Clinical Preventability of 30-Day Readmission After Percutaneous Coronary Intervention

Jason H. Wasfy, MD, MPhil; Jordan B. Strom, MD; Stephen W. Waldo, MD; Cashel O'Brien, BA; Neil J. Wimmer, MD, MSc; Adrian H. Zai, MD, PhD, MPH; Jennifer Luttrell, MBA; John A. Spertus, MD, MPH; Kevin F. Kennedy, MS; Sharon-Lise T. Normand, PhD; Laura Mauri, MD, MSc; Robert W. Yeh, MD, MSc

Background—Early readmission after PCI is an important contributor to healthcare expenditures and a target for performance measurement. The extent to which 30-day readmissions after PCI are preventable is unknown yet essential to minimizing their occurrence.

Methods and Results—PCI patients readmitted to hospital at which PCI was performed within 30 days of discharge at the Massachusetts General Hospital and Brigham and Women's Hospital were identified, and their medical records were independently reviewed by 2 physicians. Each reviewer used an ordinal scale (0, not; 1, possibly; 2, probably; and 3, definitely preventable) to rate clinical preventability, and a total sum score ≥2 was considered preventable. Characteristics of preventable and unpreventable readmissions were compared, and predictors of clinical preventability were assessed by using multivariate logistic regression. Of 9288 PCIs performed, 9081 (97.8%) patients survived to initial hospital discharge and 1007 (11.1%) were readmitted to the index hospital within 30 days. After excluding repeat readmissions, 893 readmissions were reviewed. Fair agreement between physician reviewers was observed (weighted κ statistic 0.44 [95% CI 0.39 to 0.49]). After aggregation of scores, 380 (42.6%) readmissions were deemed preventable and 513 (57.4%) were deemed not preventable. Common causes of preventable readmissions included staged PCI without new symptoms (14.7%), vascular/bleeding complications of PCI (10.0%), and congestive heart failure (9.7%).

Conclusions—Nearly half of 30-day readmissions after PCI may have been prevented by changes in clinical decision-making. Focusing on these readmissions may reduce readmission rates. (*J Am Heart Assoc*. 2014;3:e001290 doi: 10.1161/JAHA.114.001290)

Key Words: Readmission • Performance Metrics • Percutaneous Coronary Intervention • Quality Improvement • Outcomes Research

T he preventability of early hospital readmissions carries important implications not only for patients but also for hospitals and clinicians—as well as for payers and regulators. The Medicare Payment Advisory Commission has recognized hospital readmission within 30 days following an admission during which a patient received percutaneous coronary intervention (PCI) as an important source of Medicare spending.[1] In 2013, Medicare began to publish hospital performance on PCI readmissions identified as unplanned on the Hospital Compare website.[2] Others have questioned the utility of the metric, arguing that the measure may not truly reflect the quality of care.[3,4] Although the Centers for Medicare & Medicaid Services did not include PCI in the expansion of conditions for which centers will adjust Inpatient

Prospective Payment System payments to hospitals in fiscal year 2014 based on risk–standardized readmission rates,[5] PCI may become a focus in the future given the substantial Medicare expenditures[6] on PCI readmissions. Whether any future PCI readmission measure in value–based purchasing in the future would include PCI readmission is uncertain. Substantial debate exists about whether tying financial incentives to PCI readmission would enhance value and quality in PCI care.[7]

One of the most important factors in assessing the value of a quality metric is determining whether outcomes can be enhanced by improvements in hospitals' quality of care. This concept is consistent with the "actionable" attribute of a useful performance measure.[8] Defining the preventability of readmissions has been controversial, and different authors have defined "preventability" in various ways.[9–13] Because of the inherent challenges of identifying preventable and unpreventable readmissions using administrative claims data, currently used 30-day readmission measures generally include all readmissions, regardless of cause.

Nevertheless, understanding the preventability of readmissions is critical for assessing the validity of the performance measure, focusing resources on patients with modifiable risk, and developing effective strategies to reduce readmissions. Both changes in healthcare delivery systems and clinical decision-making in individual cases have the potential to prevent readmissions. Here, we sought to assess clinical preventability of 30-day readmissions following PCI.

Methods

Study Population

We studied patients in the Partners PCI Readmission Project, which is a database created from readmissions within 30 days of PCI within the Partners Healthcare system in Boston, Massachusetts. Causes of readmission in the study cohort have been described previously.[14] Partners Healthcare is an integrated healthcare system founded in 1994 by Massachusetts General Hospital (MGH) and Brigham and Women's Hospital (BWH), the 2 largest hospitals affiliated with Harvard Medical School. The network currently includes 8 Massachusetts hospitals, 21 community health centers, and a network of independent ambulatory practices with >500 affiliated primary care physicians. Three of the hospitals are PCI capable, 2 of which (MGH and BWH) comprise 88.8% of the PCI procedures performed within the entire healthcare network. PCIs performed at the MGH or BWH were included in this analysis.

Data were available for all patients who received PCI at BWH during June 2009 to December 2011 and at MGH during January 2007 to December 2011. PCI procedures were then linked to hospital administrative discharge and admission data to determine which patients were readmitted to the hospital at which PCI was performed within 30 days of discharge. To ensure complete access to the hospital records for the readmission hospitalization, only readmissions to the index hospital were considered, which constitute about two-thirds of all readmissions after PCI.[14] For this study, only the first readmission within 30 days for each PCI was included. For example, if a patient received PCI during a first admission, received repeat PCI during a readmission, and then was admitted to the hospital for a third time (a second readmission), only the first readmission was included.

Chart Review and Data Analysis

The determination of preventability by retrospective chart review is inherently subjective and has not been well defined. In that context, we used 2 or 3 different reviewers from different specialties to gain insight into the disagreements between physicians about preventability and to establish standards for our research.

For this analysis, we sought to identify readmissions that were "clinically preventable"—defined as those preventable by a change in clinical decision-making by a clinician under the current standards of care. In most cases, this change in clinical decision-making would be expected to lead to the prevention or amelioration of the process that led to readmission. Readmissions that could have been prevented by reorganization of the health system, changes in current standards of care, or the addition of clinical resources were not considered preventable for the purposes of this analysis.

Two physicians (JHW, a cardiologist, and JBS, an internist) initially reviewed medical records of all eligible patients and independently assigned a clinical preventability rating according to a classification system (Figure 1). This system categorized the preventability ratings for readmissions, and we then refined the system after an exploratory review of the first 50 cases. Examples of representative but fictional cases in each category appear in the Appendix. "Not preventable" readmissions are due to factors not related to the index admission or the PCI procedure or due to an unavoidable consequence of the PCI procedure. "Possibly preventable" readmissions could have been foreseen by an astute clinician and possibly could have been prevented by changing care during the index admission, discharge, or postdischarge period. "Probably preventable" readmissions may have been averted had the procedural or postprocedural care (femoral versus radial, choice of angioplasty balloon size, choice of antiplatelet therapy) been different. "Definitely preventable" readmissions clearly could have been avoided with appropriate care, counseling, or coordination, given the current standards of care. Scheduled readmissions within 30 days were considered

Not preventable: A clinician could not have prevented the readmission. Readmission due to factors not related to the index admission or the PCI procedure, or due to an unavoidable consequence of the PCI procedure.

Possibly preventable: An astute clinician could have foreseen the readmission and possibly could have prevented the readmission by changing care during the index admission, discharge, or post-discharge.

Probably preventable: Performing the procedure or post-procedural care differently (femoral vs. radial, choice of antiplatelet therapy) may have averted the readmission.

Definitely preventable: The readmission could have clearly been avoided with appropriate care or counseling. Scheduled readmissions within 30 days are definitely preventable, unless a clinical reason exists to schedule the readmission within 30 days.

Figure 1. Definitions of Preventability Categories.

"definitely preventable," unless a clinical reason to schedule the readmission within 30 days was identified. Interobserver agreement was evaluated using a weighted κ statistic.

The classification system was converted to an ordinal rank system (0=not preventable, 3=definitely preventable) and the ordinal rankings of the 2 physician reviewers were added to provide a composite ranking (0=least preventable, 6=most preventable). In the composite ranking, we elected to consider readmissions with scores ≥2 as "preventable." All other readmissions, those with composite scores of 1 or 0, were considered not preventable. We then compared baseline patient and procedural characteristics for preventable versus nonpreventable readmissions, including baseline risk of readmission as assessed by a previously validated prediction model.[15] Multivariable logistic regression was used to determine "independent" predictors of possible preventability. To test the effect of dichotomizing the variable, as a sensitivity analysis, predictors of preventability using the 0-to-6 scale as a continuous variable in linear regression was performed.

In addition to independent reviews by 2 physicians for all readmissions, the records of patients readmitted with stent thrombosis, vascular or bleeding complications of PCI, myocardial infarction on readmission, or repeat PCI on readmission were reviewed independently by an interventional cardiologist (SWW) with an identical classification scheme focusing only on technical and procedural aspects of the index PCI that may led to readmission. Finally, the medical records of all readmissions deemed preventable were then rereviewed to determine how the readmission might have been prevented, and results were tabulated. We developed this method of assessing preventability based on independent review of multiple physicians because previous studies have shown wide variation in agreement between physician chart reviewers in assessment of the preventability of readmission.[9,10,16,17] Although this method is time-intensive, we believe that capturing the opinions of multiple physicians creates a more objective standard for an inherently subjective assessment.

All analyses were performed using SAS version 9.3 (SAS Institute). Categorical variables were compared using the χ^2 test, and continuous variables were compared using the Student t test. The association between reasons for readmission and preventable readmissions was assessed by a χ^2 trend test. A value of $P<0.05$ was considered statistically significant.

The institutional review board at Partners Healthcare approved this study. Because the project involved retrospective review of medical records, the need for informed consent was waived.

Results

During the time periods of the study, 9288 PCI procedures were performed on 7773 unique patients. Patients were alive on hospital discharge following 9081 PCI procedures (97.8%). Of 1007 readmissions, 893 (9.8% of patients surviving initial discharge) met inclusion criteria, representing 852 unique patients. A flow chart for excluded and included PCIs appears in Figure 2. Detailed causes of readmission ascertained by physician chart review in this dataset have been previously reported[14] and are listed in the Appendix.

Preventability Ratings for 2 Reviewers

One reviewer rated 600 (67.2%) readmissions as "not preventable," 59 (6.6%) as "possibly preventable," 83 (9.3%) as "probably preventable," and 151 (16.9%) as "definitely preventable." The second reviewer rated 476 (53.4%) readmissions as "not preventable," 115 (12.9%) as "possibly preventable," 107 (12.0%) as "probably preventable," and 195 (21.8%) as "definitely preventable." A full categorization of the
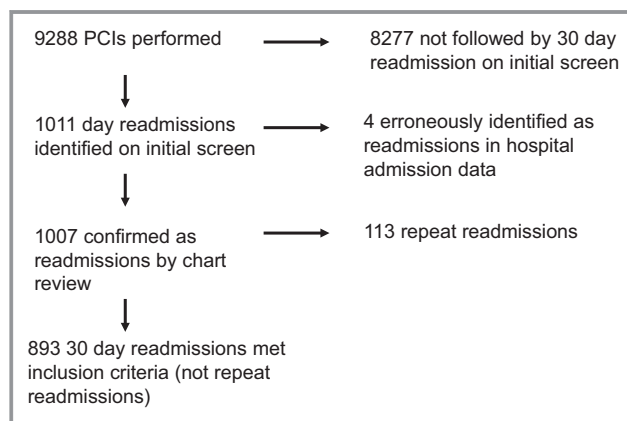

Figure 2. Flow chart for excluded and included percutaneous coronary interventions (PCIs) in the creation of the database.

Ratings for reviewer #2				
	Not preventable	**Possibly preventable**	**Probably preventable**	**Definitely preventable**
Ratings for reviewer #1				
Not preventable	408 (45.6%)	81 (9.1%)	46 (5.1%)	66 (7.4%)
Possibly preventable	25 (2.8%)	10 (1.1%)	13 (1.5%)	11 (1.2%)
Probably preventable	24 (2.7%)	9 (1.0%)	31 (3.5%)	19 (2.1%)
Definitely preventable	20 (2.2%)	15 (1.7%)	17 (1.9%)	99 (11.1%)

Figure 3. Preventability ratings of 2 reviewers

preventability ratings appears in Figure 3. The weighted κ was 0.44 (95% CI 0.39 to 0.49), indicating fair agreement between physician reviewers.

Although both reviewers agreed that 407 (45.6%) cases were "not preventable," the remaining 486 (54.4%) cases were rated at least possibly preventable by at least 1 of the 2 reviewers. At least 1 reviewer rated 247 (27.6%) cases as "definitely preventable," and both reviewers rated 99 (11.1%) readmissions as "definitely preventable." Examples of reviewer ratings and disagreements can be found in the Appendix.

Composite Ratings and Risk of Readmission

In the composite rankings (combined preventability score ≥2), 380 (42.6%) readmissions were classified as preventable and 513 (57.4%) as not preventable. Patient characteristics of these 2 groups are shown in Table 1. Preventable readmissions were more likely in patients with peripheral arterial disease (29.7% versus 21.6%, *P*=0.006), renal insufficiency (glomerular filtration rate 62.7 versus 70.4 mL/min per 1.73 m^2, *P*<0.001), diabetes (46.1% versus 36.3%, *P*=0.003), heart failure (29.2% versus 23.0%, *P*=0.036), and older patients (68.3 years versus 65.8 years, *P*=0.004). Preventable readmissions were also more common following elective procedures (23.2% versus 15.4%) and for ambulatory patients (32.6% versus 25.2%, *P*=0.049). The mean predicted risk of readmission for the preventable readmissions based on

a previously developed PCI readmission risk model[15] was 16.9% compared with 16.2% for not preventable readmissions (*P*=0.261). After multivariable adjustment, only diabetes, glomerular filtration rate, prior PCI, and elective index PCI procedure were associated with preventable readmissions (Figure 4). Model results were similar when treating preventability score as a continuous variable, and therefore only the primary analysis is presented here.

Technical and Procedural Factors

Of all readmissions, 121 were due to stent thrombosis, myocardial infarction, vascular or bleeding complications, or the requirement for repeat coronary revascularization and were thus reviewed for technical and procedural factors related to readmission. This review identified 9.9% (12/121) of cases as at least possibly preventable through technical changes in the procedure that were rated not otherwise preventable in the main analysis. All of these involved patients who had recurrent symptoms after discharge and received repeat PCI of a different lesion during readmission. Furthermore, 14.0% (17/121) of cases were rated as not preventable from a technical standpoint but at least possibly preventable through other changes in medical care in the main analysis. Of those 17 cases, 5 were due to medication noncompliance that could have been prevented by caregivers or inability to obtain an outpatient appointment, 4 were due to suboptimal medication management, and 3 were rated possibly

Table 1. Characteristics of Readmitted Patients, Separated by Preventable and Not Preventable Readmissions (N=893)

Characteristic	Preventable (n=380)	Not Preventable (n=513)	P Value
Age, mean±SD y	68.3±11.5	65.8±13.8	0.004
Male, %	254 (66.8%)	322 (62.8%)	0.208
Risk of readmission, mean ± SD	16.9±9.9%	16.2±9.2%	0.261
Race/ethnicity, %			0.829
Black	18 (4.7%)	27 (5.3%)	
Hispanic	13 (3.4%)	23 (4.5%)	
White	333 (87.6%)	445 (86.7%)	
Asian	14 (3.7%)	14 (2.7%)	
Native American	0	1 (0.2%)	
Other	2 (0.53%)	3 (0.58%)	
Admission status, %			0.049
Emergency department	137 (36.1%)	207 (40.4%)	
Transfer from acute care	119 (31.3%)	177 (35.5%)	
Other	124 (32.6%)	129 (25.2%)	
Insurance, %			0.928
Government	225 (59.2%)	294 (57.3%)	
Commercial	102 (26.8%)	148 (28.9%)	
HMO	45 (11.8%)	59 (11.5%)	
None	5 (1.3%)	9 (1.8%)	
Non-US insurance	3 (0.8%)	3 (0.6%)	
Prior MI >7 days, %	158 (41.6%)	203 (39.6%)	0.546
CHF history, %	111 (29.2%)	118 (23.0%)	0.036
Prior valve surgery, %	20 (5.3%)	17 (3.3%)	0.148
Prior PCI, %	134 (35.3%)	199 (38.8%)	0.281
Prior CABG, %	82 (21.6%)	105 (20.5%)	0.687
Diabetes, %	175 (46.1%)	186 (36.3%)	0.003
GFR, mL/min±SD	62.7 ± 26.5	70.4 ± 31.0	<0.001
Hypertension, %	330 (86.8%)	427 (83.2%)	0.138
Dyslipidemia, %	359 (94.5%)	488 (95.1%)	0.662
CVD, %	88 (23.2%)	114 (22.2%)	0.741
PAD, %	113 (29.7%)	111 (21.6%)	0.006
Chronic lung disease, %	79 (20.8%)	106 (20.7%)	0.963
Arterial access site			0.503
Femoral, %	333 (87.6%)	431 (84.0%)	
Brachial, %	3 (0.8%)	6 (1.2%)	
Radial, %	37 (9.7%)	64 (12.5%)	
PCI status			< 0.001
Elective, %	88 (23.2%)	79 (15.4%)	

Continued

Table 1. Continued

Characteristic	Preventable (n=380)	Not Preventable (n=513)	P Value
Urgent, %	208 (54.7%)	341 (66.5%)	
Emergency, %	81 (21.3%)	93 (18.1%)	
Salvage, %	3 (0.8%)	0	
Drug eluting stent used, %	167 (49.7%)	253 (52.7%)	0.398

HMO indicates health maintenance organization; MI, myocardial infarction; CHF, congestive heart failure; PCI, percutaneous coronary intervention; CABG, coronary artery bypass graft surgery; GFR, glomerular filtration rate; CVD, cerebrovascular disease; PVD, peripheral vascular disease.

preventable because a less potent antiplatelet agent was used in stent thrombosis cases. In the remaining 5 cases, the procedural reviewer rated a case not preventable that was believed to be at least possibly preventable by the noninterventional physician through changes in procedural technique or decision-making.

Association With Cause of Readmission

A plurality of preventable readmissions were due to staged PCI without new symptoms (56, 14.7% of preventable readmissions), followed by vascular/bleeding complications of PCI (38, 10.0%), congestive heart failure (37, 9.7%), chest pain or other symptoms concerning for angina (32, 8.4%), and stent thrombosis (21, 5.5%). Preventable and nonpreventable readmissions, listed by cause of readmission, appear in Table 2.

Tactics to Prevent Preventable Readmissions

Of the 380 preventable readmissions, the greatest proportion (130/380, 34.2%) could have been prevented by performing an elective procedure at a different time, potentially during the index admission. Other ways that a preventable readmission could have been averted included different medical management (110/380, 28.9%), better access to outpatient care (39/380, 10.3%), or performing a procedure differently (39/380, 10.3%), such as avoiding or treating a stent-associated edge dissection. Improved communication (32/380, 8.4%) and prevention of vascular access complications (30/380, 7.9%) also accounted for some ways in which preventable readmissions could have been averted.

Discussion

In a detailed review of 893 consecutive readmissions within 30 days of discharge for PCI, we found that nearly half of readmissions are preventable and that >1 of 10 were
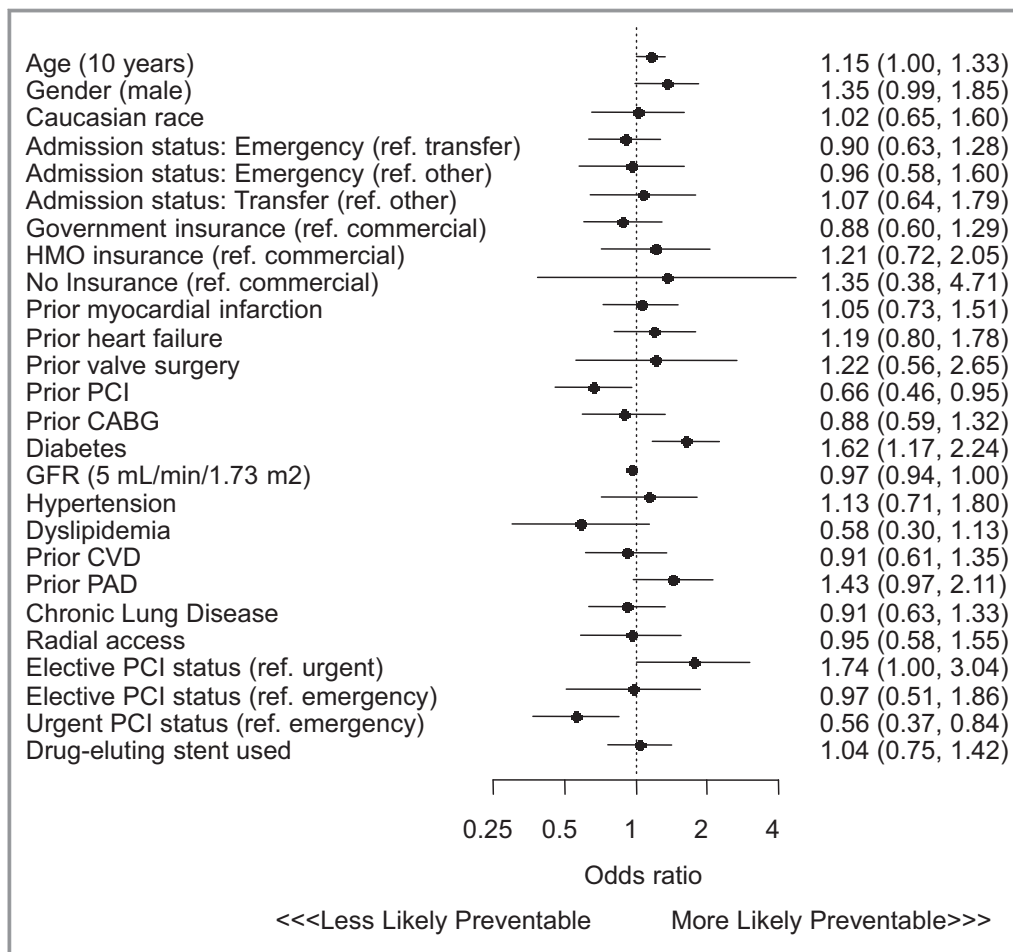
	Odds ratio
Age (10 years)	1.15 (1.00, 1.33)
Gender (male)	1.35 (0.99, 1.85)
Caucasian race	1.02 (0.65, 1.60)
Admission status: Emergency (ref. transfer)	0.90 (0.63, 1.28)
Admission status: Emergency (ref. other)	0.96 (0.58, 1.60)
Admission status: Transfer (ref. other)	1.07 (0.64, 1.79)
Government insurance (ref. commercial)	0.88 (0.60, 1.29)
HMO insurance (ref. commercial)	1.21 (0.72, 2.05)
No Insurance (ref. commercial)	1.35 (0.38, 4.71)
Prior myocardial infarction	1.05 (0.73, 1.51)
Prior heart failure	1.19 (0.80, 1.78)
Prior valve surgery	1.22 (0.56, 2.65)
Prior PCI	0.66 (0.46, 0.95)
Prior CABG	0.88 (0.59, 1.32)
Diabetes	1.62 (1.17, 2.24)
GFR (5 mL/min/1.73 m2)	0.97 (0.94, 1.00)
Hypertension	1.13 (0.71, 1.80)
Dyslipidemia	0.58 (0.30, 1.13)
Prior CVD	0.91 (0.61, 1.35)
Prior PAD	1.43 (0.97, 2.11)
Chronic Lung Disease	0.91 (0.63, 1.33)
Radial access	0.95 (0.58, 1.55)
Elective PCI status (ref. urgent)	1.74 (1.00, 3.04)
Elective PCI status (ref. emergency)	0.97 (0.51, 1.86)
Urgent PCI status (ref. emergency)	0.56 (0.37, 0.84)
Drug-eluting stent used	1.04 (0.75, 1.42)

Odds ratio: 0.25 0.5 1 2 4

<<<Less Likely Preventable   More Likely Preventable>>>

Figure 4. Factors associated with possible preventability for 30-day readmission among readmitted patients. CABG indicates coronary artery bypass graft surgery; CVD, cerebrovascular disease; GFR, glomerular filtration rate; PCI, percutaneous coronary intervention; HMO, health maintenance organization; PAD, peripheral vascular disease.

considered "definitely preventable" by 2 independent reviewers. Staged PCI, vascular access complications, congestive heart failure, and elective vascular surgeries and procedures were the most common causes of preventable readmissions. Our results suggest that clinicians and hospitals might reduce readmission rates by avoiding reflexive staged procedures in the absence of new or persistent clinical symptoms, carefully avoiding vascular access complications and bleeding through methods such as transradial access, careful titration of medications for heart failure patients, and minimizing the risk of stent thrombosis through careful technique and intensification of dual antiplatelet therapy in selected high-risk patients. Despite these opportunities for improvement, our results also suggest that the majority of readmissions would not be prevented with simple changes in clinical decision-making. In addition, our study showed only moderate agreement among physicians about the likelihood that a given readmission could be prevented, illustrating the subjective nature of such an assessment despite attempts to standardize definitions between reviewers.

Prior literature on assessing the preventability of PCI readmissions is sparse. A study from Geisinger Medical Center identified readmissions within 30 days after PCI and determined cause of readmission via physician record review.[4] In that work, Yost et al determined that only 11.9% of readmissions were due to complications of the PCI procedure and that 40.2% were unrelated to the index admission. They concluded that this low rate of readmission for PCI complications does not support the use of readmission after PCI as a quality metric of the index admission. Our data confirm and extend these results. In particular, we also have shown a very low rate of readmissions related to technical complications of the PCI procedure.[14] By seeking to define preventability, as opposed to relation to the index admission, however, we have characterized readmissions differently. In particular, the 42.6% of preventable readmissions offer

Table 2. Preventable and Not Preventable Readmissions, as Determined by the Dichotomized Rating, Listed by Reason for Readmission in Order of Descending Preventable Readmissions (N=893)

Reason for Readmission	Preventable (n=380)	Not Preventable (n=513)	Total
Staged PCI without new symptoms	56 (14.7%)	3	59
Vascular/bleeding complication of PCI	38 (10.0%)	1	39
Congestive heart failure	37 (9.7%)	16	53
Chest pain or other symptoms concerning for angina	32 (8.4%)	309	341
Stent thrombosis	21 (5.6%)	1	22
Elective peripheral procedure/ surgery unrelated to PCI	20 (5.2%)	0	20
Elective CABG	19 (5.0%)	0	19
Syncope or presyncope	14 (3.7%)	8	22
Atrial fibrillation	6 (1.6%)	6	12
Stroke or TIA (not related to PCI)	6 (1.6%)	4	10
Cholecystitis, colitis/enteritis, pancreatitis, cholangitis, or abdominal pain	5 (1.3%)	13	18
Aortic stenosis	5 (1.3%)	4	9
Venous thromboembolism	5 (1.3%)	3	8
Bacteremia or endocarditis	5 (1.3%)	2	7
Categories with <5 preventable cases	111 (29.2%)	143	287

CABG indicates coronary artery bypass graft surgery; PCI, percutaneous coronary intervention; TIA, transient ischemic attack.

potential opportunities for reducing 30-day readmissions after PCI.

To minimize the subjectivity inherent in such an analysis, we narrowed our definition of preventability to include only those readmissions that might have been prevented through changes in clinical decision-making within the current rubric of healthcare delivery. In doing so, we may not be accounting for readmissions that could be preventable through changes in healthcare systems. For example, we have previously shown that symptoms concerning for angina prompt a plurality of early readmissions following PCI, although few patients have myocardial infarction or require repeat PCI.[14] As such, we and others[18] have proposed that redesigning care systems may allow alternative management such as outpatient care for some of these patients, preventing some readmissions. For this study, we deliberately avoided including readmissions for which improvements in technology, such as more effective telemonitoring, or innovations in care delivery, such as chest pain units that

could accommodate patients after PCI, could have averted the readmission.

Studies using clinical chart review to assign subjective preventability have used a variety of methods. Some studies have defined a readmission as preventable only if multiple chart reviewers deemed the readmission preventable,[9] and others have used a third reviewer as a "tie-breaker" to adjudicate disagreements.[10] Still others have predefined clinical circumstances that constitute a preventable readmission,[11,12] or trained physician reviewers with common principles.[13] We have demonstrated only fair agreement (weighted κ=0.44) between 2 physician reviewers with nearly 1 in 10 rated "definitely preventable" by one reviewer and "not preventable" by the other reviewer. These findings highlight the subjectivity inherent in these assessments and are within the range of previous studies on preventability of readmission by chart review. Studies of the preventability of general medical readmissions show wide variance in interobserver variation from excellent[9,10] to poor.[16] One study of pediatric readmissions found that multiple reviewers initially disagreed about preventability in 62.5% of cases.[17] Given the substantial heterogenity in past work with respect to assessing preventability and given the wide range in interobserver variation reported in previous studies, we decided to use multiple independent physician reviewers in assessing preventability in this study. The 3M Health Information Systems Potentially Preventable Readmissions Classification System, which is a classification based on coded discharge diagnoses, avoids this subjectivity by defining combinations of diagnosis billing codes that constitute preventable readmissions.[19,20] The 2007 Medical Payment Advisory Commission report to the US Congress used the 3M methodology to conclude that 13.3% of Medicare readmissions are preventable.[1] We believe our results showing disagreement among physicians using standardized evaluation of clinical records should raise skepticism that an automated system derived from administrative claims data could accurately identify preventable readmissions. We also believe that our results may suggest that financial penalties based on billing code algorithms identifying "preventable" readmissions may not be effective and support a shift to assessing "all-cause" readmissions.

We have also shown that preventability of readmission does not correlate with the predicted risk of readmission as calculated by a validated risk model. The mean risk of readmission for the patients who had preventable readmissions was 16.9%, and the mean risk of readmission for the patients who had nonpreventable readmissions was 16.2% (P=0.261). As such, high-risk patients are at high risk of both preventable and nonpreventable readmissions. Since high-risk patients are at higher risk of preventable readmissions—despite the fact that they are also at higher risk of nonpreventable readmissions—interventions targeting these

patients may still be more likely to yield effective results. We believe that this result should therefore support the identification and targeting of higher-risk patients for interventions.

We have also found that specific reasons for readmission are associated with different degrees of preventability, which has important implications for strategies to reduce readmissions. Our intention in this analysis was to identify reasons why patients are being readmitted and which readmissions could plausibly be prevented, even if those mechanisms do not all improve value for patients. This type of broad assessment is important for understanding the overall utility of PCI readmission as a quality metric. In particular, performing staged PCI or coronary artery bypass graft surgery during a single admission and deferring staged PCI unless a patient has persistent symptoms have uncertain implications for quality and value. Potential for manipulation—for example, scheduling a planned procedure >30 days after a PCI discharge—highlights a weakness of all-cause PCI readmission as a quality metric.

Other categories of readmissions offer clearer opportunities for care improvement, however. Although not common, procedural and bleeding complications of PCI, including stent thrombosis, were also associated with high preventability. Congestive heart failure exacerbations and episodes of syncope/presyncope were more common, and many were considered preventable. Careful titration of medications before discharge and early follow-up of patients susceptible to syncope, presyncope, and congestive heart failure exacerbations may offer an opportunity to improve care. Other types of readmissions associated with low clinical preventability, such as chest pain after PCI, may still be associated with higher nonclinical preventability, such as establishing chest pain units with the capacity to accept patients with recent PCI. Both clinical and nonclinical preventability may enhance improvements in performance on this quality metric. We believe that even a minimalist interpretation of our results—that only the 11% of readmissions rated as "definitely preventable" by 2 independent physicians are actually preventable—supports the role of PCI readmission as a quality metric. Although some readmissions were rated more preventable because of patient noncompliance, PCI readmission as a performance metric will engage hospitals and physicians to work with patients to enhance compliance. The metric could also improve prospective shared decision-making, such as avoiding drug-eluting stents in patients who have a history of medical noncompliance and/or patients who doubt their own ability to reliably manage prolonged dual-antiplatelet therapy.

Our results should be interpreted in the context of several important limitations. First, as a study of a particular health system, the extent to which we can generalize our findings to other hospitals and healthcare systems is unclear. Second,

the retrospective assessment of preventability from chart review is inherently subjective and offers a lower standard of evidence than prospective trials that could prove specific care innovations reduce readmissions. We view our results as hypothesis-generating; as such, the tactics we have identified should be prospectively tested. In particular, the proportion of "preventable" cases would have changed had we lowered or raised the point threshold for preventability in the dichotomized ranking. Third, we were not able to review medical records from the readmission of patients readmitted to a different hospital than the hospital at which PCI was performed, which may limit the generalizability of our findings. We have previously established that over two-thirds of patients in this health system who are readmitted within 30 days are readmitted to the index hospital. The major difference in readmissions to nonindex hospitals is that patients are more likely to be readmitted with heart failure (13.8% versus 7.1%, $P=0.003$)[14] than are readmissions to the index hospital. Since heart failure readmissions were associated with high preventability (69.8%), our results may underestimate overall preventability. Fourth, we cannot know from retrospective chart review if preventing the readmission (eg, using a more potent antiplatelet agent to prevent stent thrombosis) would have led to another unforeseen complication (eg, bleeding). Fifth, we cannot be certain about the extent to which we can extrapolate our findings to the conditions (acute myocardial infarction, congestive heart failure, and pneumonia) that are currently included in value-based purchasing, although many of the patients who are admitted with acute myocardial infarction and congestive heart failure are likely also receiving PCI during the index admission. Sixth, by including elective and staged PCI in our database, our data differ from the current PCI readmission metric reported on Hospital Compare. The reported readmission metric excludes planned readmissions based on an algorithm based on billing codes. The Hospital Compare algorithm first excludes readmissions for organ transplantation, then identifies procedural readmissions, and excludes them if the discharge is not either an acute medical issue or a procedural complication. We created the database including elective readmissions because the extent to which a billing code algorithm corresponds with physician-adjudicated chart review is unclear. Furthermore, whether any future PCI readmission metric in value-based purchasing might include elective readmissions is uncertain. Seventh, since we reviewed medical records for readmitted patients, we do not have information about opportunities to improve quality of care for patients who were not readmitted. Although this was out of scope for the present analysis, this is an important issue that merits investigation. Finally, our definition of preventability did not include use of wider health systems reforms or changes in standards of care, such as raising

readmission thresholds for post-PCI patients, that might effectively reduce readmission rates.

In conclusion, we have demonstrated that nearly half of 30-day readmissions after PCI episodes may be clinically preventable. Clinicians can use these results to reduce readmissions, often in ways that enhance value and quality.

Sources of Funding

Disclosures

Drs Wasfy, Strom, Waldo, Wimmer, Zai, Normand report no disclosures. Ms O'Brien, Ms Luttrell, and Mr Kennedy report no disclosures. Dr Spertus reports receiving research support from the American College of Cardiology Foundation and reports equity in Health Outcomes Sciences. Dr Mauri reports receiving research support from Abbott, Boston Scientific, Cordis, Medtronic, Eli Lilly, Daiichi Sankyo, Bristol Myers Squibb, and sanofi-aventis and serving as a consultant for Cordis and Medtronic. Dr Yeh receives research support from the National Heart, Lung, and Blood Institute, American Heart Association, Massachusetts General Hospital, and Harvard Clinical Research Institute and serves as a consultant for Gilead Sciences and Abbott Vascular.

Appendix
Theoretical Examples of Readmissions in Different Preventability Categories

Not Preventable

A 65 year old man admitted initially for ST-segment elevation myocardial infarction and discharged from the hospital is readmitted within 2 weeks following a motor vehicle accident.

An 84 year old woman underwent PCI for STEMI and then was readmitted 28 days after discharge for community-acquired pneumonia.

Possibly Preventable

A 72 year old woman with an LVEF of 46% following NSTEACS but euvolemic on discharge is readmitted within 3 weeks for congestive heart failure without an outpatient visit.

A 48 year old man following PCI for STEMI had a beta-blocker added during the index hospitalization felt well ambulating prior to discharge, but was readmitted to the hospital 3 days after discharge for syncope and orthostatic hypotension.

Probably Preventable

A 51 year old diabetic man, with no history of bleeding or stroke, following STEMI that was treated with bifurcation stenting in the proximal LAD and first diagonal, discharged on aspirin and clopidogrel (rather than prasugrel or ticagrelor) and is readmitted with stent thrombosis after 20 days.

A 63 year old woman underwent PCI for unstable angina from the femoral approach and was readmitted with a symptomatic pseudoaneursym of the femoral artery.

Definitely Preventable

A 74 year old man with mild muscle aches and elevated CK during the index hospitalization attributed to his new high dose statin is discharged with a plan for outpatient follow up, but is readmitted in 1 week with rhabdomyolysis.

A 70 year old ambulatory man who walks every day without angina undergoes elective PCI of his distal left circumflex artery "just to get him through" an elective repair of an aortic aneurysm and then is readmitted 2 weeks after the PCI for aortic aneurysm surgery.

Example of Disagreement (1)

A 66 year old woman with class 3 stable angina despite appropriate medical management has severe lesions of both the right coronary artery and the left circumflex artery. Both lesions have fractional flow reserve assessed suggesting ischemia, and the right coronary artery is stented. The patient continues to have angina after discharge, and she is readmitted for stenting of the circumflex lesion with subsequent relief of symptoms. Reviewer A thinks that this case is probably preventable, because the other lesion could have been stented during the index procedure, per the results of randomized clinical trials. Reviewer B thinks that this case is not preventable, because there was no way that the operator could have known which lesion was responsible for the symptoms, and a reasonable approach was to stent one of the vessels and follow the clinical response.

Example of Disagreement (2)

A 78 year old man with STEMI treated with angioplasty and placement of a drug-eluting stent to the LAD has a stroke 2 days after the procedure. Complications of the stroke lead to a readmission. After review of the angiogram and clinical documentation, reviewer A finds no evidence of procedural complications, and concludes that the timing of the stroke is

coincidental. Reviewer A therefore rates the readmission as not preventable. Reviewer B agrees with the interpretation of the clinical data, but thinks that the timing of the stroke is not likely coincidental, and therefore rates the case as possibly preventable.

Example of Disagreement (3)

A 92 year old man with chronic hip arthritis has a NSTEMI treated with a drug eluting stent to the RCA. Three weeks after discharge, his chronic opioid medications cause severe constipation requiring hospitalization. Reviewer A rates the case as definitely preventable because the symptoms had been worsening in the outpatient setting for 3 days. Reviewer B rates the case as not preventable because the patient had intractable pain that required narcotics, and constipation is a known side effect. Neither Reviewer A nor Reviewer B think the readmission had anything to do with the PCI procedure, although they still disagree on preventability.

Example of Disagreement (4)

A 67 year old man with chronic heart failure received PCI for stable angina. His beta blockers were uptitrated during the hospital stay, with vital signs in an appropriate range at discharge and without symptoms. He then was readmitted with syncope 2 weeks later due to bradycardia. Reviewer A rates the case as only possibly preventable given the appropriate indication for uptitration of the beta blocker and Reviewer B rates the case as definitely preventable given the known side effect of beta blockers, saying that better inpatient assessment and/or outpatient monitoring is sure to have prevented the medication-related readmission.

Detailed Causes of Readmission in the Partners PCI Database

Reason for Readmission	Number of Patients (N=893)
Chest pain or other symptoms concerning for angina	341 (38.1%)
Staged PCI without new symptoms	59 (6.6%)
Congestive heart failure	53 (5.9%)
Vascular/bleeding complication of PCI	39 (4.4%)
Gastrointestinal hemorrhage	28 (3.1%)
Stent thrombosis	22 (2.5%)
Syncope or presyncope	22 (2.5%)
Elective peripheral procedure or surgery not related to PCI	20 (2.2%)
Elective CABG	19 (2.1%)
Cholecystitis, colitis/enteritis, pancreatitis, cholangitis, or abdominal pain	18 (2.0%)

Reason for Readmission	Number of Patients (N=893)
Pneumonia	15 (1.7%)
Atrial fibrillation	12 (1.3%)
Urinary tract infection or urosepsis	11 (1.1%)
Stroke or TIA (not related to PCI)	10 (1.1%)
Aortic stenosis	9 (1.0%)
Venous thromboembolism	8 (0.9%)
Ventricular tachycardia	8 (0.9%)
Bacteremia or endocarditis	7 (0.8%)
Viral infection, upper respiratory infection, or bronchitis	7 (0.8%)
Bradycardia	5 (0.6%)
Dehydration	5 (0.6%)
Sepsis	5 (0.6%)
Sudden cardiac death without proven stent thrombosis (probable ST)	4 (0.4%)
Rhabdomyolysis	4 (0.4%)
Chronic obstructive lung disease	4 (0.4%)
Hematuria	4 (0.4%)
Anxiety, depression, or panic attack	4 (0.4%)
Hypotension	4 (0.4%)
Fever	4 (0.4%)
Elective ICD placement	4 (0.4%)
Renal failure	4 (0.4%)
Causes with fewer than 4 cases (listed below)	133 (14.9%)

Abdominal pain (2), abscess, acute peripheral ischemia not related to catheterization, accelerated idioventricular rhythm, acute renal failure, alcohol withdrawal, allergic reaction to unclear source, allergic reaction to contrast dye, allergic reaction to cefepime, allergic reaction to hydralazine, allergic reaction to non-steroidal anti-inflammatory agent, allergy to plavix (2), altered mental status, amputation not related to catheterization (2), anemia without bleeding (2), arm hematoma not related to catheterization, arm pain after receiving pneumovaccine, arthritis, atrial flutter, chronic back pain (2), back pain after motor vehicle accident, beta blocker toxicity (3), biliary stent occlusion, elective bladder fulguration, bladder spasm due to urinary catheter, tongue bleeding, epistaxis, endometrial bleeding, uterine fibroid, bradycardia (3), broken tooth, bursitis, cellulitis, elective chemotherapy admission (3), non-sustained ventricular tachycardia, elective dilatation and curettage for endometrial cancer, dehydration (3), diabetic neuropathy, dialysis line infection, digoxin toxicity, diabetic ketoacidosis (2), dysarthria, dyspnea, elective tricuspid valve annuloplasty/mitral commissurotomy/aortic valve replace-

ment, elective resection of a retroperitoneal sarcoma, elective placement of a cardiac resynchronization device, elective electrophysiologic study, elective implanted cardioverter-defibrillator device (3), elective mediastinoscopy, elective mitral valve replacement, elective percutaneous tricuspid valve replacement, elective pacemaker placement, elective transcatheter aortic valvular replacement (2), elective total hip replacement, elective closure of a ventricular septal defect, encephalopathy, endomyocardial biopsy, failure to thrive, fatigue (2), hypotension, gangrene, gastroparesis, headache (3), hemorrhagic conversion of periprocedural stroke, hemoptysis, hernia, hospice admission, hyperglycemia, hypertension (3), hypoglycemia (2), hyponatremia, intracerebral hemorrhage, infected dialysis fistula (2), interstitial lung disease, large bowel obstruction, leukemia exacerbation, lithium overdose, loss of consciousness during dialysis, mechanical fall, migraine, misplaced nasogastric tube, nausea, paresthesias (2), non-healing vascular bypass graft, orthostasis (2), osteomyelitis (3), pacemaker bleeding, palpitations (2), panniculitis, pericardial effusion (2), peritonitis related to a peritoneal dialysis catheter, wound infection, pleural effusion (2), poor oral intake, progression of lung cancer, pseudogout, premature ventricular contractions, pulmonary tuberculosis, evaluation for cardiac transplantation, seizure, shortness of breath, slurred speech, spinal fusion, elevated INR without bleeding, superficial phlebitis, surgical site infection after hip surgery, tachycardia, tamponade, thrombotic occlusion of peripheral vascular graft, thyrotoxicosis, heart transplant, gastric ulcer, need for urgent dialysis, urgent peripheral arterial procedure not related to catheterization, placement of a ventricular assist device, vomiting (2), mitral stenosis.

References

1. Promoting Greater Efficiency in Medicare. Medical Payment Advisory Commission (MedPAC), Washington, DC. 2007.

2. Landen R. Hospital compare site adds PCI readmission [Internet]. *Mod Healthc*. 2013. Available at: http://www.modernhealthcare.com/article/20130718/NEWS/307179924. Accessed September 17, 2014.

3. SCAI. SCAI Urges a No Endorsement Vote on NQF All-cause PCI Readmission Measure [Internet]. Available at: http://www.scai.org/Advocacy/Detail.aspx?cid=4af2ee5f-23c2-4827-9b45-63f6affd4862. Accessed February 24, 2014.

4. Yost GW, Puher SL, Graham J, Scott TD, Skelding KA, Berger PB, Blankenship JC. Readmission in the 30 days after percutaneous coronary intervention. *JACC Cardiovasc Interv*. 2013;6:237–244.

5. Centers for Medicare and Medicaid Services. FY 2014 IPPS Final Rule Home Page. Available at: http://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/AcuteInpatientPPS/FY2014-IPPS-Final-Rule-Home-Page.html. Accessed September 17, 2014.

6. Curtis JP, Schreiner G, Wang Y, Chen J, Spertus JA, Rumsfeld JS, Brindis RG, Krumholz HM. All-cause readmission and repeat revascularization after percutaneous coronary intervention in a cohort of medicare patients. *J Am Coll Cardiol*. 2009;54:903–907.

7. Yeh RW, Rosenfield K, Zelevinsky K, Mauri L, Sakhuja R, Shivapour DM, Lovett A, Weiner BH, Jacobs AK, Normand S-LT. Sources of hospital variation in short-term readmission rates after percutaneous coronary intervention. *Circ Cardiovasc Interv*. 2012;5:227–236.

8. Drozda J, Messer JV, Spertus J, Abramowitz B, Alexander K, Beam CT, Bonow RO, Burkiewicz JS, Crouch M, Goff DC, Hellman R, James T, King ML, Machado EA, Ortiz E, O'Toole M, Persell SD, Pines JM, Rybicki FJ, Sadwin LB, Sikkema JD, Smith PK, Torcson PJ, Wong JB. ACCF/AHA/AMA-PCPI 2011 performance measures for adults with coronary artery disease and hypertension: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Performance Measures and the American Medical Association—Physician Consortium for Performance Improvement. *Circulation*. 2011;124:248–270.

9. Frankl SE, Breeling JL, Goldman L. Preventability of emergent hospital readmission. *Am J Med*. 1991;90:667–674.

10. Oddone EZ, Weinberger M, Horner M, Mengel C, Goldstein F, Ginier P, Smith D, Huey J, Farber NJ, Asch DA, Loo L, Mack E, Hurder AG, Henderson W, Feussner JR. Classifying general medicine readmissions. Are they preventable? Veterans Affairs Cooperative Studies in Health Services Group on Primary Care and Hospital Readmissions. *J Gen Intern Med*. 1996;11:597–607.

11. Experton B, Ozminkowski RJ, Pearlman DN, Li Z, Thompson S. How does managed care manage the frail elderly? The case of hospital readmissions in fee-for-service versus HMO systems. *Am J Prev Med*. 1999;16:163–172.

12. Dormann H, Neubert A, Criegee-Rieck M, Egger T, Radespiel-Tröger M, Azaz-Livshits T, Levy M, Brune K, Hahn EG. Readmissions and adverse drug reactions in internal medicine: the economic impact. *J Intern Med*. 2004;255:653–663.

13. Koekkoek D, Bayley KB, Brown A, Rustvold DL. Hospitalists assess the causes of early hospital readmissions. *J Hosp Med*. 2011;6:383–388.

14. Wasfy JH, Strom JB, O'Brien C, Zai AH, Luttrell J, Kennedy KF, Spertus JA, Zelevinsky K, Normand ST, Mauri L, Yeh RW. Causes of short-term readmission after percutaneous coronary intervention. *Circ Cardiovasc Interv*. 2014;7:97–103.

15. Wasfy JH, Rosenfield K, Zelevinsky K, Sakhuja R, Lovett A, Spertus JA, Wimmer NJ, Mauri L, Normand S-LT, Yeh RW. A prediction model to identify patients at high risk for 30-day readmission after percutaneous coronary intervention. *Circ Cardiovasc Qual Outcomes*. 2013;6:429–435.

16. Bates DW, O'Neil AC, Petersen LA, Lee TH, Brennan TA. Evaluation of screening criteria for adverse events in medical patients. *Med Care*. 1995;33:452–462.

17. Hain PD, Gay JC, Berutti TW, Whitney GM, Wang W, Saville BR. Preventability of early readmissions at a children's hospital. *Pediatrics*. 2013;131:e171–e181.

18. Minges KE, Curtis JP. Living in the readmission era. *Circ Cardiovasc Interv*. 2014;7:9–10.

19. Vachon CM, Aaland M, Zhu TH. Readmission of trauma patients in a nonacademic level II trauma center. *J Trauma*. 2011;72:531–536.

20. Potentially Preventable Readmissions Classification System: Methodology Overview. 3M Health Information Systems. 2008.