

## ONLINE FIRST

# Factors Associated With 30-Day Readmission Rates After Percutaneous Coronary Intervention

Farhan J. Khawaja, MD; Nilay D. Shah, PhD; Ryan J. Lennon, MS; Joshua P. Slusser, BS; Aziz A. Alkatib, MD; Charanjit S. Rihal, MD, MBA; Bernard J. Gersh, MB, ChB, DPhil; Victor M. Montori, MD, MSc; David R. Holmes, MD; Malcolm R. Bell, MBBS; Jephtha P. Curtis, MD; Harlan M. Krumholz, MD, SM; Henry H. Ting, MD, MBA

**Background:** Thirty-day readmission rates have become a publicly reported quality performance measure for congestive heart failure, acute myocardial infarction, and percutaneous coronary intervention (PCI). However, little is known regarding the factors associated with 30-day readmission after PCI.

**Methods:** To assess the demographic, clinical, and procedural factors associated with 30-day readmission rates after PCI, we identified 15 498 PCI hospitalizations (elective or for acute coronary syndromes) from January 1998 through June 2008 at Saint Marys Hospital, Rochester, Minnesota. All were included in this analysis. Multivariate logistic regression models were used to estimate the adjusted association between demographic, clinical, and procedural variables and 30-day readmission. The association between 30-day readmission and 1-year mortality was estimated using Cox proportional hazards models with readmission as a time-dependent covariate and by using landmark analysis. The main outcome measures were all-cause 30-day readmission to any hospital following PCI and 1-year mortality.

**Results:** Overall, 9.4% of PCIs (n=1459) were readmitted, and 0.68% of PCIs (n=106) resulted in death within 30 days after discharge. After multivariate analysis, female sex, Medicare insurance, having less than a high school education, unstable angina, cerebrovascular accident or transient ischemic attack, moderate to severe renal disease, chronic obstructive pulmonary disease, peptic ulcer disease, metastatic cancer, and a length of stay of more than 3 days were associated with an increased risk of 30-day readmission after PCI. Thirty-day readmission after PCI was associated with a higher risk of 1-year mortality (adjusted hazard ratio, 1.38; 95% CI, 1.08-1.75;  $P=.009$ ).

**Conclusions:** Nearly 1 in 10 patients undergoing PCI were readmitted within 30 days. Thirty-day readmission after PCI was associated with a higher risk of 1-year mortality.

*Arch Intern Med.* 2012;172(2):112-117.

Published online November 28, 2011.

doi:10.1001/archinternmed.2011.569

**T**HIRTY-DAY READMISSION rates have become a quality performance measure, and the Center for Medicare and Medicaid Services (CMS) publicly reports hospital-level, 30-day, risk-standardized readmission rates for patients hospitalized with congestive heart failure (CHF), acute myocardial infarction (AMI), and for patients undergoing percutaneous coronary intervention (PCI).<sup>1-3</sup> The Patient Protection and Affordable Care Act of 2010 will link quality outcomes, such as 30-day readmission rates, to hospital reimbursement with the expected implementation of value-based purchasing.<sup>4-6</sup> Hence, there is great interest from hospitals and clinicians to understand and improve modifiable factors associated with 30-day readmission rates.

Percutaneous coronary interventions are among the most commonly per-

formed procedures in the United States, and a recent analysis of Medicare beneficiaries who underwent PCI in 2005 demonstrated that 30-day readmission and mortality rates were 14.6% and 1.0%, respectively, and that readmitted patients had a higher risk of 30-day mortality.<sup>7</sup>

## See Invited Commentary at end of article

However, we have limited knowledge regarding demographic, clinical, and procedural factors associated with 30-day readmission after PCI for a general population because Medicare beneficiaries account for only 49% of all PCIs.<sup>8</sup> Moreover, the association between 30-day readmission after PCI and 1-year mortality is not known. The Mayo Clinic (Rochester, Minnesota) PCI registry prospectively collects demographic, clinical, and procedural variables, as well as follow-up

Author Affiliations are listed at the end of this article.

outcomes, including readmission and mortality, for all patients undergoing PCI. Accordingly, we sought to identify factors associated with 30-day readmission rates, the reason for the readmission, and the association of 30-day readmission with 1-year mortality for patients after PCI.

## METHODS

All patients undergoing PCI at Saint Marys Hospital in Rochester are followed in a prospective registry. Data elements include demographic, clinical, angiographic, procedural, and follow-up variables. Postprocedural and in-hospital events are recorded, and each patient is contacted by telephone using a standardized questionnaire at 6 months, 1 year, and then annually by trained personnel to document long-term outcomes. During the 6-month follow-up contact, details of any readmission during that time period are collected, including the date, name of hospital, and if the reason for readmission was cardiovascular or noncardiovascular. All adverse events are confirmed by reviewing the medical records for patients followed at our institution and by contacting the patients' physicians and requesting hospital records for patients treated elsewhere.

All patients undergoing PCI (including elective or for an acute coronary syndrome) from January 1998 to June 2008 were included in this analysis. A total of 375 patients were excluded because they declined authorization allowing the use of their medical records for research, as required by a State of Minnesota statute, and 499 patients were excluded because their health care was paid for by the Federal Bureau of Prisons or by non-US governments. In addition, 289 patients who died prior to discharge and 425 patients without 30-day follow-up were excluded. We identified 15 498 PCI hospitalizations (in 12 813 unique patients) that met the inclusion criteria. The study was approved by the Mayo Clinic institutional review board.

Demographic variables, including age and sex, were collected from the Mayo Clinic PCI registry. Other demographic variables were collected from Mayo Clinic administrative databases and merged with the PCI registry. These variables included marital status (single, married, divorced, separated, or widowed), education level (eighth grade or less, some high school, high school graduate or equivalent, some college, college graduate, postgraduate studies, or unknown), miles traveled to Mayo Clinic, and insurance type (Medicare, Medicaid, uninsured, or privately insured).

Clinical variables included myocardial infarction (MI) type (ST-elevation myocardial infarction [STEMI] or non-ST-elevation myocardial infarction [NSTEMI]); unstable angina; time since most recent MI; multivessel disease; body mass index (BMI) (calculated as weight in kilograms divided by height in meters squared); CHF status; diabetes mellitus; hypertension; hyperlipidemia; moderate to severe renal dysfunction (defined as a creatinine level of  $>3.0$  mg/dL [ $265.2$   $\mu$ mol/L] or a history of hemodialysis or renal transplant); history of cerebrovascular accident or transient ischemic attack (CVA/TIA); peripheral vascular disease (PVD); chronic obstructive pulmonary disease (COPD); peptic ulcer disease; tumor, lymphoma, or leukemia; metastatic cancer; preprocedure shock; and left ventricular ejection fraction. Procedural characteristics included the urgency of PCI, drug-eluting stent use, intra-aortic balloon pump use, procedural success (defined as  $<20\%$  residual stenosis without in-hospital death, MI, or stroke), in-hospital MI, in-hospital MI/CABG/TVR (target vessel revascularization), and length of stay. All patients who receive PCI at Mayo Clinic receive a baseline troponin level and electrocar-

diogram prior to PCI and have 3 follow-up troponin levels with an electrocardiogram to detect in-hospital MI. Procedural complications included major bleeding, blood transfusions, and post-PCI renal failure.

The study outcomes were all-cause readmission to any hospital within 30 days of discharge and 1-year mortality following PCI. During the study period, all patients undergoing PCI were hospitalized, and no same-day discharges occurred after PCI. Continuous data are summarized as mean (SD) unless otherwise stated. Categorical data are summarized as frequency and group percentage. Differences between patients who were vs those who were not readmitted within 30 days were tested with generalized estimating equations to account for the correlation between multiple hospitalizations on the same patients. Logistic regression models were built for 30-day readmission by selecting from the 40 covariates associated with the end point at the 0.15 significance level and then choosing the best subset of covariates according to an overall model score test. The covariates in the model included age (forced covariate), procedure date (per year), female sex, insurance status (Medicare, Medicaid, privately insured, and uninsured), education level (eighth grade or less, some high school, high school graduate or equivalent, some college, college graduate, postgraduate studies, or unknown), distance traveled to Mayo Clinic per 100 miles, time since most recent MI ( $<24$  hours, 1-7 days,  $>7$  days, never [reference group]), unstable angina, CHF on presentation, hyperlipidemia, PVD, CVA/TIA, moderate to severe renal disease, COPD, peptic ulcer disease, metastatic cancer, elective PCI, drug-eluting stent use, procedural success, extreme blood loss, and length of stay of more than 3 days. To assess model performance, we calculated the maximum rescaled  $R^2$  statistic,<sup>9</sup> the receiver operating characteristic area under the curve (AUC), and the observed readmission rates in the lowest and highest risk deciles. We also performed a sensitivity analysis at the patient level that included only the first PCI for each patient ( $n=12\ 813$ ), and all subsequent PCIs for the same patient were excluded. The results from the sensitivity analysis are similar to those from the analysis at the PCI hospitalization level and are not reported separately.

The association between 30-day readmission and 1-year mortality was estimated using hazard ratios (HRs) from Cox proportional hazards models. Thirty-day readmission was coded as a time-dependent covariate and was considered "absent" until readmission within 30 days after discharge. In addition, the partial HR was also estimated in a Cox HR using a 3-*df* spline function of the linear predictor for 30-day readmission from the previous logistic regression model for risk adjustment. For the Cox regression analysis for mortality, time zero started at the time of discharge, and only the first PCI per patient was included. We also performed a landmark analysis for mortality by 30-day readmission status calculated with Kaplan-Meier methods, which included only patients after first PCI who survived to 30 days after hospital discharge. Time zero for the Kaplan-Meier landmark analysis plot was 30 days after hospital discharge to discriminate between those who were and those who were not readmitted within 30 days.

## RESULTS

This study included 15 498 PCI procedures, which met the inclusion criteria, at St Marys Hospital from January 1998 through June 2008. Overall, 1459 PCI procedures (9.4%) were readmitted within 30 days. There were 106 deaths within 30 days (0.68%), including 33 deaths that occurred during or after a readmission and 73 deaths that were not associated with a readmission.

**Table 1. Demographic Characteristics**

Variable	No. (%)		P Value
	No 30-Day Readmission (n=14 039)	30-Day Readmission (n=1459)	
Age, mean (SD), y	67 (12)	69 (12)	<.001
Female sex	4070 (29)	540 (37)	<.001
Marital status			
Single	848 (6)	70 (5)	<.001
Married	10 737 (78)	1066 (74)	
Divorced	847 (6)	103 (7)	
Separated	27 (0.2)	0	
Widowed	1381 (10)	204 (14)	
Education level			
≤8th grade	1094 (8)	175 (12)	<.001
Some high school	1023 (7)	143 (10)	
High school graduate or GED	4768 (34)	467 (32)	
Some college	2438 (17)	261 (18)	
College graduate	1088 (8)	83 (6)	
Postgraduate studies	1396 (10)	116 (8)	
Unknown	2232 (16)	214 (15)	
Insurance category			
Medicaid	436 (3)	51 (3)	<.001
Medicare	7947 (57)	967 (66)	
Privately insured	5497 (39)	424 (29)	
Uninsured	159 (1)	17 (1)	
Miles traveled to Mayo Clinic, Rochester, Minnesota, median (Q1-Q3 <sup>a</sup> )	51.8 (30.8-109.9)	40.8 (16.4-86.4)	.003

Abbreviation: GED, General Educational Development.  
<sup>a</sup>The 25th to 75th quartiles.

**FACTORS ASSOCIATED WITH 30-DAY READMISSION**

Demographic characteristics are shown in **Table 1**, and clinical and procedural characteristics are shown in **Table 2**. After multivariate analysis (**Figure 1**), demographic factors associated with an increased risk of 30-day readmission after PCI included female sex (odds ratio [OR], 1.32; 95% CI, 1.17-1.48), Medicare insurance (OR, 1.20; 95% CI, 1.01-1.43; the reference group was all other insurance types), and less than a high school education (OR, 1.35; 95% CI, 1.17-1.55; the reference group was high school graduate or higher education levels). The clinical and procedural factors associated with an increased risk of readmission included CHF at presentation (OR, 1.36; 95% CI, 1.15-1.60), CVA/TIA (OR, 1.22; 95% CI, 1.04-1.44), moderate to severe renal disease (OR, 1.46; 95% CI, 1.12-1.89), COPD (OR, 1.31; 95% CI, 1.12-1.54), peptic ulcer disease (OR, 1.29; 95% CI, 1.05-1.59), metastatic cancer (OR, 1.92; 95% CI, 1.19-3.09), and a length of stay of more than 3 days (OR, 1.59; 95% CI, 1.37-1.84). The general R<sup>2</sup> statistic for the model for 30-day readmission was 0.052, the AUC was 0.65 (**Figure 2**), and the observed readmission rates ranged from 3.2% in the lowest predicted decile to 19.7% in the highest decile.

**Table 2. Clinical and Procedural Characteristics**

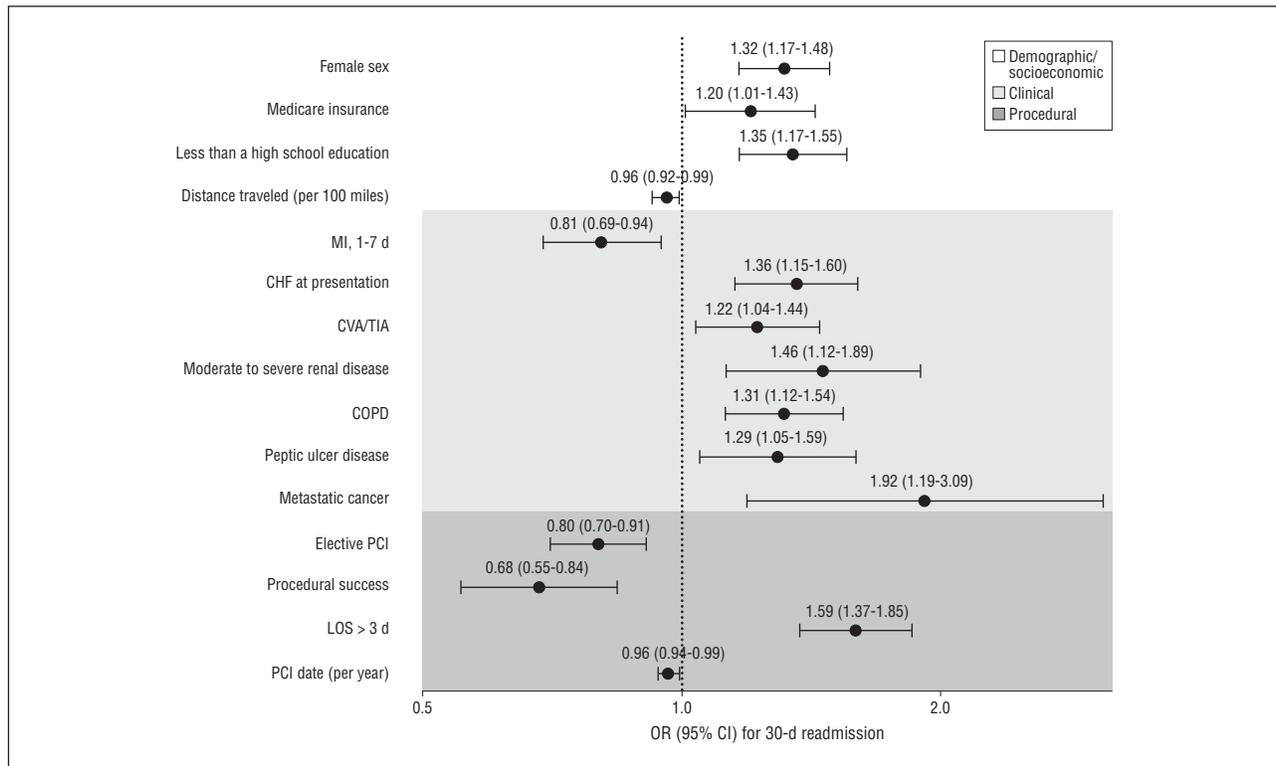
Variable	No 30-Day Readmission (n=14 039)	30-Day Readmission (n=1459)	P Value
<b>Clinical Characteristics</b>			
Unstable angina	8014 (57)	864 (59)	.19
MI type, STEMI/NSTEMI			
No MI	9465 (67)	918 (63)	.003
STEMI	2399 (17)	276 (19)	
NSTEMI	2175 (15)	265 (18)	
Most recent MI			
<24 h	2498 (18)	330 (23)	<.001
1-7 d	2076 (15)	211 (15)	
>7 d	3322 (24)	344 (24)	
Never	5918 (43)	556 (39)	
Multivessel disease	8966 (68)	970 (70)	.08
BMI, mean (SD)	29.7 (5.7)	29.4 (6.1)	.03
CHF at presentation	1427 (11)	254 (18)	<.001
Diabetes mellitus	3555 (25)	390 (27)	.23
Hyperlipidemia	10 404 (81)	1042 (78)	.01
Hypertension	9864 (73)	1084 (77)	.004
Moderate to severe renal disease	447 (3)	88 (6)	<.001
CVA/TIA	1573 (11)	237 (17)	<.001
Peripheral vascular disease	1451 (11)	210 (15)	<.001
COPD	1489 (11)	237 (17)	<.001
Peptic ulcer disease	814 (6)	129 (9)	<.001
Tumor/lymphoma/leukemia	1687 (12)	220 (15)	<.001
Metastatic cancer	107 (1)	27 (2)	<.001
Preprocedural shock	379 (3)	77 (5)	<.001
LVEF measure			<.001
>40%	6511 (46)	586 (40)	<.001
NA	6131 (44)	684 (47)	
≤40%	1397 (10)	189 (13)	
<b>Procedural Characteristics</b>			
Urgency of PCI			
Elective	4887 (35)	390 (27)	<.001
Urgent	6581 (47)	714 (49)	
Emergency	2567 (18)	355 (24)	
Drug-eluting stents	5104 (36)	426 (29)	<.001
IABP use	218 (2)	41 (3)	<.001
Procedural success	13 285 (95)	1327 (91)	<.001
In-hospital MI	562 (4)	86 (6)	<.001
In-hospital MI/CABG/TVR	694 (5)	113 (8)	<.001
Blood transfusion	597 (4)	126 (9)	<.001
GI tract bleeding	108 (1)	24 (2)	<.001
Renal failure post-PCI	98 (1)	26 (2)	<.001
Length of stay, median (Q1-Q3 <sup>a</sup> ), d	1.0 (1.0-3.0)	2.0 (1.0-4.0)	.004

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); CABG, coronary artery bypass graft; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; CVA/TIA, cerebrovascular accident/transient ischemic attack; GI, gastrointestinal; IABP, intra-aortic balloon pump; LVEF, left ventricular ejection fraction; MI, myocardial infarction; NA, not available; NSTEMI, non-ST-elevation myocardial infarction; PCI, percutaneous coronary intervention; STEMI, ST-elevation myocardial infarction; TVR, target vessel revascularization.

<sup>a</sup>The 25th to 75th quartiles.

**READMISSION DIAGNOSES**

Of the 1459 PCIs readmitted within 30 days, 1003 (69%) were readmitted for cardiac-related reasons. Only 4.2% (n=61) had repeated PCI within 30 days of discharge, and 8.9% (n=130) had PCI or CABG within 30 days of discharge.



**Figure 1.** Factors associated with 30-day readmission after multivariate analysis. CHF indicates congestive heart failure; COPD, chronic obstructive pulmonary disease; CVA/TIA, cerebrovascular accident/transient ischemic attack; LOS, length of stay; MI, myocardial infarction; OR, odds ratio; PCI, percutaneous coronary intervention.

### READMISSION AND SUBSEQUENT MORTALITY

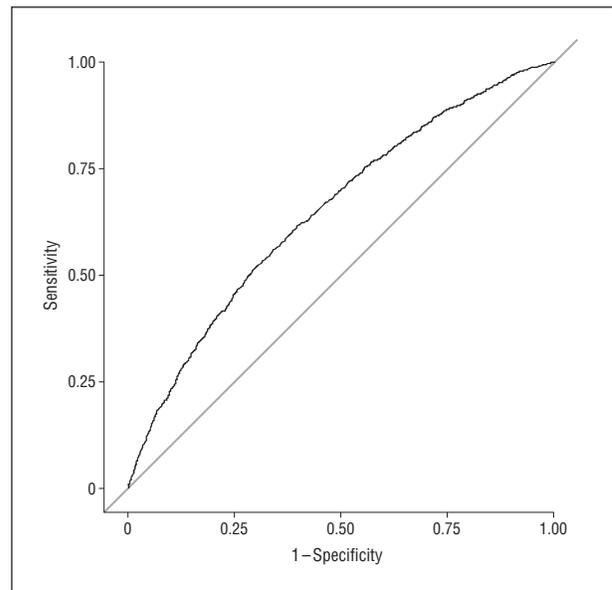
In unadjusted analysis, 30-day readmission after PCI was associated with a higher risk of 1-year mortality (HR, 1.99; 95% CI, 1.57-2.52;  $P < .001$ ). After adjustment using the Cox proportional hazards model for factors associated with 30-day readmission, 30-day readmission remained associated with a higher risk of 1-year mortality (HR, 1.38; 95% CI, 1.08-1.75;  $P = .009$ ).

**Figure 3** shows the Kaplan-Meier landmark analysis plot for mortality rates by 30-day readmission status. This landmark analysis included only patients who survived to 30 days after discharge. Patients who were readmitted within 30 days had higher mortality at 1 year compared with patients who were not readmitted ( $P < .001$ ).

### COMMENT

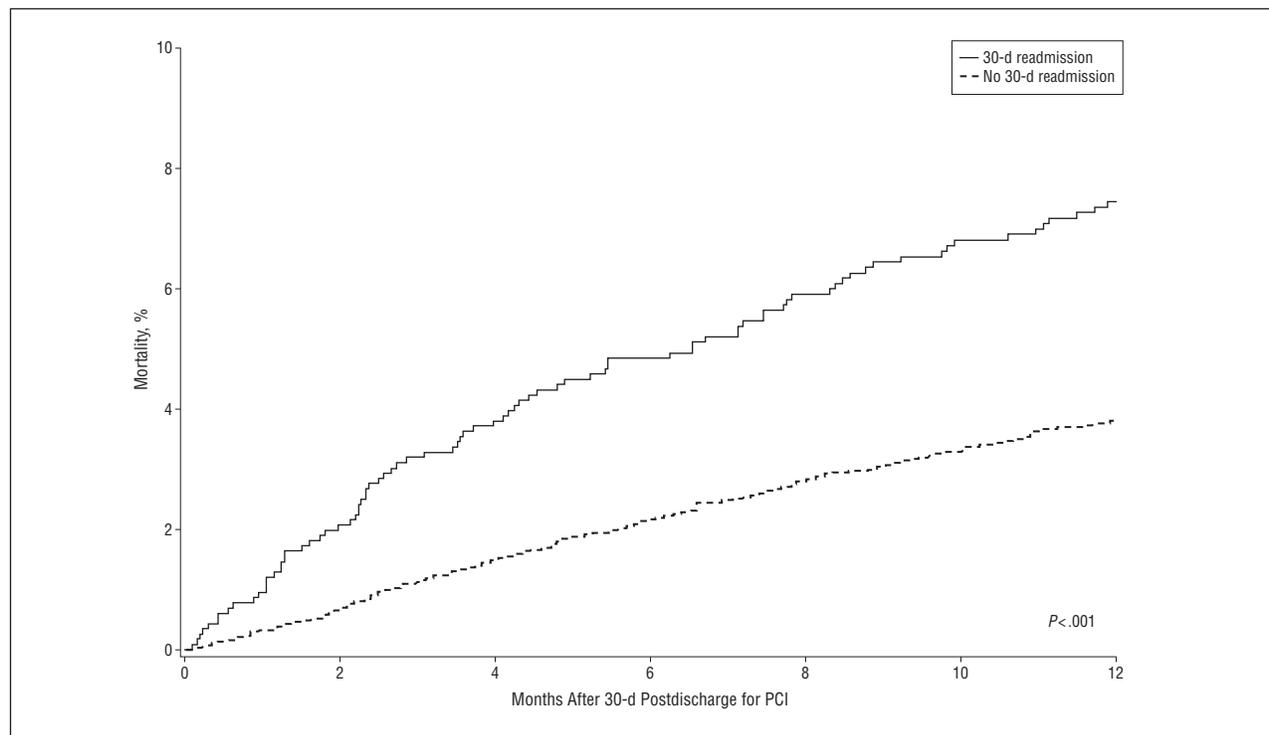
Preventable readmissions have become a focus of national quality improvement efforts. The current focus is on readmissions for patients hospitalized with AMI and HF, although it has been recently extended to PCI.<sup>3</sup> Among 15 498 PCI hospitalizations from 1998 to 2008, including Medicare beneficiaries and other payer types, we found that almost 1 in 10 patients is readmitted within 30 days after PCI, and most readmissions (69%) were related to a cardiac reason. Furthermore, 30-day readmission was associated with an increased risk of 1-year mortality.

Thirty-day risk-standardized readmission rates after PCI have become a publicly reported performance mea-



**Figure 2.** Receiver operating characteristic curve for model discrimination.

sure, and there is high interest from hospitals and clinicians to understand and improve modifiable factors associated with 30-day readmission rates. We identified several factors associated with a higher risk for 30-day readmission after PCI using a prospective, clinical database that included patients with Medicare and non-Medicare insurance; however, most of the variables are not readily modifiable, such as female sex, Medicare in-



**Figure 3.** Kaplan-Meier landmark analysis of mortality after readmission. PCI indicates percutaneous coronary intervention.

insurance, having less than a high school education, CHF at presentation, and moderate renal disease. Even though these variables are not modifiable, interventions to improve access and follow-up care should be studied to assess impact on readmission rates.

Our model had a modest ability to discriminate the risk for 30-day readmission with a general  $R^2$  statistic of 0.052, an AUC of 0.65, and observed readmission rates that ranged from 3.2% in the lowest predicted decile to 19.7% in the highest decile. The discriminatory ability (both  $R^2$  and AUC) of our model is comparable with previously published models for the risk of readmissions for patients with AMI and CHF.<sup>10,11</sup> The discriminatory ability of our model would likely be improved by additional variables that were not available, such as patient literacy, frailty, access to care, and socioeconomic status. Furthermore, since all patients in this study received PCI at a single health care system, we did not have the capability to compare system-level factors associated with 30-day readmissions.

Prior to this study, knowledge of readmission rates after PCI was limited to administrative data from Medicare patients.<sup>7</sup> Our study extended these findings because we found that 30-day readmission rates after PCI were high across all insurance types and ranged from 7.2% in the privately insured group to 10.8% in the Medicare group. Among insurance categories, Medicare patients experienced the highest readmission rate. Gaps in transitions in care from the inpatient to the outpatient context may account for many of the observed readmissions, especially among Medicare, Medicaid, and uninsured patients who may experience difficulty in accessing outpatient care.<sup>12,13</sup>

Lack of early follow-up has been associated with increased risk of readmission among patients with heart failure<sup>14</sup> and

may also be playing a role in patients undergoing PCI. Early follow-up allows patients and clinicians to ensure understanding and compliance and to gauge the effectiveness of therapies. The educational component of follow-up cannot be underestimated because in 1 study, less than half of patients were able to list their diagnoses and the names, purpose, and adverse effects of their medications at the time of discharge.<sup>15</sup> Education at the time of discharge and early follow-up also needs to be tailored to patient education level, which has previously been shown to be associated with the risk of readmission among Medicare beneficiaries.<sup>16</sup> In our study, patients with less than a high school education were more likely to be readmitted after PCI than those with high school or higher education.

There are several limitations to this study. This is a prospective registry that collected demographic, clinical, procedural, and outcomes variables and merged with socioeconomic variables from an administrative database and, hence, cannot demonstrate if any of the observed associations are causal in nature. Although multivariate modeling was performed, residual unmeasured confounders may exist. We have no data regarding outpatient clinic follow-up, medication compliance, health literacy, frailty, or other barriers to health care access.

In summary, about 1 in 10 PCI procedures resulted in a readmission within 30 days, and most readmissions were due to a cardiovascular cause. Patients who were readmitted within 30 days of discharge were at an increased risk of 1-year mortality compared with those who were not readmitted.

Accepted for Publication: August 29, 2011.

Published Online: November 28, 2011. doi:10.1001/archinternmed.2011.569

**Author Affiliations:** Divisions of Cardiovascular Diseases (Drs Khawaja, Rihal, Gersh, Holmes, Bell, and Ting), Health Care Policy and Research, and Biomedical Statistics and Informatics (Mssrs Lennon and Slusser), and Department of Health Sciences Research (Dr Shah), and Knowledge and Evaluation Research Unit (Drs Shah, Montori, and Ting), Mayo Clinic and Mayo Foundation, Rochester, Minnesota; Division of Cardiovascular Diseases, UMDNJ (University of Medicine and Dentistry, New Jersey)—Robert Wood Johnson Medical School, New Brunswick, New Jersey (Dr Alkatib); and Yale University School of Medicine and Yale—New Haven Hospital Center for Outcomes Research and Evaluation, New Haven, Connecticut (Drs Curtis and Krumholz).

**Correspondence:** Henry H. Ting, MD, MBA, Division of Cardiovascular Diseases, Mayo Clinic, 200 First St SW, Rochester, MN 55905 (ting.henry@mayo.edu).

**Author Contributions:** Drs Khawaja and Ting and Mssrs Lennon and Slusser had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. *Study concept and design:* Khawaja, Shah, Alkatib, Holmes, Bell, and Ting. *Acquisition of data:* Alkatib, Holmes, and Ting. *Analysis and interpretation of data:* Khawaja, Shah, Lennon, Slusser, Alkatib, Rihal, Gersh, Montori, Bell, Curtis, Krumholz, and Ting. *Drafting of the manuscript:* Khawaja, Alkatib, Rihal, Montori, Holmes, and Ting. *Critical revision of the manuscript for important intellectual content:* Khawaja, Shah, Lennon, Slusser, Alkatib, Rihal, Gersh, Montori, Bell, Curtis, Krumholz, and Ting. *Statistical analysis:* Khawaja, Lennon, and Slusser. *Obtained funding:* Ting. *Administrative, technical, and material support:* Khawaja, Alkatib, Rihal, and Ting. *Study supervision:* Holmes, Bell, and Ting.

**Financial Disclosure:** Dr Krumholz chairs a cardiac scientific advisory board for United Healthcare and is the recipient of a research grant from Medtronic Inc through Yale University.

**Funding/Support:** This study was funded by the Division of Cardiovascular Diseases, Mayo Clinic, Rochester, Minnesota. Dr Krumholz is supported by grant U01-HL105270-02 (Center for Cardiovascular Outcomes

Research at Yale University) from the National Heart, Lung, and Blood Institute.

## REFERENCES

1. Krumholz HM, Normand SL, Spertus JA, Shahian DM, Bradley EH. Measuring performance for treating heart attacks and heart failure: the case for outcomes measurement. *Health Aff (Millwood)*. 2007;26(1):75-85.
2. Krumholz HM, Normand SL. Public reporting of 30-day mortality for patients hospitalized with acute myocardial infarction and heart failure. *Circulation*. 2008; 118(13):1394-1397.
3. Kereiakes DJ. Return to sender hospital readmission after percutaneous coronary intervention. *J Am Coll Cardiol*. 2009;54(10):908-910.
4. Patient Protection and Affordable Care Act of 2010. Pub L No. 111-148. 124 Stat 119.
5. Epstein AM. Paying for performance in the United States and abroad. *N Engl J Med*. 2006;355(4):406-408.
6. Straube B, Blum JD. The policy on paying for treating hospital-acquired conditions: CMS officials respond. *Health Aff (Millwood)*. 2009;28(5):1494-1497.
7. Curtis JP, Schreiner G, Wang Y, et al. All-cause readmission and repeat revascularization after percutaneous coronary intervention in a cohort of Medicare patients. *J Am Coll Cardiol*. 2009;54(10):903-907.
8. Epstein AJ, Rathore SS, Krumholz HM, Volpp KG. Volume-based referral for cardiovascular procedures in the United States: a cross-sectional regression analysis. *BMC Health Serv Res*. 2005;5:42.
9. Nagelkerke NJD. A note on a general definition of the coefficient of determination. *Biometrika*. 1991;78:691-692.
10. Krumholz HM, Lin Z, Drye EE, et al. An administrative claims measure suitable for profiling hospital performance based on 30-day all-cause readmission rates among patients with acute myocardial infarction. *Circ Cardiovasc Qual Outcomes*. 2011;4(2):243-252.
11. Keenan PS, Normand SLT, Lin Z, et al. An administrative claims measure suitable for profiling hospital performance on the basis of 30-day all-cause readmission rates among patients with heart failure. *Circ Cardiovasc Qual Outcomes*. 2008;1(1):29-37.
12. Chou WC, Cooney LM Jr, Van Ness PH, Allore HG, Gill TM. Access to primary care for Medicare beneficiaries. *J Am Geriatr Soc*. 2007;55(5):763-768.
13. Asplin BR, Rhodes KV, Levy H, et al. Insurance status and access to urgent ambulatory care follow-up appointments. *JAMA*. 2005;294(10):1248-1254.
14. Hernandez AF, Greiner MA, Fonarow GC, et al. Relationship between early physician follow-up and 30-day readmission among Medicare beneficiaries hospitalized for heart failure. *JAMA*. 2010;303(17):1716-1722.
15. Makaryus AN, Friedman EA. Patients' understanding of their treatment plans and diagnosis at discharge. *Mayo Clin Proc*. 2005;80(8):991-994.
16. Arbaje AI, Wolff JL, Yu Q, Powe NR, Anderson GF, Boulton C. Postdischarge environmental and socioeconomic factors and the likelihood of early hospital readmission among community-dwelling Medicare beneficiaries. *Gerontologist*. 2008; 48(4):495-504.

## INVITED COMMENTARY

### ONLINE FIRST

# Prediction Is Very Hard, Especially About the Future

## Can We Prevent Events That Lead to Readmission Following Percutaneous Coronary Intervention?

Cardiovascular hospitalization and its early aftermath define a period of vulnerability,<sup>1</sup> during which clinical deterioration leads to readmission. Since readmission is common, expensive, and varies across hospitals, suggesting preventable events, the Centers for Medicare and Medicaid Services (CMS) has identified readmission as an opportunity to improve quality of

care and reduce costs. Since the CMS began publicly reporting hospital readmission rates in 2009 and now plans to link reimbursement to processes and outcomes through value-based purchasing, health systems have devoted increased resources to reducing readmissions following specific conditions, such as heart failure, acute myocardial infarction, and pneumonia.<sup>2</sup> Moving forward, there are