Causes of Short-Term Readmission After Percutaneous Coronary Intervention

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

Background—Rehospitalization within 30 days after an admission for percutaneous coronary intervention (PCI) is common, costly, and a future target for Medicare penalties. Causes of readmission after PCI are largely unknown.

Methods and Results—To illuminate the causes of PCI readmissions, patients with PCI readmitted within 30 days of discharge between 2007 and 2011 at 2 hospitals were identified, and their medical records were reviewed. Of 9288 PCIs, 9081 (97.8%) were alive at the end of the index hospitalization. Of these, 893 patients (9.8%) were readmitted within 30 days of discharge and included in the analysis. Among readmitted patients, 341 patients (38.1%) were readmitted for evaluation of recurrent chest pain or other symptoms concerning for angina, whereas 59 patients (6.6%) were readmitted for staged PCI without new symptoms. Complications of PCI accounted for 60 readmissions (6.7%). For cases in which chest pain or other symptoms concerning for angina prompted the readmission, 21 patients (6.2%) met criteria for myocardial infarction, and repeat PCI was performed in 54 patients (15.8%). The majority of chest pain patients (288; 84.4%) underwent ≥1 diagnostic imaging test, most commonly coronary angiography, and only 9 (2.6%) underwent target lesion revascularization.

Conclusions—After PCI, readmissions within 30 days were seldom related to PCI complications but often for recurrent chest pain. Readmissions with recurrent chest pain infrequently met criteria for myocardial infarction but were associated with high rates of diagnostic testing. **(*Circ Cardiovasc Interv*. 2014;7:97-103.)**

Key Words: outcome assessment (health care) ■ patient readmission ■ percutaneous coronary intervention

Readmission after inpatient hospitalization is common and costly. According to an analysis of Medicare claims data, 19.6% of Medicare patients discharged after a hospital admission during which percutaneous coronary intervention (PCI) is performed are readmitted within 30 days, and the Medicare Payment Advisory Commission has estimated that preventable readmissions cost Medicare as much as $12 billion per year.[1] The Affordable Care Act has created financial penalties for hospitals that have risk-adjusted readmission rates for specific conditions exceeding specific benchmarks.[2] Some have criticized this strategy, arguing that few readmissions are preventable and variation in readmission rates reflects differences in patient populations rather than hospital quality.[3] Despite these concerns, and driven by a need to improve care and lower costs, Medicare has begun implementing its value-based purchasing program to provide incentives for hospitals to reduce readmissions after acute myocardial infarction, pneumonia, and congestive heart failure. The Affordable Care Act empowers the Secretary of Health and Human Services to expand the applicable conditions beyond these 3 diagnoses in fiscal year 2015 to readmissions that represent conditions or procedures that are high volume or costly,[2] including chronic obstructive lung disease, coronary artery bypass grafting, vascular surgery, and PCI.[4] In 2011, the National Quality Forum endorsed 30-day readmission after PCI as an important quality measure, and hospitals that had chosen to participate in voluntary reporting had risk-adjusted readmission rates published publicly in the summer of 2013.[5]

Editorial see p 9

Received August 19, 2013; accepted December 19, 2013.

From the Cardiology Division (J.H.W., C.O'B., R.W.Y.), Department of Medicine (J.H.W., C.O'B., R.W.Y., J.B.S.), and Laboratory of Computer Science (A.H.Z., J.L.), Massachusetts General Hospital, Harvard Medical School, Boston; Saint Luke's Mid America Heart Institute/UMKC, Kansas City, MO (K.F.K., J.A.S.); Department of Biostatistics, Harvard School of Public Health, Boston, MA (K.Z., S.-L.T.N.); Cardiovascular Division, Department of Medicine, Brigham and Women's Hospital, Harvard Medical School, Boston, MA (L.M.); and Harvard Clinical Research Institute, Boston, MA (L.M., R.W.Y.).

Guest Editor for this article was Sunil V. Rao, MD.

The Data Supplement is available at http://circinterventions.ahajournals.org/lookup/suppl/doi:10.1161/CIRCINTERVENTIONS.113.000988/-/DC1.

Correspondence to Robert W. Yeh, MD, MSc, Cardiology Division, GRB 8–843, Massachusetts General Hospital, 55 Fruit St, Boston, MA 02114. E-mail ryeh@partners.org

WHAT IS KNOWN

- Early readmission after percutaneous coronary intervention is a major source of healthcare costs and an important quality metric.
- Risk models exist that predict a particular patient's risk of 30-day readmission after percutaneous coronary intervention.

WHAT THE STUDY ADDS

- A plurality of patients who are readmitted to the hospital are admitted because of a concern for angina although few rule in for myocardial infarction or require repeat percutaneous coronary intervention.
- Many patients are admitted to the hospital for elective and staged procedures.
- Alternatives to inpatient admission to evaluate symptoms concerning for angina has the potential to reduce readmission rates after percutaneous coronary intervention.

Given hospitals' incentives to lower readmission rates, understanding reasons for readmission within 30 days of a PCI admission is critically important to identify strategies for improvement. Although administrative claims databases have been used to categorize readmission discharge diagnoses broadly,[6–8] few studies have been conducted using detailed medical record reviews to characterize patient presentations for readmission, the care received or the associated use of resources during these hospitalizations.[9]

To address this gap in knowledge, we sought to characterize reasons for 30-day readmission after PCI through detailed exploration of the medical records at 2 hospitals within a large integrated healthcare system. We further examined the use of diagnostic testing and therapeutic procedures for the most common causes of readmission. On the basis of these findings, we propose implementable strategies by which hospitals might reduce readmission rates after PCI that could be the target of future interventions.

Methods

Study Population

Partners Healthcare is an integrated healthcare system founded in 1994 by Massachusetts General Hospital and Brigham and Women's Hospital, 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 doctors. Three of the hospitals are PCI-capable, 2 of which (Massachusetts General Hospital and Brigham and Women's Hospital) comprise 88.8% of the PCI procedures performed within the entire healthcare network. PCIs performed at the Massachusetts General Hospital or Brigham and Women's Hospital were included in this analysis.

Data were available for all patients who received PCI at Brigham and Women's Hospital from June 2009 to December 2011 and at Massachusetts General Hospital from 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 index hospital within 30 days of discharge from an admission in which PCI was performed. Only readmissions to the index hospital were considered, and only the first readmission within 30 days for each PCI was included in the analysis. 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. Because inpatient admissions and observation admissions are similar from the patient perspective and both contribute to costs, both inpatient admissions and observation admissions were considered admissions.

Chart Review and Data Analysis

Two physicians (J.H.W. and J.B.S.) reviewed the medical records of patients readmitted within 30 days to the hospital at which PCI was initially performed that met inclusion criteria. One physician (J.H.W.) recorded the reason for readmission. Specific reasons for readmission were recorded and categorized according to a taxonomy developed after review of the first 50 records, allowing for the addition of new categories as needed. Among patients readmitted with chest pain or other symptoms concerning for angina, the same physician determined rates of resource use, including echocardiograms, single-photon emission computed tomography (SPECT) imaging, repeat catheterization, repeat revascularization (both percutaneous and surgical), target vessel revascularization, and target lesion revascularization. SPECT imaging included positron emission tomography scans, and any stress echocardiography was considered an echocardiogram. Because data collection involved direct observation of the electronic medical records, blinding was not possible.

Analysis of Location of Hospital Readmission

To test the validity and explore the implications of our findings further, we conducted additional analyses using a statewide database that allowed the assessment of readmissions to nonindex hospitals. The Massachusetts Department of Public Health collects data on all PCI admissions performed in adults ≥18 years of age at all nonfederal Massachusetts hospitals. The data are collected by trained hospital personnel using the National Cardiovascular Data Registry CathPCI data collection instrument and are submitted electronically to the Massachusetts Data Analysis Center at Harvard Medical School. Definitions for the data elements of the CathPCI registry are available at https://www.ncdr.com/webncdr/cathpci/home/datacollection. In Massachusetts, selected covariates and outcomes are audited, adjudicated, and verified as previously described.[10] To obtain data on patients subsequent to discharge, including information on readmissions, we then linked data from the Massachusetts Data Analysis Center to hospital discharge billing data collected by the Massachusetts Division of Health Care Finance and Policy.

Data on readmissions contemporaneous with the entire period of the chart review were not available because of the lag time in public availability of the data. Therefore, we considered all PCI admissions that occurred at the 2 institutions between October 1, 2005, and September 30, 2008, and examined the prevalence of readmissions to any Massachusetts hospital within 30 days of discharge after PCI at both of the hospitals in our study. We compared the percentage of readmissions that occurred at the index hospital versus other hospitals. Furthermore, we compared clinical characteristics and the principal diagnoses for the readmission episode of care at index hospitals with other hospitals. Both the institutional review board at Partners Healthcare and the Research and Data Access Review Committee at the Massachusetts Department of Public Health approved this project. 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 and 9081 patients survived to hospital discharge (97.8%). Of 1011 potential readmissions from hospital data within 30 days, 1007 were confirmed as actual 30-day readmissions by chart review, and 893 met inclusion criteria,

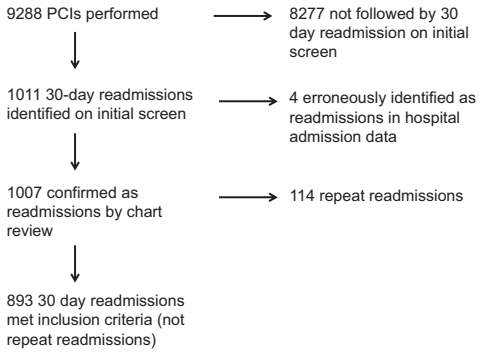

Figure 1. Flow chart for excluded and included percutaneous coronary interventions (PCIs).

representing 852 unique patients (Figure 1). Because repeat readmissions in the same care episode were excluded, only those patients who were readmitted after different PCI procedures during separate care episodes were included multiple times in the data set. Clinical characteristics of the included patients (n=893) are shown in Table 1. Of all readmitted patients, 858/1007 (85.2%) were readmitted through the hospital emergency department. Clinical characteristics of readmitted and not readmitted patients in the broader Massachusetts PCI population have been published previously.[10]

Reasons for Readmission

Reasons for readmission were diverse (Table 2). The largest category of reasons for readmission was chest pain or other symptoms concerning for angina, accounting for 341 readmissions (38.1%). Of these, 21 patients (6.2%) presented with a new or repeat myocardial infarction. Patients readmitted with chest pain or other symptoms concerning for angina were younger (63.7 versus 66.8 years; $P<0.001$) than other readmitted patients and more likely to have commercial insurance (34.3% versus 24.2%; $P<0.001$). Clinical characteristics of patients admitted with chest pain or other symptoms concerning for angina and those admitted with all other reasons for admission are shown in Table 1.

Vascular or bleeding complications after the PCI procedure accounted for 39 readmissions (4.4%). Nonaccess site bleeding (gastrointestinal bleeding, hematuria, or gynecological bleeding) was responsible for 3.7% (33/893) of readmissions. Total vascular complications, access site bleeding, and nonaccess site bleeding, therefore, accounted for 72 readmissions (8.1%). Stent thrombosis accounted for 22 readmissions (2.5%). Of the stent thrombosis cases, 12 presented as ST-segment–elevation myocardial infarction or new Q waves, 5 presented with ST depression or T wave changes, 3 presented as positive troponin with preexisting left bundle-branch block, 1 presented as a cardiac arrest, and 1 presented with elevated troponin without ECG changes. Staged PCI without new symptoms accounted for 59 readmissions (6.6%) and elective coronary artery bypass graft surgery accounted for 19 (2.1%). Hospital data to indicate type of readmission (inpatient versus observation) were available for 848 out of the 1007 readmissions. Of those, 788 readmissions (92.9%) were inpatient readmissions and 60 readmissions (7.1%) were observation readmissions. A total of 873 patients (97.8%) survived to discharge.

Readmission Diagnosis and Location of Readmission

We were able to identify the proportion of the readmitted patients who are readmitted to the hospital at which the index PCI was performed between October 1, 2005, and September 30, 2008. During that time period, 7147 patients underwent PCI at either Massachusetts General Hospital or Brigham and Women's Hospital, survived to discharge, and were able to be matched to a claims database to ascertain readmission status. Of those, 906 patients (12.7%) were readmitted to any hospital in the state. Of the readmitted patients, 609 patients (67.2%) were readmitted to the same hospital at which PCI was performed.

For patients readmitted to the index hospital, the most common primary billing diagnosis for the readmission was chronic ischemic heart disease (414.xx) followed by symptoms involving respiratory system and other chest symptoms (786.xx). For patients readmitted to a different hospital, the most common billing diagnosis for the readmission was heart failure (786.xx) followed by symptoms involving respiratory system and other chest symptoms (786.xx). A list of the most common diagnoses prompting readmission at index hospital and at other hospitals appears in Tables 3 and 4.

Resource Use in Chest Pain Readmissions

Of the 341 patients with chest pain or other symptoms concerning for angina, 288 (84.5%) had ≥1 diagnostic imaging study (echocardiogram, SPECT, or coronary angiography) during the readmission. Specifically, 63 (18.5%) had an echocardiogram, 99 (29.0%) had a SPECT imaging study, and 193 (56.6%) had diagnostic coronary angiography during rehospitalization (Figure 2). Diagnostic angiography resulted in repeat PCI in 54 patients (15.8%), which was of the target vessel in 19 patients (5.6%) and nontarget vessel in the remaining 35 patients (10.3%). Target lesion revascularization was performed in 9 patients (2.6%). The need for target lesion revascularization was driven by edge dissection (4 cases), previously underexpanded stent requiring angioplasty (1 case), inability to cross a lesion with a wire during the initial PCI attempt (1 case), and stenosis adjacent to previously placed stent (3 cases).

Discussion

Given the growing demand to reduce readmissions, we performed a detailed medical record review of PCI readmissions within 2 large academic medical centers. We found that readmissions after PCI most frequently occurred because of recurrent chest pain or angina symptoms, only a small minority of whom were ultimately diagnosed with myocardial infarction. Many of these admissions were associated with diagnostic imaging studies or procedures, but few resulted in discovery of a technical problem with the original PCI or the need for new unplanned interventions. In addition, we found that a significant proportion of readmissions was associated with elective procedures, including elective vascular procedures, staged PCI, or planned coronary artery bypass graft surgery.

Providers at hospitals with more 30-day readmissions than expected given case mix and patient characteristics may wish

Table 1. Clinical Characteristics of Patients Readmitted to the Index Hospital Within 30 Days After Discharge After a PCI Procedure (N=893)

Characteristic	All Patients (N=893)	Admitted With Concern for Angina (n=341)	All Others (n=552)	*P* Value (Comparing Patients With Concern for Angina vs Others)
Age (mean±SD)	66.8±12.9	63.7±13.3	68.8±12.2	<0.001
Women (%)	317 (35.5%)	110 (32.3%)	207 (37.5%)	0.112
Race/ethnicity (%)				0.592
Black	45 (5.0%)	21 (6.2%)	24 (4.4%)	
Hispanic	36 (4.0%)	12 (3.5%)	24 (4.4%)	
White	778 (87.1%)	293 (85.9%)	485 (87.9%)	
Asian	28 (3.1%)	12 (3.5%)	16 (2.9%)	
Native American	1 (0.1%)	1 (0.3%)	0 (0.0%)	
Other	5 (0.6%)	2 (0.6%)	3 (0.5%)	
Admission status (%)				0.003
Emergency department	344 (38.5%)	143 (41.9%)	201 (36.4%)	
Transfer from acute care	296 (33.2%)	124 (36.4%)	172 (31.2%)	
Other	253 (28.3%)	74 (21.7%)	179 (32.4%)	
Insurance (%)				<0.001
Government	519 (58.1%)	166 (48.7%)	353 (64.0%)	
Commercial	250 (28.0%)	117 (34.3%)	133 (24.1%)	
HMO	104 (11.7%)	50 (14.7%)	54 (9.8%)	
None	14 (1.6%)	6 (1.8%)	8 (1.5%)	
Non-US insurance	6 (0.7%)	2 (0.6%)	4 (0.7%)	
Prior MI >7 d (%)	361 (40.4%)	118 (34.6%)	243 (44.0%)	0.005
CHF history (%)	229 (25.6%)	57 (16.7%)	172 (31.2%)	<0.001
Prior valve surgery (%)	37 (4.1%)	6 (1.8%)	31 (5.6%)	0.005
Prior PCI (%)	333 (37.3%)	137 (40.2%)	196 (35.5%)	0.161
Prior CABG (%)	187 (21.0%)	63 (18.5%)	124 (22.5%)	0.155
Diabetes mellitus (%)	361 (40.4%)	104 (30.5%)	257 (46.6%)	<0.001
GFR (mL/min±SD)	67.1±29.4	74.9±26.2	62.3±30.2	<0.001
Hypertension (%)	757 (84.8%)	271 (79.5%)	486 (88.0%)	<0.001
Dyslipidemia (%)	847 (94.9%)	326 (95.6%)	521 (94.4%)	0.424
CVD (%)	202 (22.6%)	56 (16.4%)	146 (26.5%)	<0.001
PAD (%)	224 (25.1%)	48 (14.1%)	176 (31.9%)	<0.001
Chronic lung disease (%)	185 (20.7%)	57 (16.7%)	128 (23.2%)	0.020
Arterial access site				0.084
Femoral (%)	764 (85.6%)	279 (81.8%)	485 (87.9%)	
Brachial (%)	9 (1.0%)	4 (1.2%)	5 (0.9%)	
Radial (%)	101 (11.3%)	50 (14.7%)	51 (9.2%)	
PCI status				0.011
Elective (%)	167 (18.7%)	49 (14.4%)	118 (21.4%)	
Urgent (%)	549 (61.5%)	230 (67.5%)	319 (57.8%)	
Emergency (%)	174 (19.5%)	62 (18.2%)	112 (20.3%)	
Salvage (%)	3 (0.3%)	0 (0.00%)	3 (0.5%)	
Cardiogenic shock (%)	21 (2.4%)	4 (1.2%)	17 (3.1%)	0.068
IABP placed (%)	52 (5.8%)	17 (5.0%)	35 (6.3%)	0.401
Drug-eluting stent used (%)	420 (51.5%)	180 (55.9%)	240 (48.6%)	0.041

CABG indicates coronary artery bypass graft surgery; CHF, congestive heart failure; CVD, cerebrovascular disease; GFR, glomerular filtration rate; HMO, health maintenance organization; IABP, intra-aortic balloon pump; MI, myocardial infarction; PAD, peripheral artery disease; and PCI, percutaneous coronary intervention.

Table 2. Causes of Readmission in Order of Decreasing Frequency

Reason for Readmission	No. 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%)
Pneumonia	15 (1.7%)
Atrial fibrillation	12 (1.3%)
Urinary tract infection or urosepsis	11 (1.1%)
Stroke or transient ischemic attack (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 implantable cardioverter-defibrillator placement	4 (0.4%)
Renal failure	4 (0.4%)
Causes with <4 cases*	133 (14.9%)

CABG indicates coronary artery bypass graft surgery; and PCI, percutaneous coronary intervention.

*A full list of other causes for readmission appears in the Appendix in the Data Supplement.

to reduce their 30-day readmission rate after PCI. Our results emphasize several important implications for those hospitals and providers. First, we have shown that evaluations of chest pain or symptoms concerning for angina, by far, constitute the largest proportion of readmissions (38.1%) within 30 days. These results confirm and extend the results of a recent study[9] that found 26.7% of readmissions evaluate chest pain

Table 3. Most Common Reasons for Readmission for All Patients Readmitted to the Index Hospital, as Identified From Billing Data (Total N=609)

ICD-9 Code for Principal Diagnosis at Readmission	Number Readmitted Into Same Hospital (N=609)	Proportion of All Those Readmitted to Same Hospital, %
414: Other forms of chronic ischemic heart disease	189	31.0
786: Symptoms involving respiratory system and other chest symptoms	71	11.7
428: Heart failure	43	7.1
410: Acute myocardial infarction	29	4.8
996: Complications peculiar to certain specified procedures	21	3.4

ICD-9 indicates *International Classification of Diseases, Ninth Edition*.

or other symptoms concerning for angina (adding unstable angina, non–ST-segment–elevation myocardial infarction, stable angina, noncardiac chest pain, and pericarditis) and support the generalizability of our findings. Among patients readmitted with chest pain or possible angina, a large proportion received diagnostic imaging during the readmission, with more than half undergoing repeat coronary angiography. However, fewer than 1 in 8 patients readmitted with chest pain required a repeat revascularization procedure, with only 2.6% requiring repeat revascularization of the vessel treated on initial presentation. Fewer than 1 in 14 met criteria for myocardial infarction during the readmission. These readmissions and diagnostic procedures are likely associated with high healthcare costs related to the diagnostic testing and prolongation of hospital length of stay.

Of patients readmitted with chest pain or other symptoms concerning for angina, the vast majority did not require repeat PCI. Of the 22 patients with stent thrombosis, 21 presented with immediately manifest high-risk features, such as ST-segment–elevation myocardial infarction, cardiac arrest, or ongoing ECG changes. Because we observed that (1) patients with stent thrombosis generally demonstrated high-risk features, and (2) chest pain patients had low rates of PCI and low rates of myocardial infarction during readmission, our results

Table 4. Most Common Reasons for Readmission for All Patients Readmitted to a Nonindex Hospital, as Identified From Billing Data (Total N=297)

ICD-9 Code for Principal Diagnosis at Readmission	Number Readmitted to a Nonindex Hospital (N=297)	Proportion of All Those Readmitted Into a Nonindex Hospital, %
428: Heart failure	41	13.8
786: Symptoms involving respiratory system and other chest symptoms	33	11.1
414: Other forms of chronic ischemic heart disease	22	7.4
427: Cardiac dysrhythmias	13	4.4
578: Gastrointestinal hemorrhage	9	3.0

ICD-9 indicates *International Classification of Diseases, Ninth Edition*.

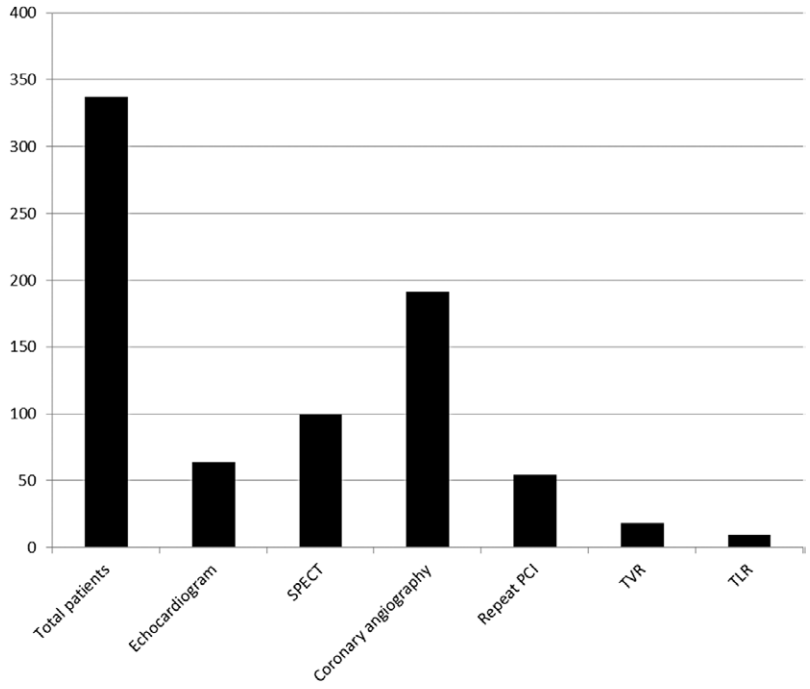

Figure 2. Diagnostic resource use and percutaneous coronary intervention (PCI) in patients readmitted with chest pain or other symptoms concerning for angina (patients can appear in multiple categories). SPECT indicates single-photon emission computed tomography; TLR, target lesion revascularization; and TVR, target vessel revascularization.

suggest that many patients with low-risk chest pain or other symptoms concerning for angina may be effectively evaluated in the outpatient or observational setting.

In general, physicians evaluating patients in the office, over the phone, or in the emergency department may perceive the need to admit patients to the hospital if they return with angina symptoms after a PCI procedure. Similarly, cardiologists may maintain a heightened sense of concern soon after a PCI procedure that they think justifies coronary angiography to ensure technical success of the original procedure. Our results suggest that in this healthcare network, chest pain or other symptoms concerning for angina, in the absence of immediately obvious stent thrombosis, rarely led to repeat PCI and rarely met criteria for myocardial infarction.

As such, we would propose that a hospital could potentially reduce short-term readmission rates after PCI by implementing an algorithm to prevent potential unnecessary readmissions. This type of algorithm is amenable to both outpatients and patients presenting to the emergency department. Such an algorithm could entail, first, the rapid clinical assessment of any patient with angina for signs and symptoms consistent with stent thrombosis or myocardial infarction, including ECG changes and elevated serum troponin. Outpatients considered to be at higher risk based on typical symptoms or ECG changes would be referred to an emergency department thereafter. All patients with stent thrombosis, acutely ischemic ECG changes, or positive troponin would be admitted to the hospital and treated appropriately. Second, patients with reassuring initial ECG and troponin could be evaluated by a cardiologist in the emergency department before admission. Patients considered low risk by the cardiologist based on interview, physical examination, review of emergency room data, and the prior angiographic images could be discharged directly, whereas those with high-risk features (classic angina, residual coronary obstruction noted on previous angiogram) could be admitted for further evaluation. This type of algorithm should be assessed prospectively in future research.

We found that the incidence of 30-day readmission because of complications of PCI is relatively low. Vascular or bleeding complications of PCI or stent thrombosis accounted for only 4.3% and 2.5% of 30-day readmissions after PCI, respectively. Nonaccess site bleeding accounted for 3.7% (33/893) of 30-day readmissions after PCI. If these results are generalizable to other health systems, genuine improvements in quality that reduce PCI complications will not likely reduce hospital readmission rates significantly, consistent with prior work.[7] However, the high frequency of 30-day readmission because of chest pain or angina symptoms raises the possibility that improvements in patient selection and PCI strategy may result in improvements both in quality of care and in reductions in costs within our health system.

Underscoring the opportunity to design more efficient approaches to treating patients after a recent PCI, a significant proportion of early readmissions was elective. In particular, staged PCI readmissions accounted for 6.6%, elective peripheral procedure or surgery not related to PCI accounted for 2.2%, and elective coronary artery bypass graft surgery accounted for 2.1% of 30-day readmissions. It is possible that deferring a repeat procedure beyond 30 days, or even longer, may permit optimal medical therapy alone to alleviate patients' symptoms and obviate the need for a repeat revascularization procedure at all. Revascularization of secondary lesions in staged PCI may not be indicated unless patients develop angina refractory to optimal medical therapy.

The information we obtained from the Massachusetts Data Analysis Center provides insight about the external validity of our chart review findings. In particular, because we found that 32.3% of patients readmitted within 30 days were readmitted to a nonindex hospital, our results may not apply to approximately one third of patients. Those patients seem to

have a lower incidence of readmission for symptoms concerning for coronary artery disease and a higher incidence of readmission for heart failure. Because these patients are admitted with different diagnoses, preventing these readmissions may require different strategies. Future analyses exploring why patients present to different hospitals and how their patterns of resource use differ may further hone our ability to reduce the overall readmission rate and reduce unnecessary costs.

Our study should be interpreted in the context of several potential limitations. First, as a study of a single integrated health network, the extent to which we can generalize our results to other hospitals and healthcare systems is unclear. Second, we were not able to perform detailed medical record review for readmissions to hospitals other than the hospital at which PCI was performed. Third, eastern Massachusetts is characterized by a low proportion of uninsured patients. Although this enhances our study by ensuring that a broad variety of patients are included, reasons for readmission related to uninsurance may be under-represented when compared with readmissions in other regions. Fourth, to reflect actual cost of all admissions, we included both inpatient and observation admissions in our analysis although this does differ from the National Quality Forum measure and current Center for Medicare and Medicaid Services policy, which includes only inpatient admissions. Also, because the time periods of the state-level analysis and the chart reviews overlapped but were not totally contemporaneous, we cannot confidently conclude that the differences in admission diagnoses apply exactly to our chart review population. Finally, although we think that these results may inform the development of strategies that might reduce readmissions, such strategies need to be evaluated prospectively to determine their value.

In conclusion, within a large integrated healthcare network, the plurality of readmissions within 30 days after PCI evaluate chest pain or other symptoms concerning for angina. These readmissions are associated with high use of diagnostic testing but low rates of target lesion revascularization or myocardial infarction. Complications of PCI account for substantially fewer readmissions. Reducing readmissions for low-risk chest pain after PCI has the potential to save substantial healthcare costs. The effects of those changes on safety and patient satisfaction deserve further investigation.

Acknowledgments

We thank Patrick Cronin for his assistance with this article.

Sources of Funding

This work was supported in part by the Massachusetts Department of Public Health and a grant from the American Heart Association (12CRP9010016).

Disclosures

Dr Spertus: research grant, American College of Cardiology Foundation, amount: >$10 000; Equity, Health Outcomes Sciences, amount: <$10 000; Dr Mauri: research grant: Abbott, amount: ≥$10 000; Boston Scientific, amount: ≥$10,000; Cordis, amount: ≥$10 000; Medtronic, amount: ≥$10 000; Eli Lilly, amount: ≥$10 000; Daiichi Sankyo, amount: ≥$10 000; Bristol Myers Squibb, amount: ≥$10 000; Sanofi-Aventis, amount: ≥$10,000; Consultant/Advisory Board: Cordis, amount: <$10 000; Medtronic, amount: ≥$10 000. The other authors report no conflicts.

References

1. Jencks SF, Williams MV, Coleman EA. Rehospitalizations among patients in the Medicare fee-for-service program. *N Engl J Med*. 2009;360:1418–1428.
2. *Public Law 111-148 - Patient Protection and Affordable Care Act*; 2010.
3. Joynt KE, Jha AK. Thirty-day readmissions–truth and consequences. *N Engl J Med*. 2012;366:1366–1369.
4. MedPAC. *Report to the Congress: Promoting Greater Efficiency in Medicare*. Washington, DC: Medicare Payment Advisory Commission (MedPAC); 2007.
5. National Quality Forum. *Endorsement Summary: All-Cause Readmissions*. Washington, DC: National Quality Forum; 2012.
6. Ricciardi MJ, Selzer F, Marroquin OC, Holper EM, Venkitachalam L, Williams DO, Kelsey SF, Laskey WK. Incidence and predictors of 30-day hospital readmission rate following percutaneous coronary intervention (from the National Heart, Lung, and Blood Institute Dynamic Registry). *Am J Cardiol*. 2012;110:1389–1396.
7. Yeh RW, Rosenfield K, Zelevinsky K, Mauri L, Sakhuja R, Shivapour DM, Lovett A, Weiner BH, Jacobs AK, Normand SL. Sources of hospital variation in short-term readmission rates after percutaneous coronary intervention. *Circ Cardiovasc Interv*. 2012;5:227–236.
8. 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.
9. 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.
10. Wasfy JH, Rosenfield K, Zelevinsky K, Sakhuja R, Lovett A, Spertus JA, Wimmer NJ, Mauri L, Normand SL, 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.