Journal of the American College of Cardiology
Vol. 60, No. 20, 2012
ISSN 0735-1097/$36.00
http://dx.doi.org/10.1016/j.jacc.2012.08.966
Published by Elsevier Inc.

CLINICAL RESEARCH **Interventional Cardiology**

A Contemporary View of Diagnostic Cardiac Catheterization and Percutaneous Coronary Intervention in the United States

A Report From the CathPCI Registry of the National Cardiovascular Data Registry, 2010 Through June 2011

Gregory J. Dehmer, MD,* Douglas Weaver, MD,† Matthew T. Roe, MD,‡ Sarah Milford-Beland, MS,§ Susan Fitzgerald, RN,‖ Anthony Hermann, RN, MBA,‖ John Messenger, MD,¶ Issam Moussa, MD,# Kirk Garratt, MSc, MD,** John Rumsfeld, MD, PhD,¶ Ralph G. Brindis, MD, MPH††

Temple, Texas; Detroit, Michigan; Durham, North Carolina; Washington, DC; Denver, Colorado; Jacksonville, Florida; New York, New York; and San Francisco, California

Objectives This study sought to provide a report to the public of data from the CathPCI Registry of the National Cardiovascular Data Registry.

Background The CathPCI Registry collects data from approximately 85% of the cardiac catheterization laboratories in the United States.

Methods Data were summarized for 6 consecutive calendar quarters beginning January 1, 2010, and ending June 30, 2011. This report includes 1,110,150 patients undergoing only diagnostic cardiac catheterization and 941,248 undergoing percutaneous coronary intervention (PCI).

Results Some notable findings include, for example, that on-site cardiac surgery was not available in 83% of facilities performing fewer than 200 PCIs annually, with these facilities representing 32.6% of the facilities reporting, but performing only 12.4% of the PCIs in this data sample. Patients 65 years of age or older represented 38.7% of those undergoing PCI, with 12.3% being 80 years of age or older. Almost 80% of PCI patients were overweight (body mass index $\geq$25 kg/m^2), 80% had dyslipidemia, and 27.6% were current or recent smokers. Among patients undergoing elective PCI, 52% underwent a stress study before the procedure, with stress myocardial perfusion being used most frequently. Calcium scores and coronary computed tomography angiography were used very infrequently (<3%) before diagnostic or PCI procedures. Radial artery access was used in 8.3% of diagnostic and 6.9% of PCI procedures. Primary PCI was performed with a median door-to-balloon time of 64.5 min for nontransfer patients and 121 min for transfer patients. In-hospital risk-adjusted mortality in ST-segment elevation myocardial infarction patients was 5.2% in this sample.

Conclusions Data from the CathPCI Registry provide a contemporary view of the current practice of invasive cardiology in the United States. (J Am Coll Cardiol 2012;60:2017–31)

From the *Texas A&M Health Science Center College of Medicine, Division of Cardiology, Scott & White Healthcare, Temple, Texas; †Cardiology Division, Henry Ford Hospital, Detroit, Michigan; ‡Cardiology Division, Duke University Medical Center, Durham, North Carolina; §Duke Clinical Research Institute, Durham, North Carolina; ‖American College of Cardiology, Washington, DC; ¶Division of Cardiology, University of Colorado, Denver, Colorado; #Division of Cardiology, Mayo Clinic, Jacksonville, Florida; **Department of Interventional Cardiology, Lenox Hill Hospital, New York, New York; and the ††Department of Medicine, University of California San Francisco, San Francisco, California. Dr. Dehmer has received honoraria/speaking fees from Sanofi-aventis, Daiichi-Sankyo, The Medicines Company, Boston Scientific, Medtronic, and Abbott Vascular; consultancies from The Medicines Company, Boston Scientific, and Abbott Vascular; equity holdings in Infarct Reduction Technologies (co-founder), Guided Delivery Systems, MedLogics, and Arstasis; and research support from Abbott Vascular (institutional PI) and Boston Scientific (national PI). Dr. Weaver is a member of the Data and Safety Monitoring Board of Boston Scientific. Dr. Roe is a consultant to AstraZeneca, Bristol-Myers Squibb, Eli Lilly & Company, GlaxoSmithKline, Merck & Co., Novartis Pharmaceutical Corporation, sanofi-aventis, and Schering-Plough Corporation; and has received research grants from Bristol-Myers Squibb, Eli Lilly & Company, sanofi-aventis, and Schering-Plough Corporation. Dr. Messenger has received an institutional research grant from Medtronic and Site PI. Dr. Garratt has received honoraria, and has investments. All other authors have reported that they have no relationships relevant to the contents of this paper to disclose.

Manuscript received June 9, 2012; revised manuscript received July 25, 2012, accepted August 13, 2012.

JACC Vol. 60, No. 20, 2012
November 13, 2012:2017–31

Abbreviations and Acronyms

ACCF = American College of Cardiology Foundation

BMS = bare-metal stent(s)

CABG = coronary artery bypass graft

CAD = coronary artery disease

DES = drug-eluting stent(s)

NCDR = National Cardiovascular Data Registry

PCI = percutaneous coronary intervention

STEMI = ST-segment elevation myocardial infarction

STS = Society of Thoracic Surgeons

The National Cardiovascular Data Registry (NCDR) of the American College of Cardiology Foundation (ACCF) was developed to assist healthcare providers and institutions in documenting their processes and outcomes of care in the cardiac catheterization laboratory. As a resource, the NCDR is positioned to help medical professionals and participating hospitals identify and close gaps in the quality of care; reduce wasteful and inefficient care variations; and implement effective, continuous quality improvement processes. As we move into the era of transparency and public reporting, the value of the NCDR is increasing, not only for benchmarking outcomes, but also as a potent repository of clinical data to answer research questions.

History of the CathPCI Registry

A full description of the historical development of the NCDR is presented elsewhere (1,2). Today, 1,488 facilities in the United States are enrolled in the CathPCI Registry, which captures an estimated 85% of the percutaneous coronary interventions (PCI) performed in the United States (Fig. 1). The Society for Cardiovascular Angiography and Interventions collaborates with the ACCF on the registry effort.

Participation, Data Definitions, and Collection

Participation in the NCDR CathPCI Registry is voluntary. Most participating facilities (68%) submit data on diagnostic catheterization and PCI procedures, 29% submit data only on PCI procedures, and 3% provide information only on diagnostic procedures. Because interventional practices are driven by technologies that change quickly, there have been several registry modifications leading to the current version 4.4 that began receiving data on April 1, 2011. This version expanded data collection on pre-catheterization imaging procedures, used a new bleeding definition, and provided the first report of test metrics for assessment of the appropriate use criteria for coronary revascularization. The current version has 253 data fields, with definitions and specifications available online (3). Data are collected up to the time of hospital discharge, which is a potential limitation (4).

Site Performance and Auditing Program

The NCDR Data Quality Program was developed to ensure that data submitted are complete, consistent, and accurate and thus usable to improve the quality of clinical practice. Participant submissions are reviewed for completeness and are not accepted if data completeness criteria are unmet. Each year, 25 sites are selected randomly for a comprehensive on-site data audit. The structure of the Data Quality Program and audit results recently were reported (5). Several states conduct more extensive audits of data, because they are used for statewide reporting programs.

NCDR Reports and Risk Adjustment Methods

Participants in the registry receive quarterly reports reflecting their aggregate data and a rolling summary of the previous 4 quarters. Results from facilities with similar procedure volumes and from the entire registry are provided for comparison with a recent online tool developed to allow facilities to perform a detailed analysis of their own data. An executive summary of key metrics is provided in a box-and-whisker plot format (Fig. 2). The NCDR provides an in-hospital risk-adjusted mortality model that is endorsed by the National Quality Forum (6,7). Bleeding and acute kidney injury risk models also have been developed (8).

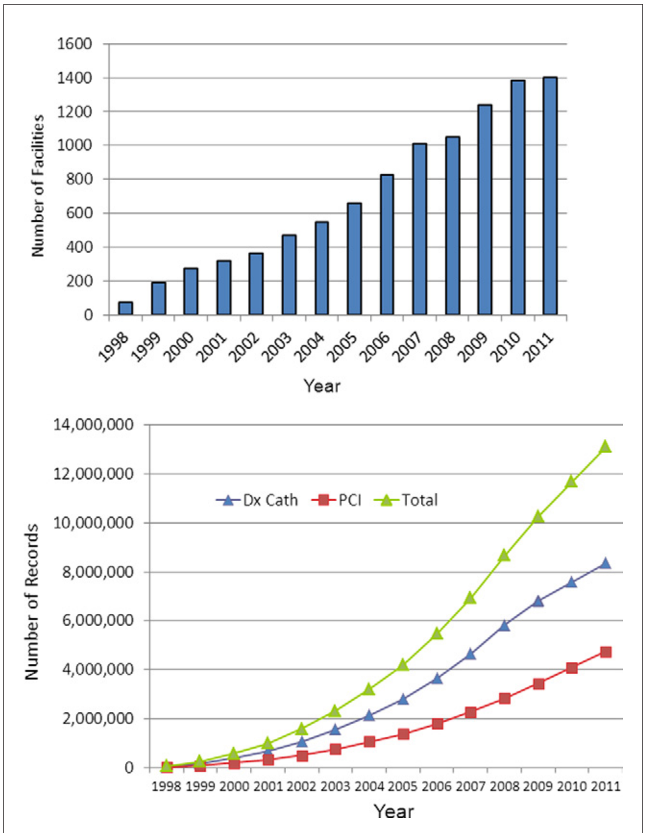

Figure 1 **Cumulative Facilities and Records in the CathPCI Registry**

(Top) Facilities and **(bottom)** individual records in the registry. Dx Cath = diagnostic cardiac catheterization; PCI = percutaneous coronary intervention.

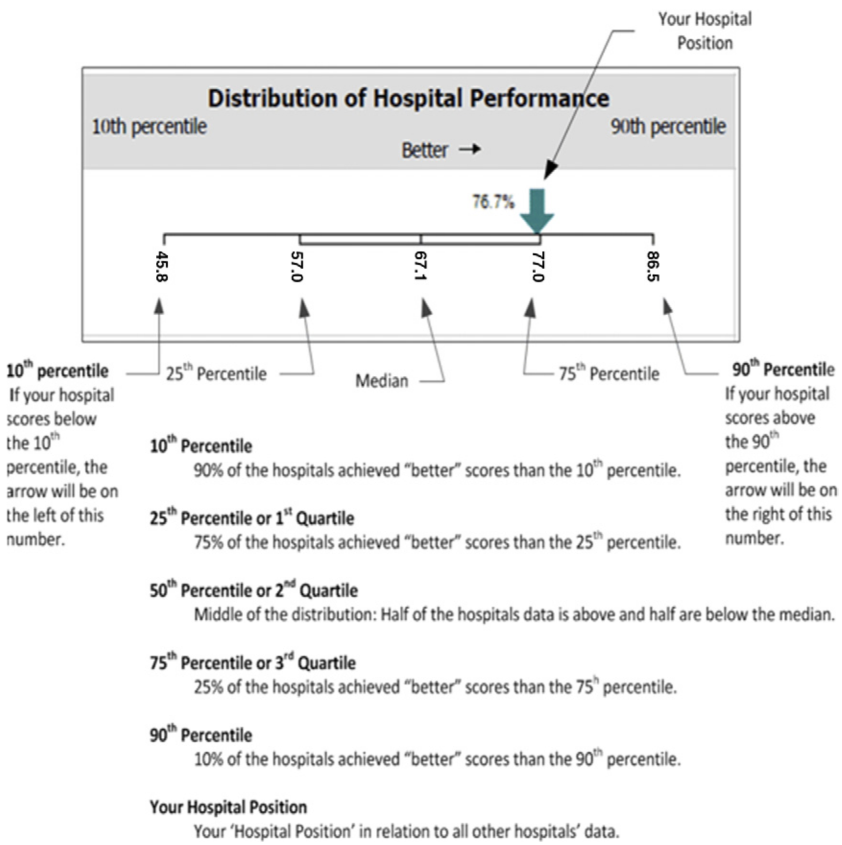

Figure 2 **Box-and-Whisker Plot of Facility Performance**

Example of a box-and-whisker plot used in the executive summary of the registry report.

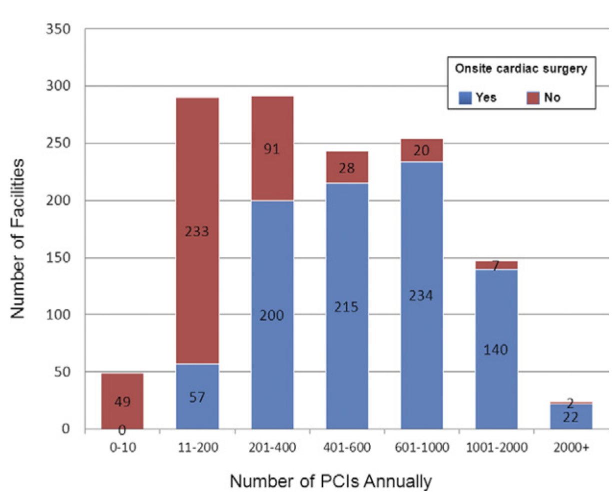

Figure 3 **PCI Volume at Facilities With and Without On-Site Cardiac Surgery**

Abbreviation as in Figure 1.

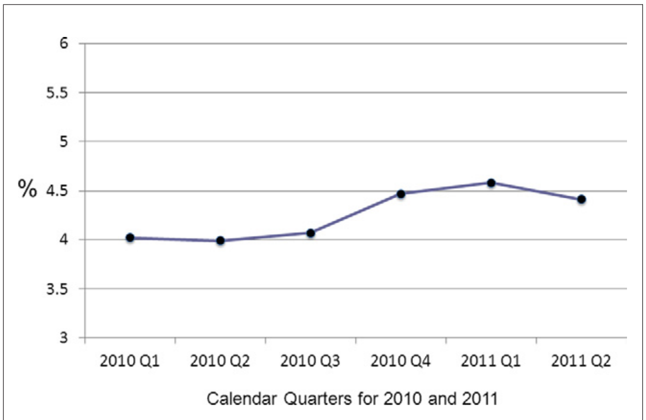

Figure 4 **Percent of PCIs Performed at Low-Volume Facilities**

Low-volume facilities are defined as performing fewer than 200 PCIs annually. Q = quarter; other abbreviation as in Figure 1.

Table 1 Patient Demographics

	Patients Undergoing PCI (n = 941,248)	Patients Undergoing Only Diagnostic Catheterization (n = 1,110,150)
Male/female (%)	67.4/32.6	55.9/44.1
Age		
Median (yrs)	65	64
<55 (%)	21.2	25.6
≥55 to <65 (%)	27.8	26.7
≥65 to <80 (%)	38.7	37.3
≥80 (%)	12.3	10.4
Race (%)		
White	88.3	85.7
Black	8.1	11.4
Asian	2.1	1.7
American Indian/Alaskan	0.5	0.5
Hawaiian/Pacific Islander	0.2	0.2
Hispanic or Latino ethnicity	4.9	5.0
Insurance payers (%)*		
Private	63.6	63.0
Medicare	51.2	49.2
Medicaid	9.3	10.9
Other	4.4	4.5
None	6.4	5.2

*Totals exceed 100% because many entries list more than 1 type of insurance payer.
PCI = percutaneous coronary intervention.

Table 2 Clinical Characteristics

	Patients Undergoing PCI (n = 941,248)	Patients Undergoing Only Diagnostic Catheterization (n = 1,110,150)
Body mass index		
Median	29.1	29.6
Overweight (BMI ≥25 kg/m^2) (%)	79.5	79.3
Obese (BMI ≥30 kg/m^2) (%)	43.4	47.2
Thin (BMI ≤18.5 kg/m^2) (%)	1.1	1.4
Prior (>7 days) myocardial infarction (%)	30.0	20.6
Prior heart failure (%)	11.8	NR
Prior PCI (%)	40.6	24.5
Prior PCI ≤1 yr (%)	33.9	NR
Prior CABG surgery (%)	18.8	13.6
Prior CABG surgery ≤5 yrs (%)	24.4	NR
Current/recent smoker (%)	27.6	NR
Hypertension (%)	82.0	NR
Dyslipidemia (%)	80.0	NR
Chronic lung disease (%)	15.2	NR
Diabetes mellitus (%)	36.2	33.6
Peripheral arterial disease (%)	12.5	NR
Cerebrovascular disease (%)	12.3	NR
GFR, mean ± SD	75.6 ± 30.6	NR
GFR <60 (%)	27.2	NR
Currently undergoing dialysis (%)	2.3	2.5

BMI = body mass index; CABG = coronary artery bypass graft; GFR = glomerular filtration rate; NR = not reported; SD = standard deviation. Other abbreviation as in Table 1.

Current Registry Data

These data provide a contemporary snapshot of diagnostic cardiac catheterization and PCI as performed in the United States, and thus provide an important perspective on many aspects of invasive cardiac procedures, including their current use and outcomes (9). Summary reports from the Implantable Cardioverter Defibrillator Registry have been published (10), and it is the intent of the NCDR to publish aggregate data from all its registries in the future.

The following sections provide an overview of invasive cardiology as cataloged by the NCDR. The tabular data and figures represent summary data for 6 consecutive calendar quarters using version 4 beginning January 1, 2010, and ending June 30, 2011. Data are presented in 2 groups representing patients undergoing only diagnostic cardiac catheterization (n = 1,110,150) and patients undergoing PCI (n = 941,248) during their episode of care.

PCI volume per facility. Among the facilities included in this report, 49% performed 400 or fewer PCI procedures annually and 13% performed more than 1,000 PCI procedures annually (Fig. 3). Three hundred thirty-nine facilities (26%) performed 200 or fewer PCI procedures annually, and these facilities accounted for approximately 4% of the total PCI procedures (Fig. 4). PCI without on-site cardiac surgery was performed at 32.6% of facilities, representing 12.4% of all PCI procedures performed. Among facilities performing PCI without on-site surgery, 89% had a case volume of fewer than 400 PCI procedures annually. Although data showing a relationship between case volume and outcomes are mixed and uncertain, the 2011 PCI guidelines recommend that low-volume operators (fewer than 75 cases annually) not perform PCI procedures at low-volume facilities (fewer than 400 procedures annually)

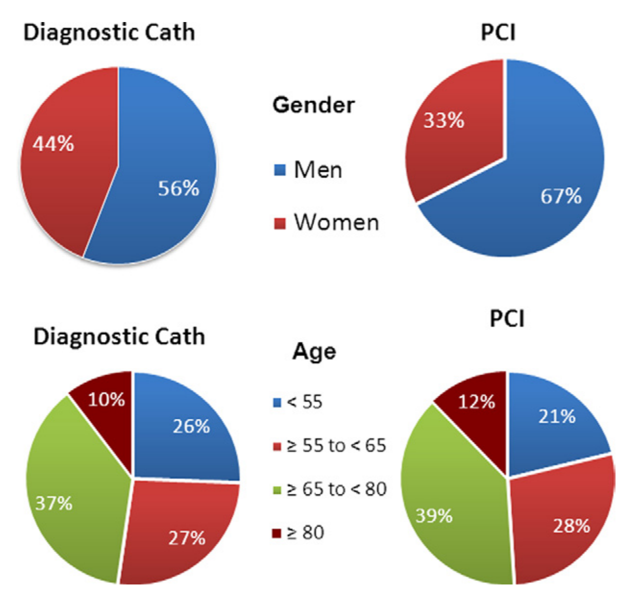

Figure 5 Sex and Age Distributions in the Registry

Age ranges are expressed in years. Cath = cardiac catheterization; other abbreviation as in Figure 1.

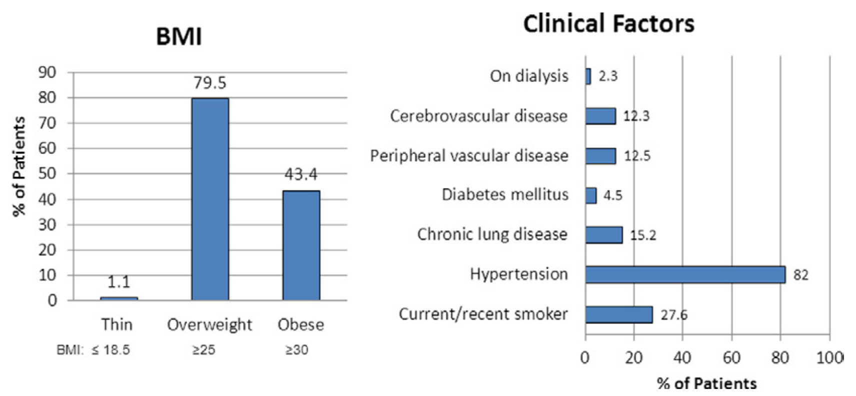

Figure 6 **Clinical Characteristics of Patients Undergoing PCI**

BMI = body mass index in kilograms per square meter; other abbreviation as in Figure 1.

and that facilities performing fewer than 200 PCI procedures annually, unless geographically isolated, carefully consider whether to continue to offer this service (11).

Registry demographics. Demographic data for patients undergoing only diagnostic procedures and those undergoing PCI are shown in Table 1. Approximately two-thirds of those undergoing PCI were male, whereas 56% of those undergoing diagnostic study were male (Fig. 5). Median age and the age distribution were similar for the 2 groups, with approximately half of the patients being 65 years of age or older and approximately 10% of the patients being 80 years of age or older (Fig. 5). Coronary intervention was performed during the same laboratory session as the diagnostic catheterization (so called ad hoc PCI) in 85.7% of the records.

Clinical characteristics and presentation. Approximately 80% of the patients were overweight (body mass index ≥25 kg/m^2), approximately 45% were obese, and approximately 1% were considered thin (body mass index ≤18.5 kg/m^2) (Table 2, Fig. 6). The occurrence of other clinical characteristics and risk factors also is shown. Among diabetic patients undergoing PCI, 36% were treated with insulin, 52% were treated with oral agents, 6% were treated with diet alone, and 5% were receiving no treatment.

Among patients undergoing PCI, approximately 70% had some type of acute coronary syndrome at presentation (unstable angina, non–ST-segment elevation myocardial infarction, ST-segment elevation myocardial infarction [STEMI]), 17.6% had stable angina, and 12% had either atypical symptoms or no angina (Table 3, Fig. 7). In comparison, of those undergoing only diagnostic study, 43.5% had an acute coronary syndrome at presentation—mostly unstable angina, 21.4% had stable angina, and 35.2% had either atypical or no symptoms. Heart failure within the previous 2 weeks, cardiogenic shock within the previous 24 h, and cardiac arrest were uncommon at the time of presentation in both groups. Pre-operative diagnostic catheterization before noncardiac surgery was uncommon (4.9%), as was pre-operative PCI (2.0%). Medication use, especially in patients undergoing PCI, has been examined recently within the NCDR database (12). Nearly 70% of patients undergoing PCI were prescribed antianginal medications within 2 weeks of their procedure; 44% had 1 drug prescribed, whereas 24% had 2 or more drugs prescribed.

Table 3 **Clinical Presentation**

	Patients Undergoing PCI (n = 941,248)	Patients Undergoing Only Diagnostic Catheterization (n = 1,110,150)
CAD presentation (%)		
No symptoms and no angina	9.0	17.6
Symptoms unlikely to be ischemic	3.0	17.6
Stable angina	17.6	21.4
Unstable angina	36.7	33.0
NSTEMI	17.9	8.8
STEMI	15.8	1.7
Heart failure within the previous 2 weeks (%)	9.6	13.6
Cardiogenic shock within the preceding 24 h (%)	1.9	0.7
Cardiac arrest within the preceding 24 h (%)	1.9	0.7
Pre-operative evaluation/treatment before noncardiac surgery (%)	2.0	4.9
Medications		
Antianginals in the preceding 2 weeks	68.0	60.3
Patients with ACS (%)	67.3	66.7
Patients without ACS (%)	69.7	55.4
One antianginal prescribed (%)	44.1	NR
≥2 antianginals prescribed (%)	23.9	NR
Among patients with some antianginal		
Beta-blockers (%)	87.0	NR
Calcium-channel blockers (%)	22.5	NR
Long-acting nitrates (%)	26.1	NR
Ranolazine (%)	2.4	NR
Other antianginal agent (%)	4.2	NR

ACS = acute coronary syndrome; CAD = coronary artery disease; NSTEMI = non–ST-segment elevation myocardial infarction; STEMI = ST-segment elevation myocardial infarction; other abbreviation as in Tables 1 and 2.

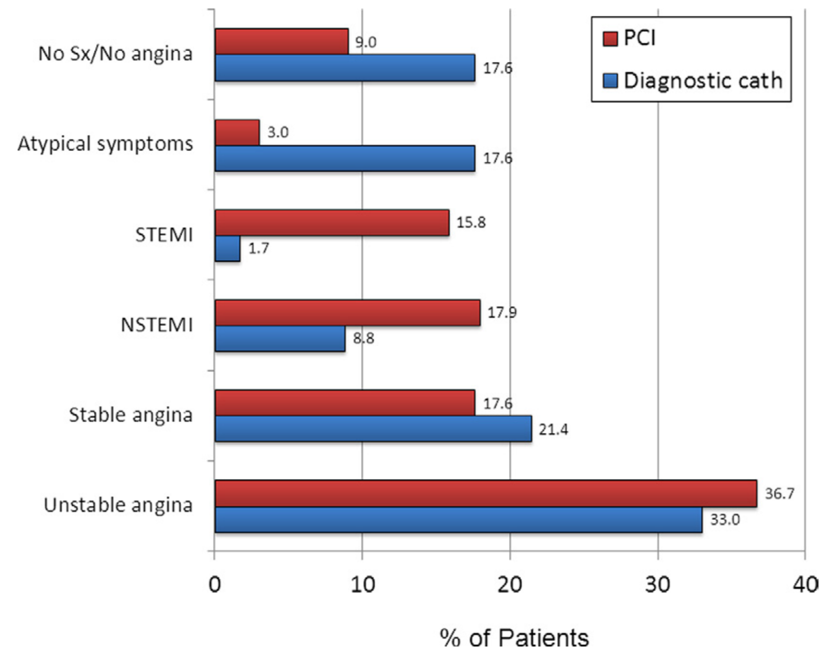

Figure 7 **Clinical Presentation of Patients in the CathPCI Registry**

No Sx = no symptoms; NSTEMI = non–ST-segment elevation myocardial infarction; STEMI = ST-segment elevation myocardial infarction; other abbreviations as in Figures 1 and 5.

Among patients with at least 1 antianginal medication prescribed, beta-blockers were used most frequently (87%), followed by long-acting nitrates (26.1%) and calcium-channel blockers (22.5%).

Use of stress testing, calcium scores, and coronary computed tomography imaging. Among patients undergoing diagnostic catheterization, 45.5% underwent some type of stress test before their procedure, but it is important to note that this includes patients undergoing study for all indications, not just coronary artery disease (CAD) (Table 4). Among patients undergoing PCI, 33.6% had undergone some type of stress study before PCI, but not all patients undergoing PCI would be appropriate candidates for a stress study. If patients who would likely not undergo stress testing are excluded (immediate PCI for STEMI, PCI for STEMI in unstable patients more than 12 h from symptom onset, rescue PCI for failed fibrinolytics, and PCI for high-risk non–ST-segment elevation myocardial infarction or unstable angina), 52.0% of patients underwent some type of stress test before PCI. As a PCI quality metric, the proportion of elective PCIs with either an abnormal stress study suggesting ischemia or a fractional flow reserve measurement 0.8 or less before PCI was assessed. The 50th percentile for this metric among all facilities was 58.7%; facilities in the top 10% for this metric obtained such testing in 76.9% of elective PCIs.

The dominant form of stress testing used was a myocardial perfusion study (Fig. 8). Across all types of stress studies in patients undergoing PCI, 9% to 12% demonstrated negative results, 3% to 6% demonstrated indeterminate results, and 81% to 88% demonstrated abnormal results. An assessment of ischemic risk from the stress study was provided in approximately 60% of the patients and indicated intermediate or high risk in 79% to 87% of PCI patients and in 66% to 76% of those undergoing diagnostic cardiac catheterization. Less than 1% of patients in the database underwent stress testing using magnetic resonance imaging. Overall, coronary calcium scores and coronary computed tomography angiography were performed in few patients before the procedure.

Procedural characteristics. For both diagnostic procedures and PCI, femoral access remains the most frequently used technique (Table 5). Mean and median fluoroscopy times for the entire cohort undergoing diagnostic catheterization are shown. These times are affected by the need to image bypass grafts if present and other diagnostic imaging such as left ventriculography. Because most PCI procedures were performed ad hoc, fluoroscopy time further depended on the number of vessels or lesions treated. Therefore, times were stratified further for single-vessel or single-lesion procedures versus multivessel procedures. As total radiation exposure receives greater attention, the values shown for fluoroscopy times are useful benchmarks for facilities to identify operators who may use excessive radiation consistently for procedures. Mean and median amounts of radiographic contrast, stratified in a similar manner, also are provided in Table 5.

Table 4 Use of Stress Testing and Calcium Scores and Coronary CT Angiography

	Patients Undergoing PCI (n = 941,248)	Patients Undergoing Only Diagnostic Catheterization (n = 1,110,150)
Entire cohort		
Stress or imaging study performed (%)	33.6	45.5
If performed, abnormal (positive) study (%)	81.8	77.7
Low-/intermediate-/high-risk test (%)	19.7/49.8/30.4	32.0/49.3/18.7
Type of stress test (when performed)		
Standard stress test (%)	8.3	8.8
Results: negative/indeterminate/abnormal (%)*	12.2/6.0/81.8	14.9/8.5/76.6
Ischemic risk: low/intermediate/high (%)†	12.5/48.4/39.1	23.8/53.0/23.2
Stress echocardiogram (%)	10.5	10.9
Results: negative/indeterminate/abnormal (%)*	12.3/6.4/81.3	16.7/9.5/73.8
Ischemic risk: low/intermediate/high (%)†	15.4/49.5/35.0	24.1/53.7/22.2
Stress myocardial perfusion imaging (%)	81.9	81.1
Results: negative/indeterminate/abnormal (%)*	9.4/2.9/87.7	12.5/4.9/82.6
Ischemic risk: low/intermediate/high (%)†	20.8/50.1/29.1	33.5/48.6/17.8
Coronary calcium score performed (%) (among stress or imaging population)	1.6	1.2
≤ 100/101 to 400/>400 (%)	13.8/24.2/60.9	20.6/23.9/53.8
Coronary CT angiogram performed (%) (among stress or imaging population)	2.7	1.7
No disease (%)	2.5	8.6
1/2/3-vessel disease (%)	37.2/25.3/20.9	32.3/19.4/17.8
Indeterminate (%)	3.9	7.8
Unavailable	10.1	14.0

*Results missing: diagnostic catheterization: 0.38%, PCI: 0.19% for standard stress test; diagnostic catheterization: 0.4%, PCI: 0.2% for stress echocardiogram; diagnostic catheterization: 0.14%, PCI: 0.09% for stress myocardial perfusion imaging; diagnostic catheterization: 0.56%, PCI: 0.39% for calcium score; diagnostic catheterization: 0.14%, PCI: 0.20% for coronary CT angiogram. †Among those with risk assessment available.

CT = computed tomography. Other abbreviations as in Tables 1 and 3.

Manual compression was the most frequent method used to obtain hemostasis for both diagnostic studies and PCI (Fig. 9). Sealant-type devices are the next most frequently used, whereas staple closure devices represented less than 0.1% of the devices used.

Medications. Anticoagulant and antiplatelet use is shown in Figure 10. Overall, aspirin was given within the 24 h before and during PCI in 87.8% of patients and was contraindicated in 0.7% of patients. By hospital discharge, nearly all patients without a contraindication were receiving aspirin; the 50th percentile of aspirin administration at discharge was 97.9% among all facilities, and in the 90th percentile (top 10% of performers), the aspirin administration rate was 99.7%. Clopidogrel was the most frequently used thienopyridine (76%), with prasugrel used in 11.2% of patients and ticlopidine used in only 0.25% of patients. Ticagrelor was not available commercially during this survey period. By hospital discharge, nearly all patients were receiving a thienopyridine; the 50th percentile of thienopyridine use among all facilities was 98.9% and the 90th percentile was 100%. Fondaparinux was used rarely (1.1%) in patients before or during PCI, with unfractionated heparin or bivalirudin used approximately equally (51% and 56%, respectively). Glycoprotein IIb/IIIa inhibitors were used overall in 28.7% of PCIs and slightly more frequently among patients with an acute coronary syndrome (34.0%). By hospital discharge, nearly all patients without a contraindication were receiving a statin medication; the 50th percentile among facilities for the administration of a statin at discharge was 90.5% and the 90th percentile was 96.5%.

Diagnostic procedure findings and recommendations. Considering patients undergoing only diagnostic procedures, 49.8% had either no CAD or nonobstructive CAD, whereas only 0.2% in the PCI cohort were classified as having all stenoses less than 50% in severity (Table 6). This seems to suggest that many diagnostic procedures were performed on patients without significant CAD. However, diagnostic studies are performed for reasons besides CAD. A more informative quality metric was developed for elective diagnostic procedures excluding patients: 1) with prior coronary artery bypass graft (CABG); 2) undergoing cardiac transplantation evaluation; 3) undergoing pre-operative evaluation for noncardiac surgery; and 4) those with a treatment recommendation other than PCI or CABG. An example of the latter would be an older patient with isolated valvular disease in whom coronary angiography is performed before valve surgery. In this restricted cohort, procedures with the finding of all coronary stenosis of less than 50% occurred at a median of 44.5% among facilities; at the 90th percentile, the value for all coronary stenosis of less than 50% was 32.6%. Furthermore, because a coronary stenosis of less than 50% can be associated with unstable coronary syndromes and roughly 10% of patients with

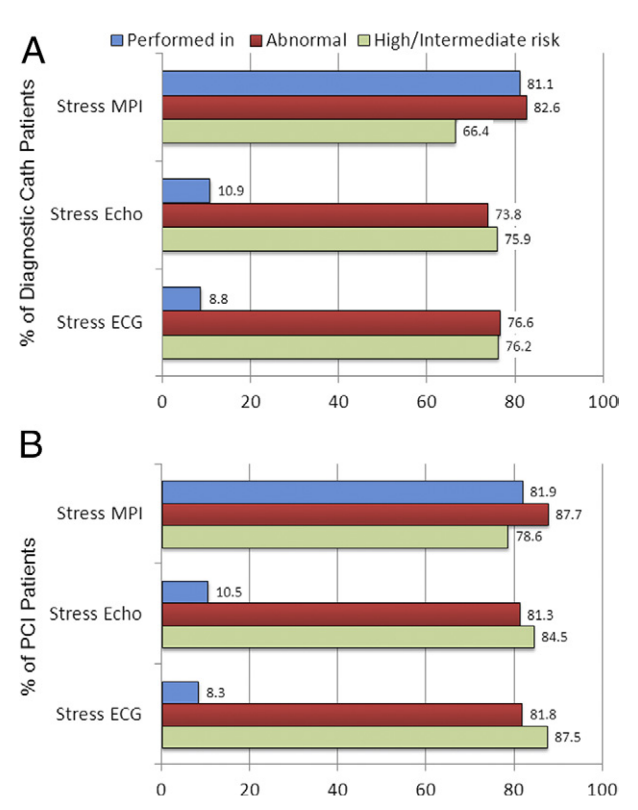

Figure 8 **Use of Stress Testing in the Registry**

(A) Patients undergoing only Dx Cath and **(B)** those undergoing PCI. The **blue bars** indicate the frequency of use for the particular test, the **red bars** indicate the percent of those tests interpreted as having abnormal results, and when available, the **green bars** indicate the percent of tests that were intermediate or high-risk tests. ECG = electrocardiogram; Echo = echocardiography; MPI = myocardial perfusion image; other abbreviations as in Figures 1 and 5.

STEMI are found to have normal coronary arteries, a finding of less than 50% stenosis in a large number of patients does not automatically indicate an overuse of diagnostic angiography (13). However, as previously reported, there is significant interhospital variation in the rate of finding obstructive CAD among patients undergoing elective, diagnostic coronary angiography (14). Left main disease (≥50%) was found in 8.2% of patients undergoing diagnostic study and in 6.4% of patient undergoing PCI, usually in conjunction with additional CAD.

Among patients undergoing only diagnostic study, the treatment recommendations were medical therapy in 69.2%, CABG in 13.0%, no subsequent therapy in 9.2%, and other cardiac therapy without CABG or PCI in 6.3%. In 2.1%, PCI without planned CABG was recommended, but was performed as a separate procedure. The indications for PCI are also shown in Table 6 and Figure 11.

PCI characteristics. Characteristics of the entire cohort of patients undergoing PCI are shown in Table 7 and Figure 12. In 6.0% of the total lesions, PCI of a bypass graft was performed, mostly in vein grafts, with 58.4% occurring in the body of the vein graft. Although PCI of arterial grafts was uncommon, when performed, it was most frequently at the distal anastomosis or in the graft body. Data on devices used were collected, and their use on a per-procedure basis was estimated. All of the adjunctive devices were used infrequently. At least 1 drug-eluting stent (DES) was used in 69.8% of PCI patients, a bare-metal stent (BMS) with no DES was used in 21.5% of PCI patients, and balloon angioplasty without stent use was used in 8.7% of patients. On average, 1.4 stents were placed per procedure performed. When DES were used, 61.6% of the patients received just 1 DES, 26.2% had 2 DES used, 8.6% had 3 DES used, and 3.6% had 4 or more DES used. When BMS were used, 70.0% of the patients received just 1 BMS, 21.9% had 2 BMS used, 6.0% had 3 BMS used, and 3.6% had 4 or more BMS used. The longest lesion length treated during PCI was more than 25 mm in 23% of patients, 10 mm or more but less than 15 mm in 24.5%, and less than 10 mm in 7.7% of patients. Bifurcation lesions were treated in 13% of patients.

Approximately 13% of all stenoses treated by PCI were graded between 40% and 70% in severity. In this subgroup, 25% were evaluated further by either intravascular ultrasound (18%) or fractional flow reserve measurements (7%). In patients with stenoses graded between 40% and 70% in severity treated by PCI, only 8.3% had either no angina or normal stress test results, and approximately 23% of these stenoses were further evaluated by intravascular ultrasound or fractional flow reserve measurements.

Cardiogenic shock was present in the preceding 24 h in 1.9% of patients undergoing PCI during admission (Table 3) and developed during or after PCI in 0.47% of patients (Table 8). Some type of mechanical support device was used in 2.9% of all PCIs performed. This was dominated by the intra-aortic balloon pump that was used alone in 84.4% of the cases with mechanical support or with another support device in 4.7%. However, the timing of support device insertion was different between intra-aortic balloon pumps and other support devices. When intra-aortic balloon pumps were used, they were in place before the procedure in 8.1%, were inserted during the procedure and before PCI in 29.3%, and inserted after the start of the PCI in 62.6%. By contrast, when other forms of mechanical support were used, they were in place at the start of the procedure in 36.3%, were inserted during the procedure and before PCI in 46.2%, and were inserted after the start of the PCI in 17.4%.

Complications during diagnostic cardiac catheterization and in PCI patients without STEMI. Any adverse event occurred in 4.53% of patients undergoing PCI and in 1.35% of patients undergoing diagnostic cardiac catheterization (Table 8). Any bleeding within 72 h occurred in 1.40% of PCI patients without STEMI and in 0.49% of patients undergoing diagnostic cardiac catheterization without STEMI. Figure 13 shows the type of bleeding event that occurred in patients undergoing diagnostic catheterization and PCI with or without STEMI.

STEMI quality metrics and complications. Table 9 shows the quality metrics and complications in STEMI patients.

Table 5 Procedure Characteristics

	Patients Undergoing PCI (n = 941,248)	Patients Undergoing Only Diagnostic Catheterization (n = 1,110,150)
Vascular access		
Femoral/brachial/radial	92.7/0.4/6.9	91.2/0.4/8.3
Fluoroscopy time (min)		
Mean (all studies)	14.5 ± 11.5	4.9 ± 5.71
Median (all studies)	11.4 (7.2, 18.1)	3.1 (2.0, 5.8)
Patients without CABG	10.6 (6.9, 16.8)	2.8 (1.8, 5.0)
PCI of 1 vessel/lesion	12.0 ± 9.9	
PCI of 1 vessel/lesion	9.3 (6.2, 14.5)	
PCI >1 vessel/lesion	17.7 ± 12.2	
PCI >1 vessel/lesion	14.7 (10.0, 22.0)	
Patients with CABG	15.2 (10.0, 23.3)	6.7 (4.2, 10.7)
PCI of 1 vessel/lesion	16.8 ± 12.2	
PCI of 1 vessel/lesion	13.8 (9.1, 21.0)	
PCI >1 vessel/lesion	22.7 ± 14.5	
PCI >1 vessel/lesion	19.4 (13.0, 28.4)	
Contrast volume (ml)		
Mean (all studies)	197.4 ± 90.1	103.2 ± 48.5
Median (all studies)	182.0 (137.0, 245.0)	96.0 (73.0, 125.0)
Patients without CABG, median (25th, 75th)	180.0 (135.0, 240.0)	90.0 (70.0, 120.0)
PCI of 1 vessel/lesion	179.9 ± 79.2	
PCI of 1 vessel/lesion	170.0 (125.0, 220.0)	
PCI >1 vessel/lesion	230.9 ± 97.9	
PCI >1 vessel/lesion	220.0 (164.0, 280.0)	
Patients with CABG	200.0 (149.0, 261.0)	128.0 (96, 170.0)
PCI of 1 vessel/lesion	199.0 ± 91.1	
PCI of 1 vessel/lesion	190.0 (137.0, 250.0)	
PCI >1 vessel/lesion	243.8 ± 106.8	
PCI >1 vessel/lesion	230.0 (170.0, 300.0)	

Values are %, mean ± SD, or median (25th, 75th).
Abbreviations as in Tables 1 and 2.

The median time (50th percentile) from hospital arrival to PCI for nontransfer STEMI patients (door-to-balloon time) was 64.5 min—a marked reduction in door-to-balloon times over a few years that reflect the success of focused process improvement initiatives (15). Nonsystem delays were identified in STEMI patients with a door-to-

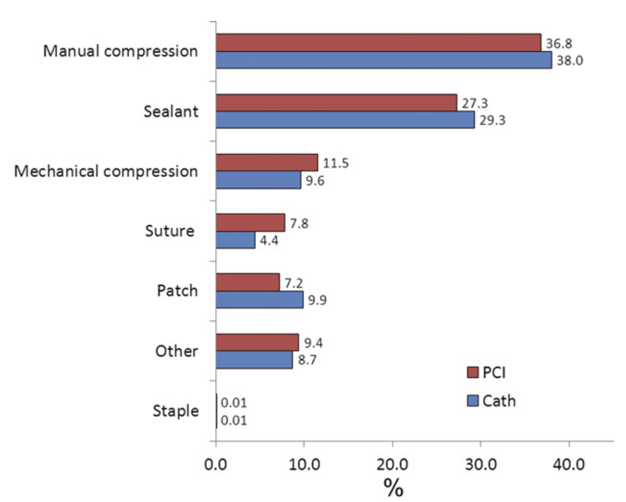

Figure 9 Hemostasis Technique Used in Procedures

Abbreviations as in Figures 1 and 5.

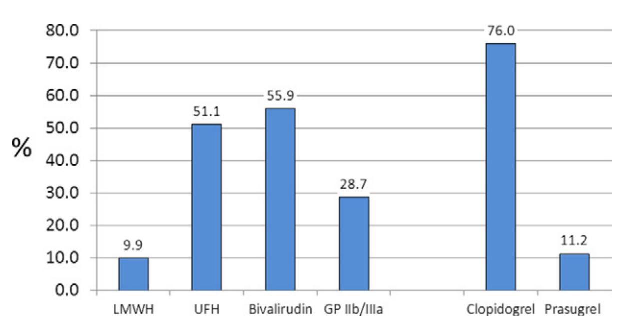

Figure 10 Medications Used During Percutaneous Coronary Intervention

GPIIb/IIIa = glycoprotein IIb/IIIa inhibitor; LMWH = low-molecular-weight heparin; UFH = unfractionated heparin.

Table 6 Diagnostic Procedure Findings and Recommendations

	Patients Undergoing PCI (n = 941,248)	Patients Undergoing Only Diagnostic Catheterization (n = 1,110,150)
Coronary dominance (%)		
Left/right/mixed	9.2/79.4/7.7	10.9/78.1/7.9
Extent of CAD (%)		
Nonobstructive CAD (all stenosis <50%)	0.2	49.8
1-vessel disease	38.1	15.9
2-vessel disease	32.6	12.9
3-vessel disease	39.1	21.1
Treatment recommendation after diagnostic study (%)		
None	0.3	9.2
Medical therapy and/or counseling	1.1	69.2
CABG (including hybrid PCI/CABG procedures)	0.8	13.0
PCI without planned CABG	83.4	2.1
Other cardiac therapy without CABG or PCI	0.1	6.3
Missing or no diagnostic study associated with PCI	14.4	0.1
Indication for PCI (%)		
Primary PCI for STEMI	13.9	
PCI for STEMI (unstable >12 h from Sx onset)	0.9	
PCI for STEMI (stable >12 h from Sx onset)	0.6	
PCI for STEMI (stable after full-dose fibrinolytics)	0.5	
Rescue PCI (after failed full-dose fibrinolytics)	0.5	
PCI for high-risk NSTEMI or unstable angina	45.0	
Staged PCI	6.4	
Other (including stable angina)	32.3	

Sx = symptoms; other abbreviations as in Tables 1, 2, 3, and 4.

balloon time of more than 90 min. Reasons listed for nonsystem delay included difficult vascular access (7.4%), cardiac arrest or need for intubation before PCI (36.2%), delays in providing consent for PCI (4.4%), difficulty crossing the culprit lesion during PCI (17.4%), and other reasons in (34.6%).

The 50th percentile for hospital risk-adjusted mortality rate among STEMI patients was 5.2%, and facilities in the

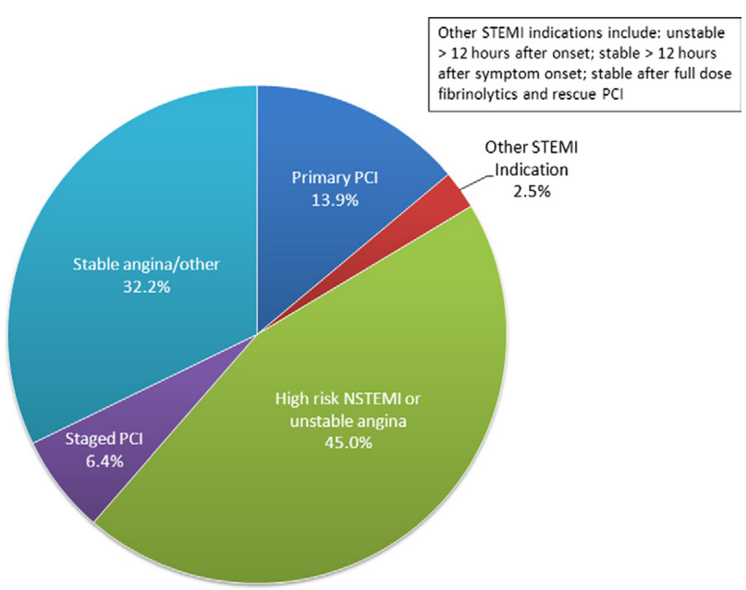

Figure 11 Indication for PCI

Abbreviations as in Figures 1 and 7.

Table 7 PCI Characteristics

No. of vessels treated during PCI (%)	
1 vessel	86.2
2 vessels	12.8
3 vessels	0.7
Multivessel PCI	13.5
Lesion location (1,275,208 lesions treated) (%)	
Left main	1.8
Left anterior descending	37.2
Circumflex	24.1
Ramus	1.6
Right coronary artery	34.9
Bypass graft lesions	6.0
Vein (% of total PCIs)	5.5
Aortic anastomosis	22.1
Body of vein graft	58.4
Distal anastomosis	19.0
Internal mammary or other arterial graft (% of total PCIs)	0.3
Aortic anastomosis	18.3
Body of arterial graft	38.6
Distal anastomosis	41.3
Intracoronary devices used (2,992,180 total devices used) (%)	
Atherectomy	1.2
Laser	0.3
Extraction catheter	3.2
Cutting balloon	6.4
Embolic protection device (based only on SVGs treated)	8.0
Thrombectomy device	5.7

941,248 PCI procedures. Values are %.
SVG = saphenous vein graft; other abbreviation as in Table 1.

top 25th percentile for this metric had a risk-adjusted mortality rate of 3.3%. The top 10th percentile for risk-adjusted STEMI mortality is not reported because it likely was skewed by the number of low-volume facilities reporting no STEMI mortalities. Among STEMI patients undergoing PCI, any adverse event occurred in 12.4%, with specific complications shown in Table 9 and bleeding complications in Figure 13.

PCI success and mortality by patient status. Procedure success typically is defined as angiographic success without associated in-hospital major clinical complications (e.g., death, myocardial infarction, stroke, emergency CABG) (11). Because of the known variability in the visual assessment of stenosis severity and the high likelihood of a good visual result after stent deployment, angiographic success no longer is reported from the CathPCI Registry. However, to provide some perspective for this report, PCI success was defined as completion of the procedure without death, CABG related to PCI failure, PCI failure without clinical deterioration, stroke, pericardial tamponade, or need for dialysis and is shown in Figure 14. Myocardial infarction was not included in this definition because cardiac enzymes were not collected consistently in patients after PCI.

For diagnostic procedures, 65.5% were classified as elective, 31.4% were classified as urgent, 3.0% were classified as emergent, and 0.1% were classified as salvage. For PCI procedures, 44.8% were classified as elective, 37.5% were classified as urgent, 17.3% were classified as emergent, and 0.3% were classified as salvage. Unadjusted mortality for PCI patients in these categories is shown in Figure 15.

Future Directions

The value of the CathPCI Registry will be demonstrated as it is used to understand further the practice of invasive cardiology and to drive a higher level of quality into individual physician practice. The ACCF and its registry partners are committed to expanding the NCDR to its full potential as the delivery of health care continues to evolve.

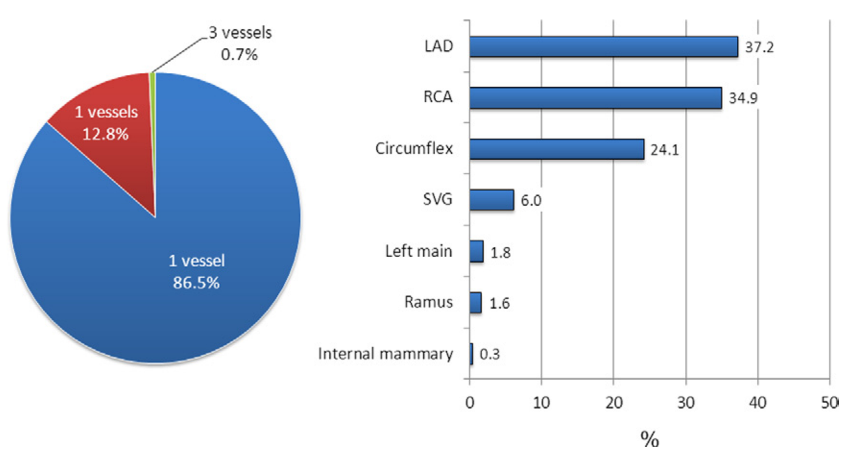

Figure 12 Vessels Treated During PCI

(Left) Number of vessels treated during PCI and **(right)** the specific vessel treated. LAD = left anterior descending; RCA = right coronary artery; SVG = saphenous vein graft; other abbreviation as in Figure 1.

Table 8 Procedure-Related Complications in Patients Without STEMI

	PCI Patients Without STEMI (n = 787,980)	Diagnostic Catheterization Only Patients Without STEMI (n = 1,091,557)
Complications (%)		
Any adverse event	4.53	1.35
Cardiogenic shock	0.47	0.24
Heart failure	0.59	0.38
Pericardial tamponade	0.07	0.03
CVA/stroke	0.17	0.17
% of total strokes that were hemorrhagic	15.6	9.16
New requirement for dialysis	0.19	0.14
In-hospital mortality		
Non–risk-adjusted	0.65	0.72
Non–risk-adjusted excluding CABG patients	0.62	0.60
CABG performed during admission	0.81	7.47
CABG status		
Salvage/emergency	0.01/0.17	0.01/0.27
Urgent/elective	0.47/0.16	5.27/1.92
CABG indication		
PCI failure without clinical deterioration	0.26	
PCI complication	0.14	
Bleeding complications (%)		
Any bleeding event within 72 h of procedure	1.40	0.49
Any other vascular complication requiring treatment	0.44	0.15
RBC/whole-blood transfusion	2.07	N/R

CVA = cerebrovascular accident; RBC = red blood cell; other abbreviations as in Tables 1 and 2.

Research productivity. Since its inception, the CathPCI Registry has been the substrate for more than 70 publications in the peer-reviewed medical literature and for more than 200 abstracts presented at national meetings. These and additional publications continue to provide key insights into the important clinical issues in the rapidly changing field of invasive cardiology.

NCDR data for maintenance of certification. Physicians who have a time-limited board certification from the American Board of Internal Medicine must complete a Maintenance of Certification process to renew their certification. CathPCI Registry data can be used to complete American Board of Internal Medicine's Self-Directed Practice Improvement Module and meet the American

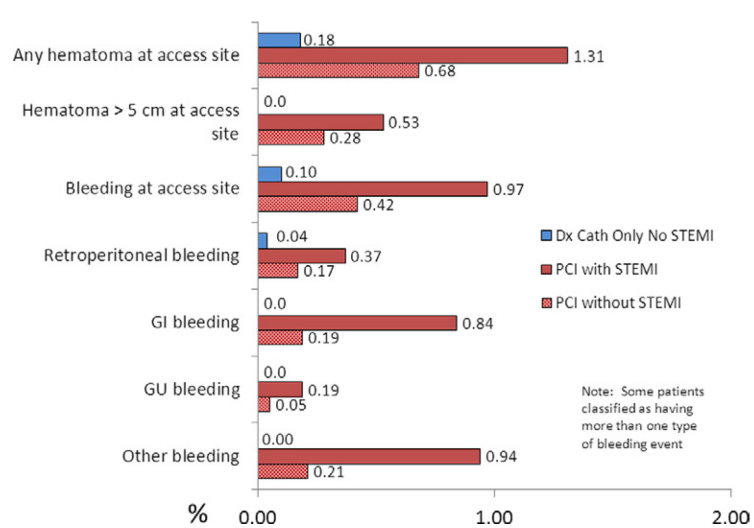

Figure 13 Type of Bleeding Complications

GI = gastrointestinal; GU = genitourinary; STEMI = ST-segment elevation myocardial infarction; other abbreviations as in Figures 1 and 7.

Board of Internal Medicine's Self-Evaluation of Practice Performance requirement (16). The goal is to use actual data from an individual's practice setting to drive quality improvement efforts. Moving forward, there are many additional areas where the organizations share common goals for collaboration, including efforts to enhance life-long learning.

Public reporting. Public reporting of outcomes is increasing in an attempt to encourage both physicians and hospitals to become engaged in quality efforts, to improve areas where problems exist, and to provide patients with information about comparative performance. Public reporting of cardiac surgical outcomes is not new and exists in several states, and the Society of Thoracic Surgeons (STS) recently instituted a voluntary public reporting effort with Consumer's Union (17,18). For such reporting, there is an important distinction between administrative (claims) data and clinical data sources. Disparities in the results between these 2 datasets have been demonstrated, with report cards using only administrative data often being different when compared with those derived from audited and validated clinical data (19). Concern exists that such programs may lead to unintended consequences that could offset their benefits (20). The NCDR is developing a plan for voluntary public reporting of selected NCDR data. Public reporting efforts of the STS have been received favorably, and the NCDR will follow the principles set forth by the ACCF (21,22).

NCDR collaborative research. The ASCERT (American College of Cardiology Foundation–The Society of Thoracic Surgeons Collaboration on the Comparative Effectiveness of Revascularization sTrategies) study is a unique collaboration between the ACCF and the STS (23). This study compared catheter-based and surgery-based revascularization procedures for stable CAD using existing databases from the ACCF and STS, as well as the Centers for Medicare and Medicare Services 100% denominator file data. Other efforts to merge NCDR data with longitudinal administrative datasets provides an efficient and low-cost method to perform longitudinal outcome assessments (24,25).

International expansion. Beginning in February 2011, Sheikh Khalifa Medical City in Abu Dhabi, United Arab Emirates, began data collection for the ACTION Registry-GWTG and CathPCI Registry. Discussions are underway to include NCDR participation for all hospitals in this system and with several other international facilities. Further international expansion of the NCDR provides several unique opportunities for comparisons among regions and different systems of care.

Table 9 STEMI Quality Metrics and PCI Complications

	All Hospitals	
	50th Percentile	90th Percentile
Process metrics		
Median time to PCI for STEMI patients (min) excluding transfer-in patients and those with acceptable reason for delay	64.5	52.0
Proportion receiving PCI in ≤90 min (%) excluding transfer-in patients and those with acceptable reason for delay	89.9%	97.7%
Median time from ED arrival at transferring facility to ED arrival at STEMI receiving facility (min)	88.0	58.0
Median time from ED arrival at transferring facility to immediate PCI at STEMI receiving facility (min)	121.0	85.0
Quality metrics		
In-hospital risk-adjusted mortality: STEMI patients (%)	5.2	3.3*
Utilization metrics		
Median post-procedure LOS for PCI patients with STEMI	3.0	2.0

	Incidence (%)
PCI complications during admission: STEMI patients (n = 153,268)	
Any adverse event	12.4
Cardiogenic shock	3.87
Heart failure	3.46
Pericardial tamponade	0.15
CVA/stroke	0.56
% of total strokes that are hemorrhagic	19.7
New requirement for dialysis	0.63
CABG performed during admission	
CABG status	
Salvage/emergency	0.05/0.87
Urgent/elective	2.08/0.43
CABG indication	
PCI failure without clinical deterioration	0.58
PCI complication	0.22
Bleeding complications	
Any bleeding event within 72 h of procedure	3.85
Any other vascular complication requiring treatment	0.62
RBC/whole-blood transfusion	5.61

*This represents the top 25th percentile rather than the top 10th percentile.
ED = emergency department; LOS = length of stay; other abbreviations as in Tables 1, 2, 3, and 8.

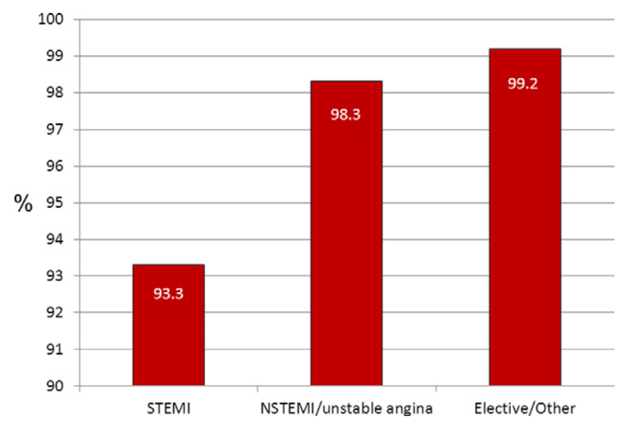

Figure 14 PCI Success

See text for the definition of success. Abbreviations as in Figures 1 and 7.

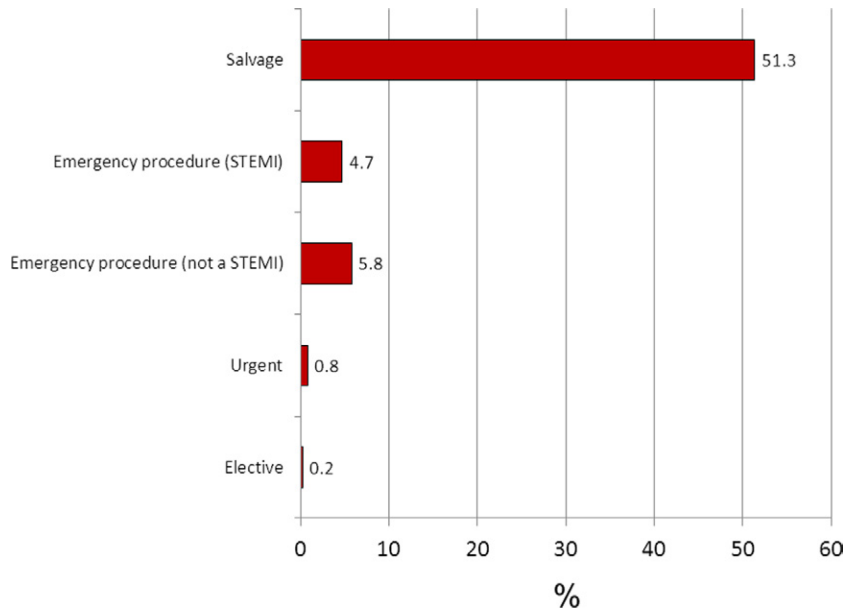

Figure 15 **Unadjusted PCI Mortality**

Unadjusted mortality is shown for the type of presentation. Abbreviations as in Figures 1 and 7.

Reprints requests and correspondence: Dr. Gregory J. Dehmer, Cardiology Division (MS-33-ST156), Scott & White Healthcare, 2401 South 31st Street, Temple, Texas 76508. E-mail: gdehmer@sw.org.

REFERENCES

1. Weintraub WS, McKay CR, Riner RN, et al. The American College of Cardiology National Database: progress and challenges. American College of Cardiology Database Committee. J Am Coll Cardiol 1997;29:459–65.
2. Brindis RG, Fitzgerald S, Anderson HV, Shaw RE, Weintraub WS, Williams JF. The American College of Cardiology-National Cardiovascular Data Registry (ACC-NCDR): building a national clinical data repository. J Am Coll Cardiol 2001;37:2240–5.
3. National Cardiovascular Data Registry. NCDR CathPCI Registry v4.4 Coder's Data Dictionary. Available at: http://www.ncdr.com/WebNCDR/NCDRDocuments/CathPCI_v4_CodersDictionary_4.4.pdf. Accessed January 10, 2012.
4. Crudu V, Blankenship J, Berger P, Scott T, Skelding K. Complications related to access site after percutaneous coronary interventions: are the adverse events underreported? Catheter Cardiovasc Interv 2011;77:643–7.
5. Messenger JC, Ho KKL, Young CH, et al., on behalf of the National Cardiovascular Data Registry Science and Quality Oversight Committee Data Quality Workgroup. NCDR data quality brief: the NCDR Data Quality Program in 2012. J Am Coll Cardiol 2012;60:1484–8.
6. Shaw RE, Anderson HV, Brindis RG, et al. Development of a risk adjustment mortality model using the American College of Cardiology-National Cardiovascular Data Registry (ACC-NCDR) experience: 1998–2000. J Am Coll Cardiol 2002;39:1104–12.
7. Peterson ED, Dai D, DeLong ER, et al. Contemporary mortality risk prediction for percutaneous coronary intervention: results from 588,398 procedures in the National Cardiovascular Data Registry. J Am Coll Cardiol 2010;55:1923–32.
8. Mehta SK, Frutkin AD, Lindsey JB, et al. Bleeding in patients undergoing percutaneous coronary intervention: the development of a clinical risk algorithm from the National Cardiovascular Data Registry. Circ Cardiovasc Interv 2009;2:222–9.
9. Roe MT, Messenger JC, Weintraub WS, et al. Treatments, trends, and outcomes of acute myocardial infarction and percutaneous coronary intervention. J Am Coll Cardiol 2010;56:254–63.
10. Hammill SC, Kremers MS, Stevenson LW, et al. National ICD Registry Annual Report 2009. Review of the registry's fourth year, incorporating lead data and pediatric ICD procedures, and use as a national performance measure. Heart Rhythm 2010;7:1340–5.
11. Levine GN, Bates ER, Blankenship JC, et al. 2011 ACCF/AHA/SCAI guideline for percutaneous coronary intervention: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. J Am Coll Cardiol 2011;58:e44–122.
12. Borden WB, Redberg RF, Mushlin AI, Dia D, Kaltenbach LA, Spertus JA. Patterns and intensity of medical therapy in patients undergoing percutaneous coronary intervention. JAMA 2011;305:1882–9.
13. Diver DJ, Bier JD, Ferreira PE, et al. Clinical and arteriographic characterization of patients with unstable angina without critical coronary arterial narrowing (from the TIMI-IIIA trial). Am J Cardiol 1994;74:531–7.
14. Douglas PS, Patel MR, Bailey SR, et al. Hospital variability in the rate of finding obstructive coronary artery disease at elective, diagnostic coronary angiography. J Am Coll Cardiol 2011;58:801–9.
15. Krumholtz HM, Herrin J, Miller LE, et al. Improvements in door-to-balloon time in the United States, 2005–2010. Circulation 2011;124:1038–45.
16. American Board of Internal Medicine. Instructions for Using NCDR Data to Complete ABIM's Self-Directed PIM. Available at http://www.abim.org/pdf/self-directed/SDPIM-NCDR-instructions.pdf. Accessed August 30, 2011.
17. New York State Department of Health. Cardiovascular Disease Data and Statistics. Available at: http://www.nyhealth.gov/statistics/diseases/cardiovascular/. Accessed July 8, 2010.
18. Department of Health Care Policy, Massachusetts Data Analysis Center (Mass-DAC). Cardiac Surgery Cohort—All Years. Available at: http://www.massdac.org/reports/surgery.html. Accessed July 8, 2010.
19. Shahian DM, Silverstein T, Lovett AF, Wolf RE, Normand SL. Comparison of clinical and administrative data sources for hospital coronary artery bypass graft surgery report cards. Circulation 2007;115:1518–27.

20. Werner RM, Asch DA. The unintended consequences of publicly reporting quality information. JAMA 2005;293:1239–44.
21. Ferris TG, Torchiana DF. Public release of clinical outcomes data—online CABG report cards. N Engl J Med 2010;363:1593–5.
22. Drozda JP Jr., Hagan EP, Mirro MJ, Peterson ED, Wright JS, American College of Cardiology Foundation Writing Committee. ACCF 2008 health policy statement on principles for public reporting of physician performance data: a report of the American College of Cardiology Foundation Writing Committee to Develop Principles for Public Reporting of Physician Performance Data. J Am Coll Cardiol 2008;51:1993–2001.
23. Weintraub WS, Grau-Sepulveda MV, Weiss JM, et al. Comparative effectiveness of revascularization strategies. N Engl J Med 2012;366:1467–76.
24. Douglas PS, Brennan JM, Anstrom KJ, et al. Clinical effectiveness of coronary stents in elderly persons: results from 262,700 Medicare patients in the American College of Cardiology–National Cardiovascular Data Registry. J Am Coll Cardiol 2009;53:1629–41.
25. Brennan JM, Peterson ED, Messenger JC, et al. Linking the National Cardiovascular Data Registry CathPCI Registry with Medicare claims data: validation of a longitudinal cohort of elderly patients undergoing cardiac catheterization. Circ Cardiovasc Qual Outcomes 2012;5:134–40.

Key Words: cardiac catheterization ▪ invasive cardiology ▪ National Cardiovascular Data Registry ▪ percutaneous coronary intervention.