national trends presented at this meeting reviewing the national inpatient sample, the Society of Thoracic Surgeons database, our own state of Washington Clinical Outcomes Assessment Program database with more than 160,000 patients treated in the past decade, which incidentally does combine

all CABG and PCI procedures in a single database, and those of other multiple states. Also indisputable is the increase in the number of PCI procedures and the increasing ratio of PCI to CABG over the same decade. I have no issues with the data, but I do have some issues with the interpretation of the data or the suggestion that this narrow gap will somehow influence treatment assignment. I have several comments and 2 questions.

Despite the marked change in treatment that continues unabated after the introduction of bare metal stents and certainly preceding drug-eluting stents, PCI and CABG still treat very different populations. In the State of Washington for CABG, more than 95% of the patients treated with coronary bypass surgery have 3-vessel disease of the left main and the average number of grafts is 3.4 grafts per patient. This is compared with only 15% of patients treated with PCI presenting with 3-vessel disease of the left main, and the average number of vessels is 1.2. Assignment to PCI and CABG surgery is also changing over this time period. Acute MI therapy has evolved dramatically in the last several years, preferentially treating acute MIs with immediate (so-called primary) PCI rather than lytic therapy or CABG, specifically targeting 1 and rarely 2 culprit lesions with a specific more limited or focused treatment strategy to minimize the morbidity of the acute MI rather than achieve complete revascularization. In fact, in our own database, acute MI therapy represents 30% of all PCIs, and that is a growing incidence.

Finally, medical therapy and perhaps the biology of disease have also evolved dramatically over this period of time with the introduction of statins, more effective and more routine antiplatelet therapy, and stricter more effective glycemic diabetic control, decreasing the morbidity and perhaps the incidence of some subsets of this condition.

Given these observations, I have 2 questions for you. Given the current approach for target lesion revascularization, particularly in unstable angina or acute MI, is it not expected that mortality rates for PCI and specifically reintervention rates either on the same or untreated vessels should increase? The correlation to this question is whether a patient who presents for repeat intervention 90 days after an acute MI really represents a true failure rate? Is the risk at reintervention not lower?

Dr Carey. The answer is that we had to lump everything together for the PCIs, and so the number of reinterventions is probably closer to half. It was not going to be easy to subset patients in this kind of a database, so we simply lumped them all together. We do understand that the PCI group is a lower risk group because of some of the factors that you mentioned, but we just thought it was interesting that despite the similar mortality rates, at least the early risk of any of these procedures is basically the same, and of course this has been reported by other groups as well.

Dr Aldea. The second question I have for you is, I expect the state or national observed/expected ratios to be equal to 1. Yours are not. Is it appropriate therefore to generate a combined model for PCI and CABG based on the last 2 years, 2005 and 2006, and retrospectively apply them to the entire cohort? This gives a significant discrepancy between the observed and the predicted or risk-adjusted mortality. This can artificially create what I call the Garrison Keillor Lake Wobegon principle, wherein all men are strong and all children above average. Your predictive model actually predicts the observed/expected ratios accurately only for the last 2 years.

Dr Carey. The reason we did it this way, and of course I have 2 PhDs working on this (and they tend to confuse me daily with their

statistical work) who wanted to compare the mortality rates over time, was to use 1 risk model over the entire 10-year period. It would have seemed to me to do a different risk model for each year, but then the years would not have been comparable. We were trying to show the difference between PCI and CABG over time rather than the actual specific differences between certain groups of patients undergoing PCI and CABG.

Dr David Follette (*Sacramento, Calif*). Joe, I rise to congratulate on an extremely well presented study and to point out to the audience that Dr Carey was head of the California STS for more than 20 years and worked closely with past-president Dr Harlan in 2000 for his presidential address and his 2 associates, Dr George Miller and Dr _____, and has made a huge contribution and dedication of his time and effort to a system that without his leadership, California would be in a lot worse shape in terms of the reporting of the data. I rise to thank you, Joe, for those 20 years of diligence and working with our other colleagues.

We are only looking at a small segment of what is being done. We are looking at isolated coronary bypass. Thus, I have 1 important question. Is there any way that you have looked at the addition of other procedures, such as an isolated mitral valve ring, in a high-risk patient who has modest or mild mitral regurgitation that may put somebody that was a high-risk patient in a different group that you are not looking at. Is there any way in our current state of affairs we can see if there has been a trend to add to the coronary bypass surgery to shift them out of the reporting group into another group?

Dr Carey. It can be done. I am not sure how well we could subset patients using this administrative database. We can probably do it in the state public database because the public report, although it only reports isolated CABG, requires all CABG procedures to be reported to the state. There is a move afoot to do some work on the nonisolated CABG procedures. Of course we are only collecting 54 elements for risk factors in the state report, and I do not know if we would be able to subset the mitral valve cases the way you would really need to. You would have to use the STS database for that, but in my opinion the STS database needs a lot of work in terms of making it accurate, because they are missing many deaths, especially these mitral valve cases. It takes them 3 months to die, as you well know.

Dr Joseph Cleveland (*Denver, Colo*). Dr Carey, I enjoyed your talk and I wanted to get you to flush out your comments a little bit on one of your conclusions that public reporting was efficacious because this is a 10-year cohort, but as I understand in the introduction I think public reporting occurred only in 2003. How can you tie in the fact that public reporting of these data may or may not have had any potential impact in terms of decreasing observed/expected ratios and things like that, particularly with the constant risk model when it has not changed when things may have changed with the risk of the patients? Can you comment on that?

Dr Carey. I think you are right; it is a little bit of backward thinking. We are waiting for our 2007 data, and it will be interesting to see whether the numbers stay where they are or maybe even keep going down, but this precipitous decrease in mortality statewide has to have some explanation. We are not really changing our techniques. It is pretty much the same surgeons. We have not imported a whole new team of surgeons from New York or somewhere

where they are getting better outcomes. Just in thinking backwards over what happens with public reporting and talking to the doctors around the state, I do think they are being a little more careful. They are being a little more selective, although it looks like our expected mortality keeps going up. The other thing is in New York, the PCI mortality is half of what it is in California. The fact that the PCI mortality stays the same in California and stays low in New York may be because cardiologists are more selective in New York. This makes me think that if we had public reporting of PCI in California, we would have lower mortality rates for PCI.

Dr Larry Cohn (*Boston, Mass*). I enjoyed your article. This is the kind of information that really needs to be publicized. I noted that one of your sponsoring groups was the Blue Cross Blue Shield. My question to you is, have any of these data made any impact on reimbursement for these procedures in the State of California, or has it actually caused the payers to say you are going to have just a limited number of PCIs, but we are not going to let you do it in certain patients, and we think surgery is actually better in the long run, especially with the internal thoracic bypass and this kind of thing. Has this had any impact on the payers in terms of determining who gets what or who does not get what?

Dr Carey. That is a good question. I think there is going to be a big delay in the impact of this kind of information at the upper echelons of these insurance companies, and this is something that we yet to deal with. Dan Ulliyot was on the board of the Blue Shield of California Foundation, and he is the one who suggested that we apply for funding. He might have some information about that. I believe he is still on the board of that foundation. I do think it is good for us to get involved with these insurance companies so that we can help steer their thinking in what we think is the right direction.

Unidentified Speaker. Dr Carey, this is a great study. Our state does not have public reporting, and certainly if you publish this we are going to follow your lead. You report high and low-volume as greater than 100 CABG procedures per year. I am curious if you looked at other numbers, and why did you choose 100 as a definition of high volume?

Dr Carey. We chose that number before because 100 cases per year is 2 coronary bypass graft cases per week. That is a not a lot obviously, but hospitals with 2 coronary bypass grafts or more have an average volume of at least more than 200 cases per year. Now as we are performing fewer and fewer procedures, the definition of high volume is changing. There is an article in this month's *Journal of Thoracic and Cardiovascular Surgery* about the volumes in Japan, where they are even lower than they are in California. Apparently they have lots of little programs in Japan and achieve good outcomes there, even in the lower-volume programs. High volume is really probably more than 100, but for the purposes of our study, it splits it right in half, making a fairly equal comparison.

Unidentified Speaker. That is interesting, because in Japan there are typically 3 surgeons for every bypass operation, 3 cardiac surgeons. They have somebody harvesting a vein, somebody harvesting a thoracic artery, and somebody actually performing the operation. In fact, that is how I believe they keep their surgeon volumes up, although their case volumes are not great.

APPENDIX 1.

Variables were selected for the regression model on the basis of known relevance from previous studies and on the ability to discriminate the risk factors using available codes. The following risk factors were used in the analysis: age categorized as less than 40 years, 40 to 44 years, 45 to 49 years, 50 to 59 years, 55 to 59 years, 60 to 64 years, 65 to 69 years, 70 to 74 years, 75 to 79 years, 80 to 84 years, 85 to 89 years, 90 years or older; gender, race categorized as white, black, Asian/Pacific Islander, or other race; Hispanic origin; dialysis before surgery or on day of surgery (39.95, 54.98); diabetes (250.0, 250.1, 250.2, 250.3, 250.4, 250.5, 250.6, 250.7, 250.9); cerebrovascular disease present at admission

(430, 431, 432, 433, 434, 435, 436, 437, 438); peripheral vascular disease present at admission (440.xx, 441.2, 441.4, 441.7, 441.9, 443.1, 443.8, 443.9, 447.1, 557.1, 557.9, V43.4); renal failure present at admission (403.11, 403.91, 404.12, 404.92, 585.xx, 586.xx, V42.0, V45.1, V56.0, V56.8); cardiomyopathy present at admission (425.xx); cardiogenic shock present at admission (785.51); acute MI present at admission (410.xx, 412.xx); congestive heart failure (428.0, 428.1, 428.9, 398.91, 402.21, 402.11, 402.91, 404.01, 404.03, 404.11, 404.13, 404.91, 404.93); prior CABG surgery (V45.81); urgent acuity (emergency admission with surgery on admission day).