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Journal of Clinical Cardiology and Cardiovascular Interventions
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Open Access

Research Article

Readmissions in the Year After Percutaneous Coronary Intervention

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Received Date: March 04, 2022; **Accepted Date:** March 21, 2022; **Published Date:** March 29, 2022

Citation: Imran Baig, Amir Eslami DO, Andrea Berger MA, Cara Nordberg MPH, James Blankenship. (2022). Readmissions in the Year After Percutaneous Coronary Intervention. *J. Clinical Cardiology and Cardiovascular Interventions*, 5(4); Doi:10.31579/2641-0419/253

Abstract

Prior studies of readmission have evaluated correlates of 30-day readmission but have not evaluated correlates of readmission after 30 days. The study sought to evaluate factors associated with re-hospitalization within one year of undergoing percutaneous coronary intervention (PCI). We analyzed 6265 patients treated at Geisinger hospitals with PCI between January 2010 and December 2015. Correlates of readmission within 1 year were identified. Sub-groups were compared based on reason for readmission (related to versus not related to ischemic heart disease) and timing of readmission (1-30 days versus 31-365 days). Mean age was 64.3 years, 70% were male, and 98.8% were Caucasian. In the first year after PCI, 2,767 patients (44.2%) were re-admitted. Within 30 days 931 patients (14.9%) were readmitted; 1836 (29.3%) were readmitted between 31 and 365 days. Nine hundred fifty (15.2%). In summary, in an unselected patient cohort treated with PCI, approximately 44% of the patients were readmitted within one year. Two-thirds of these were admitted after the first month. Efforts to prevent the need for readmission should continue beyond the first month post-discharge and center on risk factor modification.

Key-words: coronary artery disease; percutaneous coronary intervention; re-admission

Introduction

Ischemic heart disease related healthcare costs are amongst the highest for any disease entity in the United States. Approximately one in every six US health care dollars is spent on cardiovascular disease [1]. Hospital readmission rates are variable and add to the health care costs. With the high cost of ischemic heart disease and the additional cost of revascularization for this subset of patients, there is limited data on risk factors that correlate with readmission after percutaneous coronary intervention (PCI) [2-4]. Previous studies have reviewed 30-day readmissions post PCI. However, readmissions from 30 days to one-year post-PCI have received little attention. The purpose of this analysis was to identify patient and characteristics associated with hospital readmission in the year after PCI [5].

Methods

We studied 7,228 patients undergoing PCI at our medical center between January 1, 2010 and December 31, 2015. For patients with multiple PCI encounters during the study period only the first was included. Patients were excluded if they died during their hospital stay (n = 159), if the encounter was missing the admission and discharge date/time information due to PCI database and electronic health record (EHR) matching issues (n = 24), if they died within 365 days of their procedure without a readmission prior to death (n = 110), or if they were without follow-up in the Geisinger Health System for 730 days after the original PCI discharge (n = 670). The remaining 6265 patients composed the study cohort.

Hospital readmissions (including emergency department visits and inpatient admissions) within 365 days of the PCI encounter discharge date were identified. Observation unit stays were excluded.

Descriptive statistics are provided for all 6265 patients, and for patients readmitted within 30 days, readmitted within 31-365 days, and not readmitted. Categorical variables are characterized using frequency counts and percentages. Continuous variables are characterized using means and standard deviations (S.D.) or medians and interquartile ranges (IQR). Characteristics of patients readmitted within 365 days were compared to those who were not readmitted using two-sample t-tests, Wilcoxon rank-sum tests, and Pearson's chi-square, or Fisher's exact tests, as appropriate. Multinomial logistic regression modeling was used to compare patients readmitted within 30 days, those readmitted within 31-365 days, and those that were not readmitted.

Due to the large number of study variables that were significantly associated with the readmission outcomes, bootstrap resampling was used for variable selection. Starting with 64 variables (Table 1), fast step-down selection keeping factors with significance levels < 0.10 was carried out on one thousand bootstrap samples for each of five binary logistic regression models: readmitted vs. not readmitted, readmitted within 30 days vs.

	Readmit vs Not Readmitted Model	30 Day/31 to 365/Not Readmitted Model
Age (Quadratic)	x	x
Sex		x
Body Mass Index (Piecewise with knot at 30)	x	x
Insurance Payers	x	x
Current/Recent Smoker		x
Hypertension	x	x
Dyslipidemia		
Family History of Premature coronary artery disease		
Prior myocardial infarction		x
Prior Heart Failure	x	x
Prior Valve Surgery/Procedure		x
Prior percutaneous coronary intervention		
Prior Coronary artery bypass grafting		x
Currently on Dialysis		x
Cerebrovascular Disease	x	x
Chronic Lung Disease	x	x
Diabetes Mellitus	x	x
Coronary artery disease Presentation	x	x
Angina Classification within 2 Weeks		x
Heart Failure Within 2 Weeks	x	x
Cardiomyopathy or LV Systolic Dysfunction		
Cardiogenic Shock Within 24 Hours	x	x
Cardiac Arrest Within 24 Hours		
Fluoroscopy Time (Piecewise with knot at 19)	x	x
Contrast Volume		
Procedure Diagnostic	x	x
Intra-aortic balloon pump		
Arterial Access Site	x	x
Left Main		
Proximal left anterior descending artery		
Distal left anterior descending artery		
Circumflex		
Right coronary artery	x	
Ramus		
PCI Scheduling Status	x	x
Cardiogenic Shock at Start of PCI		
Pre Creatinine (Piecewise with knot at 0.8)	x	x
Pre Hemoglobin (Piecewise with knot at 15)	x	x
Low Molecular Weight Heparin (any)		x
Unfractionated Heparin (any) at Procedure		
Aspirin at Procedure		
Bivalirudin at Procedure		x
Glycoprotein IIb/IIIa Inhibitors at Procedure		
Clopidogrel at Procedure	x	x
Prasugrel at Procedure		
Ticagrelor at Procedure	x	x
Angiotensin converting enzyme inhibitors/angiotensin receptor blockers s at Discharge		

Aspirin at Discharge		
Beta Blockers at Discharge	x	x
Lipid-Lowering Agents (statins and non-statins) at Discharge		
Clopidogrel at Discharge		
Prasugrel at Discharge	x	x
Ticagrelor at Discharge	x	x
Culprit Lesion Identification	x	x
Pre-Stenosis Percent	x	x
Lesion Complexity		x
Length (mm)		
Thrombus		
Bifurcation		
Systolic Blood Pressure (Piecewise with knot at 120)	x	x
Diastolic Blood Pressure (Piecewise with knot at 70)		x
Year of Intervention	x	x
Charlson Comorbidity Index on procedure Date	x	x
Duration of Index Hospitalization	x	x

Table 1: Variables Used in Bootstrap Resampling for Variable Selection

not readmitted, and readmitted within 31-365 days vs. not readmitted. Variables selected in 50% or more of the 1000 repetitions for readmitted versus not readmitted were retained for a final multivariable logistic regression model. Variables retained in 50% or more of either the 30-day readmission versus not readmitted or 31-365-day readmission versus not readmitted model were retained for a final multivariable multinomial logistic regression model. Odds ratio estimates, 95% confidence intervals, and p-values are reported for the results of the multivariable models.

Restricted cubic splines were used to assess non-linear relationships between continuous variables and outcomes. Non-linear relationships were included in the multivariable models as quadratic terms or piecewise linear terms, as appropriate. Missingness in variables used in the variable selection process did not exceed 1.3% for categorical variables and 5.8% for continuous variables. Missing values for categorical variables were imputed by random assignment to a category proportional to the frequencies in the non-missing observations. Missing values for continuous variables were imputed using non-missing median values by sex. Analysis was performed using R version 3.5.0, and SAS 9.4.

Results

The study cohort included 6265 patients. Mean age was 64.3 years, 70% were male, and 98.8% were Caucasian. In the first year after PCI, 2,767 patients (44.2%) were re-admitted. Nine hundred thirty-one patients (14.9%) were readmitted within 30 days and 1836 (29.3%) were readmitted between 31 and 365 days.

Correlates of Readmission within 365 days: Factors associated with readmission within a year are listed in Table 2 and results of multivariable logistic regression modeling are in Table 3. These included co-morbidities (Charlston comorbidity score, age, body mass index, history of hypertension, heart failure, cerebrovascular disease, chronic lung disease, diabetes mellitus), status at time of percutaneous coronary intervention (i.e., clinical presentation), cardiogenic shock within 24 hours, pre-procedure creatinine, pre-procedure hemoglobin, systolic blood pressure), procedural factors (culprit lesion, pre-stenosis percentage, arterial access site), and post-procedural factors (beta-blockers at discharge, prasugrel at discharge, ticagrelor at discharge, and length of stay). Patients with Medicare were more likely to be readmitted than patients with Blue Cross/Blue Shield, Geisinger Health Plan, or other insurance.

	All Patients (n = 6265)		Readmitted within 1 Year (n = 2767)		Not Readmitted (n = 3498)		Readmitted vs Not Readmitted P-Value
	n	%	n	%	n	%	
Age, mean (SD)	64.3 (12.2)		65.3 (12.8)		63.5 (11.7)		< **0.0001**
Male	4401	70.2%	1830	66.1%	2571	73.5%	< **0.0001**
Body mass index, mean (SD)	30.7 (6.8)		30.3 (7.2)		30.9 (6.4)		**0.0013**
Insurance Payors							< **0.0001**
Blue cross/Blue Shield	744	11.9%	259	9.4%	485	13.9%	
Geisinger Health	2345	37.4%	982	35.5%	1363	39.0%	
Medicaid	37	0.6%	17	0.6%	20	0.6%	
Medicare	2215	35.4%	1108	40.0%	1107	31.6%	
Others	924	14.7%	401	14.5%	523	15.0%	

Hypertension	4908	78.3%	2273	82.1%	2635	75.3%	< **0.0001**
Dyslipidemia	4746	75.8%	2137	77.2%	2609	74.6%	**0.0152**
Family History of Premature Coronary Artery Disease	2219	35.4%	930	33.6%	1289	36.8%	**0.0078**
Prior Myocardial Infarction	1410	22.5%	698	25.2%	712	20.4%	< **0.0001**
Prior Heart Failure	653	10.4%	389	14.1%	264	7.5%	< **0.0001**
Prior Valve Surgery/Procedure	109	1.7%	68	2.5%	41	1.2%	**0.0001**
Prior Percutaneous Coronary Intervention	1444	23.0%	684	24.7%	760	21.7%	**0.0052**
Prior Coronary Artery Bypass Surgery	871	13.9%	462	16.7%	409	11.7%	< **0.0001**
Currently on Dialysis	112	1.8%	86	3.1%	26	0.7%	< **0.0001**
Cerebrovascular Disease	645	10.3%	387	14.0%	258	7.4%	< **0.0001**
Chronic Lung Disease	701	11.2%	387	14.0%	314	9.0%	< **0.0001**
Diabetes Mellitus	2123	33.9%	1088	39.3%	1035	29.6%	< **0.0001**
CAD Presentation							< **0.0001**
No Symptoms, No Angina	289	4.6%	152	5.5%	137	3.9%	
Non-STEMI	1455	23.2%	664	24.0%	791	22.6%	
STEMI or Equivalent	1542	24.6%	660	23.9%	882	25.2%	
Stable Angina	917	14.7%	332	12.0%	585	16.7%	
Symptom Unlikely to be Ischemic	58	0.9%	21	0.8%	37	1.1%	
Unstable Angina	1998	31.9%	933	33.8%	1065	30.5%	
Missing	*6*	*0.1%*	*5*	*0.2%*	*1*	*0.0%*	
Heart Failure Within 2 Weeks *(n missing = 16)*	539	8.6%	333	12.1%	206	5.9%	< **0.0001**
Cardiomyopathy or LV Systolic Dysfunction *(n missing = 16)*	626	10.0%	331	12.0%	295	8.4%	< **0.0001**
Cardiogenic Shock Within 24 Hours *(n missing = 16)*	121	1.9%	75	2.7%	46	1.3%	< **0.0001**
Contrast Volume, mean (SD) *(n missing = 320)*	177.3 (77.8)		173.3 (77.8)		180.4 (77.7)		**0.0005**
Intra-aortic Balloon Pump	160	2.6%	96	3.5%	64	1.8%	< **0.0001**
Arterial Access Site							< **0.0001**
Femoral	2938	46.9%	1413	51.1%	1525	43.6%	
Radial	3307	52.8%	1345	48.6%	1962	56.1%	
Brachial/Others	18	0.3%	8	0.3%	10	0.3%	
Missing	*2*	*0.0%*	*1*	*0.0%*	*1*	*0.0%*	
PCI Status							< **0.0001**
Elective	1762	28.4%	682	25.0%	1080	31.1%	
Emergency	1609	25.9%	691	25.3%	918	26.4%	
Salvage	58	0.9%	28	1.0%	30	0.9%	
Urgent	2777	44.7%	1332	48.7%	1445	41.6%	
Missing	*59*	*0.9%*	*34*	*1.2%*	*25*	*0.7%*	
Cardiogenic Shock at Start of PCI *(n missing = 79)*	126	2.0%	69	2.5%	57	1.6%	**0.0138**
Pre PCI Creatinine, median (IQR) *(n missing = 297)*	0.9 (0.8, 1.1)		1.0 (0.8, 1.2)		0.9 (0.8, 1.1)		< **0.0001**

Pre PCI Hemoglobin, mean (STD) *(n missing = 362)*	13.7 (1.9)		13.3 (2.0)		14.0 (1.7)		< **0.0001**
Discharge Medication							
Aspirin	6071	96.9%	2665	96.3%	3406	97.4%	**0.0165**
Clopidogrel	5191	82.9%	2228	80.5%	2963	84.7%	< **0.0001**
Ticagrelor	486	7.8%	247	8.9%	239	6.8%	**0.0021**
Lesions Characteristic							
Thrombus	1916	30.6%	792	28.6%	1124	32.1%	**0.0028**
Previous Analysis							
Year of Intervention							< **0.0001**
2010	1156	18.5%	450	16.3%	706	20.2%	
2011	1029	16.4%	425	15.4%	604	17.3%	
2012	933	14.9%	370	13.4%	563	16.1%	
2013	1061	16.9%	523	18.9%	538	15.4%	
2014	1098	17.5%	524	18.9%	574	16.4%	
2015	988	15.8%	475	17.2%	513	14.7%	
Charlson Comorbidity Index on Procedure Date							< **0.0001**
0	368	5.9%	144	5.2%	224	6.4%	
1 to 2	2159	34.5%	802	29.0%	1357	38.8%	
≥ 3	3738	59.7%	1821	65.8%	1917	54.8%	
Duration of Index Hospitalization							< **0.0001**
0 to 3 Days	4472	71.4%	1780	64.3%	2692	77.0%	
4 to 7 Days	1387	22.1%	720	26.0%	667	19.1%	
> 7 Days	406	6.5%	267	9.6%	139	4.0%	

STEMI = ST elevation myocardial infarction, PCI = Percutaneous Coronary Intervention, SD = standard deviation, IQR = Inter-quartile range, CK-MB = Creatine Kinase-Myocardial Band

Table 2: Summary of patient and encounter characteristics overall and by readmitted and not readmitted, excluding those not used in bootstrap variable selection an excluding those without significant differences between those readmitted and not readmitted.

Readmission within 365 Days (n = 6265)	OR	95% CI Upper, Lower		P-Value
Age Quadratic- Age 55 (Q1) one year increase	0.974	0.965	0.983	< **0.0001**
Age Quadratic- Age 64 (Median)one year increase	0.991	0.984	0.998	
Age Quadratic- Age 73 (Q3) one year increase	1.008	0.999	1.016	
Body Mass Index (1 unit increase for BMI < 30)	0.958	0.939	0.978	**0.0001**
Body Mass Index (1 unit increase for BMI ≥ 30)	1.007	0.995	1.020	
Insurance: Geisinger vs Blue Cross/Blue Shield	1.181	0.980	1.422	**0.0014**
Insurance: Medicaid vs Blue Cross/Blue Shield	1.397	0.689	2.832	
Insurance: Medicare vs Blue Cross/Blue Shield	1.447	1.191	1.758	
Insurance: Others vs Blue Cross/Blue Shield	1.198	0.969	1.480	
Hypertension	1.350	1.174	1.552	< **0.0001**
Prior Heart Failure	1.328	1.086	1.624	**0.0057**
Cerebrovascular Disease	1.663	1.390	1.989	< **0.0001**
Chronic Lung Disease	1.258	1.060	1.493	**0.0085**

Diabetes Mellitus	1.268	1.120	1.434	**0.0002**
Coronary Disease Presentation: No Symptoms/No Angina vs Unlikely Ischemic	1.754	0.943	3.262	**0.0023**
Coronary Disease Presentation: Non-STEMI vs Unlikely Ischemic	1.477	0.825	2.645	
Coronary Disease Presentation: STEMI vs Unlikely Ischemic	1.428	0.746	2.732	
Coronary Disease Presentation: Stable Angina vs Unlikely Ischemic	1.327	0.738	2.386	
Coronary Disease Presentation: Unstable Angina vs Unlikely Ischemic	1.815	1.022	3.223	
Cardiogenic Shock within 24 Hours	1.593	1.030	2.464	**0.0363**
Fluoroscopy Time (1 minute increase for time ≥ 19)	1.004	0.997	1.011	
Procedure Diagnostic	1.288	1.048	1.583	**0.0161**
Arterial Access: Radial vs Femoral	0.815	0.725	0.916	**0.0024**
Arterial Access: Brachial/Others vs Femoral	1.095	0.417	2.874	
PCI Scheduling Status: Emergency vs Elective	1.464	1.050	2.042	**0.0062**
PCI Scheduling Status: Salvage vs Elective	0.933	0.482	1.805	
PCI Scheduling Status: Urgent vs Elective	1.299	1.099	1.535	
Creatinine Pre-Procedure (0.1 increase for < 0.8)	0.896	0.828	0.969	**0.0005**
Creatinine Pre-Procedure (0.1 increase for ≥ 0.8)	1.017	1.007	1.027	
Hemoglobin Pre-Procedure (1 unit increase for < 15)	0.906	0.867	0.946	**< 0.0001**
Hemoglobin Pre-Procedure (1 unit increase for ≥ 15)	0.976	0.874	1.090	
Beta Blockers at Discharge	0.822	0.688	0.983	**0.0316**
Prasugrel at Discharge	1.317	1.033	1.679	**0.0263**
Ticagrelor at Discharge	1.519	1.052	2.193	**0.0257**
Culprit Lesion Identification vs Unknown	0.760	0.641	0.901	**0.0016**
Pre-Stenosis Percent (1 unit increase)	0.993	0.987	0.999	**0.0152**
Systolic Blood Pressure (1 unit increase < 120)	0.989	0.981	0.997	**0.0269**
Systolic Blood Pressure (1 unit increase ≥ 120)	1.003	0.999	1.007	
Procedure Year: 2011 vs 2010	1.135	0.946	1.361	**< 0.0001**
Procedure Year: 2012 vs 2010	1.130	0.934	1.367	
Procedure Year: 2013 vs 2010	1.796	1.489	2.166	
Procedure Year: 2014 vs 2010	1.653	1.367	1.999	
Procedure Year: 2015 vs 2010	1.773	1.447	2.172	
Charlson Comorbidity Index on Cath Date (3 vs 0)	1.359	1.000	1.848	
Length of Stay: (4-7 Days vs 0 to 3 Days)	1.258	1.094	1.446	**< 0.0001**
Length of Stay: (> 7 Days vs 0 to 3 Days)	1.712	1.331	2.201	

STEMI = ST elevation myocardial infarction, PCI = Percutaneous Coronary Intervention, SD = standard deviation, BMI = Body Mass Index

Table 3: Multivariable Binary Logistic Regression Results for Outcome of Readmitted within 365 Days and Not Readmitted

Acute coronary syndrome patients were more likely to be readmitted compared to patients with stable or unlikely ischemic presentations. Radial access patients were less likely to be readmitted compared to femoral access patients. Emergency and urgent procedure patients had higher odds of readmission compared to elective procedure patients. A non-linear association between systolic blood pressure and readmission was observed - as systolic pressure increased for patients with systolic pressure < 120, readmission was less likely. Poorly controlled blood pressure was a risk factor for readmission. Correlates of readmission Days 1-30 days versus Days 31 -334: Most characteristics associated with 1 to 30-day readmission by multivariable nominal logistic regression were also associated with admission from 31-334 days, but some differences were observed (Tables 4,5).

	All Patients (n = 6265)		Readmission within 30 Days (n = 931)		Readmission 31-365 Days (n = 1836)		Not Readmitted (n = 3498)		30 Day Readmission vs Not Readmitted P-Value	31-365 Day Readmission vs Not Readmitted P-Value
	n	%	n	%	n	%	n	%		
Age, mean (SD)	64.3 (12.2)		65.2 (13.1)		65.4 (12.6)		63.5 (11.7)		**0.0002**	**< 0.0001**
Male	4401	70.2%	578	62.1%	1252	68.2%	2571	73.5%	**< 0.0001**	**< 0.0001**
Body Mass Index, mean (SD)	30.7 (6.8)		30.0 (7.2)		30.5 (7.1)		30.9 (6.4)		**0.0001**	0.0676
Insurance Payors									**< 0.0001**	**< 0.0001**
Blue cross/Blue Shield	744	11.9%	92	9.9%	167	9.1%	485	13.9%		
Geisinger Health	2345	37.4%	314	33.7%	668	36.4%	1363	39.0%		
Medicaid	37	0.6%	9	1.0%	8	0.4%	20	0.6%		
Medicare	2215	35.4%	361	38.8%	747	40.7%	1107	31.6%		
Others	924	14.7%	155	16.6%	246	13.4%	523	15.0%		
Hypertension	4908	78.3%	764	82.1%	1509	82.2%	2635	75.3%	**< 0.0001**	**< 0.0001**
Dyslipidemia	4746	75.8%	697	74.9%	1440	78.4%	2609	74.6%	0.8613	**0.0018**
Family History of Premature Coronary Artery Disease	2219	35.4%	307	33.0%	623	33.9%	1289	36.8%	**0.0288**	**0.0348**
Prior Myocardial Infarction	1410	22.5%	199	21.4%	499	27.2%	712	20.4%	0.4935	**< 0.0001**
Prior Heart Failure	653	10.4%	130	14.0%	259	14.1%	264	7.5%	**< 0.0001**	**< 0.0001**
Prior Valve Surgery/Procedure	109	1.7%	24	2.6%	44	2.4%	41	1.2%	**0.0020**	**0.0009**
Prior PCI	1444	23.0%	196	21.1%	488	26.6%	760	21.7%	0.6568	**< 0.0001**
Prior Coronary Artery Bypass Surgery	871	13.9%	123	13.2%	339	18.5%	409	11.7%	0.2047	**< 0.0001**
Currently on Dialysis	112	1.8%	30	3.2%	56	3.1%	26	0.7%	**< 0.0001**	**< 0.0001**
Cerebrovascular Disease	645	10.3%	124	13.3%	263	14.3%	258	7.4%	**< 0.0001**	**< 0.0001**
Chronic Lung Disease	701	11.2%	131	14.1%	256	13.9%	314	9.0%	**< 0.0001**	**< 0.0001**
Diabetes Mellitus	2123	33.9%	354	38.0%	734	40.0%	1035	29.6%	**< 0.0001**	**< 0.0001**
Coronary Artery Disease Presentation									**< 0.0001**	**< 0.0001**
No Symptoms, No Angina	289	4.6%	44	4.7%	108	5.9%	137	3.9%		
Non-STEMI	1455	23.2%	233	25.0%	431	23.5%	791	22.6%		
STEMI or Equivalent	1542	24.6%	266	28.6%	394	21.5%	882	25.2%		
Stable Angina	917	14.7%	91	9.8%	241	13.2%	585	16.7%		
Symptom Unlikely to be Ischemic	58	0.9%	12	1.3%	9	0.5%	37	1.1%		
Unstable Angina	1998	31.9%	285	30.6%	648	35.4%	1065	30.5%		
Missing	*6*	*0.1%*	*0*	*0.0%*	*5*	*0.3%*	*1*	*0.0%*		
Heart Failure Within 2 Weeks *(n missing = 16)*	539	8.6%	118	12.7%	215	11.8%	206	5.9%	**< 0.0001**	**< 0.0001**
Cardiomyopathy or LV Systolic Dysfunction *(n missing = 16)*	626	10.0%	120	12.9%	211	11.6%	295	8.4%	**< 0.0001**	**0.0002**

Cardiogenic Shock Within 24 Hours *(n missing = 16)*	121	1.9%	38	4.1%	37	2.0%	46	1.3%	< **0.0001**	**0.0492**
Cardiac Arrest Within 24 Hours *(n missing = 16)*	142	2.3%	28	3.0%	39	2.1%	75	2.1%	0.1234	0.9772
Contrast Volume, mean (SD) *(n missing = 320)*	177.3 (77.8)		171.6 (76.1)		174.2 (78.7)		180.4 (77.7)		**0.0028**	**0.0074**
IABP	160	2.6%	42	4.5%	54	2.9%	64	1.8%	< **0.0001**	**0.0094**
Arterial Access Site									**0.0005**	< **0.0001**
Femoral	2938	46.9%	471	50.6%	942	51.3%	1525	43.6%		
Radial	3307	52.8%	456	49.0%	889	48.4%	1962	56.1%		
Brachial/Others	18	0.3%	4	0.4%	4	0.2%	10	0.3%		
Missing	*2*	*0.0%*	*0*	*0.0%*	*1*	*0.1%*	*1*	*0.0%*		
PCI Status									< **0.0001**	**0.0001**
Elective	1762	28.4%	174	18.9%	508	28.0%	1080	31.1%		
Emergency	1609	25.9%	270	29.3%	421	23.2%	918	26.4%		
Salvage	58	0.9%	16	1.7%	12	0.7%	30	0.9%		
Urgent	2777	44.7%	460	50.0%	872	48.1%	1445	41.6%		
Missing	*59*	*0.9%*	*11*	*1.2%*	*23*	*1.3%*	*25*	*0.7%*		
Cardiogenic Shock at Start of PCI *(missing = 79)*	126	2.0%	37	4.0%	32	1.8%	57	1.6%	< **0.0001**	0.7307
Pre Creatinine, median (IQR) *(n missing = 297)*	0.9 (0.8, 1.1)		0.9 (0.8, 1.2)		1.0 (0.8, 1.2)		0.9 (0.8, 1.1)		< **0.0001**	< **0.0001**
Pre Hemoglobin, mean (STD) *(n missing = 362)*	13.7 (1.9)		13.2 (2.0)		13.4 (2.0)		14.0 (1.7)		< **0.0001**	< **0.0001**
Discharge Medication										
Aspirin	6071	96.9%	901	96.8%	1764	96.1%	3406	97.4%	0.3270	**0.0099**
Lipid Lowering Agents (Statins and Non-Statins)	6028	96.2%	893	95.9%	1746	95.1%	3389	96.9%	0.1448	**0.0012**
Thienopyridines										
Clopidogrel	5191	82.9%	735	78.9%	1493	81.3%	2963	84.7%	< **0.0001**	**0.0015**
Ticagrelor	486	7.8%	95	10.2%	152	8.3%	239	6.8%	**0.0006**	0.0545
Lesions and Devices										
Pre-Stenosis Percent, median (IQR) *(n missing = 29)*	95 (90, 100)		95 (90, 100)		95 (90, 100)		95 (90, 100)		0.8073	**0.0326**
Thrombus	1916	30.6%	302	32.4%	490	26.7%	1124	32.1%	0.8592	< **0.0001**
Previous Analysis										
Year of Intervention									< **0.0001**	< **0.0001**
2010	1156	18.5%	146	15.7%	304	16.6%	706	20.2%		
2011	1029	16.4%	139	14.9%	286	15.6%	604	17.3%		
2012	933	14.9%	115	12.4%	255	13.9%	563	16.1%		
2013	1061	16.9%	171	18.4%	352	19.2%	538	15.4%		
2014	1098	17.5%	184	19.8%	340	18.5%	574	16.4%		
2015	988	15.8%	176	18.9%	299	16.3%	513	14.7%		

Charlson Comorbidity Index on Procedure Date									< **0.0001**	< **0.0001**
0	368	5.9%	40	4.3%	104	5.7%	224	6.4%		
1 to 2	2159	34.5%	285	30.6%	517	28.2%	1357	38.8%		
≥ 3	3738	59.7%	606	65.1%	1215	66.2%	1917	54.8%		
Duration of Index Hospitalization									< **0.0001**	< **0.0001**
0 to 3 Days	4472	71.4%	536	57.6%	1244	67.8%	2692	77.0%		
4 to 7 Days	1387	22.1%	277	29.8%	443	24.1%	667	19.1%		
> 7 Days	406	6.5%	118	12.7%	149	8.1%	139	4.0%		

STEMI = ST elevation myocardial infarction, PCI = Percutaneous Coronary Intervention, SD = standard deviation, IQR = Inter-quartile range, CK-MB = Creatine Kinase-Myocardial Band, CCS= Canadian Cardiovascular Society Class

Table 4: Summary of Patient and Encounter Characteristics Overall and by Readmitted Days 1-30, Readmitted Days 31 - 365, and Not Readmitted, Excluding those not use in bootstrap variable selection

Readmission within 30 Days, Readmssion Between 31 and 365 Days, and Not Readmitted (n = 6265)	Readmission within 30 Days vs Not Readmitted				Readmission 31-365 Days vs Not Readmitted			
	OR	95% CI Upper, Lower		P-Value	OR	95% CI Upper, Lower		P-Value
Age Quadratic- Age 55 (Q1) one year increase	0.966	0.953	0.978	< **0.0001**	0.981	0.971	0.992	< **0.0001**
Age Quadratic- Age 64 (Median) one year increase	0.986	0.976	0.995		0.995	0.987	1.003	
Age Quadratic- Age 73 (Q2) one year increase	1.006	0.994	1.018		1.010	1.000	1.019	
BMI (1 unit increase for BMI < 30)	0.949	0.924	0.976	**0.0001**	0.964	0.943	0.986	**0.0056**
BMI (1 unit increase for BMI ≥ 30)	0.995	0.978	1.014		1.012	0.998	1.025	
Insurance: Geisinger vs Blue Cross/Blue Shield	1.105	0.840	1.453	0.0838	1.213	0.980	1.502	**0.0026**
Insurance: Medicaid vs Blue Cross/Blue Shield	2.014	0.836	4.850		1.034	0.432	2.479	
Insurance: Medicare vs Blue Cross/Blue Shield	1.333	1.003	1.771		1.482	1.187	1.851	
Insurance: Others vs Blue Cross/Blue Shield	1.301	0.960	1.762		1.139	0.892	1.454	
Recent Smoker	0.949	0.786	1.146	0.5874	1.158	1.001	1.340	**0.0485**
Hypertension	1.550	1.259	1.907	< **0.0001**	1.249	1.065	1.464	**0.0062**
Prior Myocardial Infarction	0.943	0.773	1.150	0.5628	1.174	1.012	1.362	**0.0344**
Previous Coronary Bypass Surgery	0.951	0.735	1.230	0.6993	1.222	1.012	1.474	**0.0369**
Cerebrovascular Disease	1.576	1.232	2.016	**0.0003**	1.665	1.370	2.024	< **0.0001**
Diabetes Mellitus	1.237	1.036	1.478	**0.0188**	1.271	1.107	1.459	**0.0007**
Coronary disease Presentation: No Symptoms/No Angina vs Unlikely Ischemic	0.950	0.416	2.168	0.0725	2.916	1.277	6.659	**0.0012**
Coronary disease Presentation: Non-STEMI vs Unlikely Ischemic	0.792	0.374	1.676		2.189	0.998	4.800	
Coronary disease Presentation: STEMI vs Unlikely Ischemic	0.936	0.401	2.182		1.934	0.827	4.520	
Coronary disease Presentation: Stable Angina vs Unlikely Ischemic	0.632	0.296	1.349		1.998	0.912	4.378	

Coronary disease Presentation: Unstable Angina vs Unlikely Ischemic	0.988	0.472	2.068		2.767	1.271	6.024	
Cardiogenic Shock within 24 Hours	1.818	1.076	3.070	**0.0254**	1.414	0.855	2.338	0.1769
Fluoroscopy Time (1 minute increase for time < 19)	0.977	0.961	0.994	**0.0258**	0.987	0.974	1.000	0.1376
Fluoroscopy Time (1 minute increase for time ≥ 19)	1.007	0.997	1.017		1.002	0.994	1.009	
Procedure Diagnostic	1.461	1.094	1.950	**0.0101**	1.298	1.042	1.616	**0.0201**
Arterial Access: Radial vs Femoral	0.886	0.745	1.054	0.1919	0.812	0.710	0.930	**0.0104**
Arterial Access: Brachial/Others vs Femoral	1.947	0.580	6.540		0.770	0.233	2.543	
PCI Scheduling Status: Emergency vs Elective	1.690	1.049	2.723	**0.0039**	1.437	0.986	2.093	**0.0352**
PCI Scheduling Status: Salvage vs Elective	1.361	0.597	3.103		0.681	0.303	1.534	
PCI Scheduling Status: Urgent vs Elective	1.609	1.241	2.085		1.213	1.004	1.465	
Creatinine Pre-Procedure (0.1 increase for < 0.8)	0.965	0.858	1.084	0.3804	0.890	0.812	0.976	**0.0156**
Creatinine Pre-Procedure (0.1 increase for ≥ 0.8)	1.011	0.995	1.027		1.013	0.999	1.027	
Hemoglobin Pre-Procedure (1 unit increase for < 15)	0.898	0.844	0.954	**0.0015**	0.926	0.880	0.973	**0.0036**
Hemoglobin Pre-Procedure (1 unit increase for ≥ 15)	1.001	0.850	1.179		0.970	0.854	1.100	
Prasugrel at Discharge	1.358	0.959	1.924	0.0849	1.331	1.014	1.745	**0.0392**
Ticagrelor at Discharge	1.636	0.989	2.704	0.0550	1.519	1.001	2.306	**0.0496**
Culprit Lesion Identification vs Unknown	0.743	0.580	0.952	**0.0188**	0.765	0.634	0.922	**0.0050**
Pre-Stenosis Percent (1 unit increase)	0.992	0.983	1.000	0.0604	0.992	0.986	0.999	**0.0219**
Diastolic Blood Pressure (1 unit increase ≥ 70)	1.005	0.992	1.018		1.006	0.996	1.016	
Procedure Year: 2011 vs 2010	1.140	0.870	1.493	**< 0.0001**	1.155	0.941	1.417	**< 0.0001**
Procedure Year: 2012 vs 2010	1.085	0.816	1.444		1.160	0.936	1.437	
Procedure Year: 2013 vs 2010	1.812	1.379	2.382		1.761	1.426	2.175	
Procedure Year: 2014 vs 2010	1.703	1.282	2.263		1.507	1.207	1.882	
Procedure Year: 2015 vs 2010	1.861	1.361	2.545		1.515	1.182	1.941	
Charlson Comorbidity Index on Cath Date (1 to 2 vs 0)	1.631	1.086	2.448	**0.0180**	0.945	0.703	1.270	0.2158
Charlson Comorbidity Index on Cath Date (3 vs 0)	1.945	1.226	3.085		1.102	0.782	1.552	
Length of Stay: (4-7 Days vs 0 to 3 Days)	1.467	1.210	1.779	**< 0.0001**	1.157	0.988	1.355	**0.0186**
Length of Stay: (> 7 Days vs 0 to 3 Days)	2.180	1.590	2.989		1.449	1.091	1.923	

STEMI = ST elevation myocardial infarction, PCI = Percutaneous Coronary Intervention, SD = standard deviation, BMI = Body Mass Index

Table 5: Multivariable Multinomial Logistic Regression Results for Outcome of Readmitted within 30 Days, Readmitted Between 31 and 365 Days, and Not Readmitted

Factors correlating with later readmission, but NOT early readmission included smoking, prior MI, prior coronary artery bypass graft surgery, radial access, and creatinine. Factors associated with early readmission, but not later readmission included male gender, insurance status, pre-procedural angina classification, acute shock, radial access, beta blocker therapy at discharge, systolic blood pressure, and Charlson Co-morbidity Index.

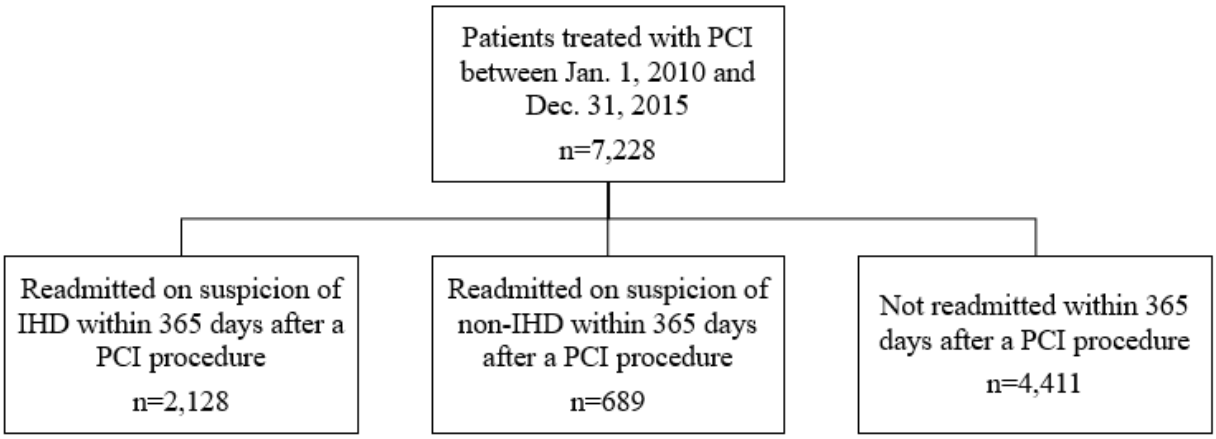

Figure: Flow-chart of PCI patients included in the study

Discussion

The most important finding of this study is that the two-fifths of patients undergoing PCI were readmitted within one year of the procedure. Of those readmitted, one-third were readmitted within the first 30 days and two-thirds were readmitted over the next 11 months. Most studies of readmission after PCI focus only on 30-day re-admissions. Our study shows that a 30-day assessment is limited and under-estimates the burden of morbidity in post-PCI patients. Care of post-PCI patients beyond 30 days should be of interest to the interventionalist.

Only two factors over which clinicians have control were associated with likelihood of readmission. First, radial access (versus femoral access) had an odds ratio of .81 (p = 0.002) of re-admission. Multiple studies have demonstrated that radial access compared to femoral access decreases vascular complications and bleeding which might explain this correlation [6]. However, use of radial access correlated with reduced rates of late but not early re-admission which is inconsistent with the hypothesis that reduced rates of procedure-related vascular access complications or bleeding are responsible for the lower re-admission rates. The association with reduced late re-admissions may be due to unknown confounders related to co-morbidities, since femoral access was often reserved for older and sicker patients.

Second, beta-blockers at discharge were associated with an odds ratio of 0.82 (p = 0.03) of any readmission. The correlation was limited to readmissions within the first 30 days (odds ratio 0.74, p = 0.02) but not after 30 days (odds ratio 0.85, p = .11). This observation has been previously reported [7], but again we cannot exclude unknown confounders since the benefit of beta-blockers is unclear in patients without MI.

Several additional findings are of interest. Urgent and emergent PCI (linked to acute coronary syndromes) status was associated with a 30-46% excess rate of re-admission compared to elective (stable) PCI status. Patients discharged on ticagrelor or prasugrel had 31-52% excess re-admission rates compared to patients discharged on clopidogrel, perhaps because these drugs were used preferentially for acute coronary syndrome patients and because they increase bleeding risk compared to clopidogrel. Finally, length of stay of 4-7 days and > 7 days correlated with 26% and 71% increased risks of readmission, respectively, compared to shorter lengths of stay, presumably because length of stay is a marker for severity of the initial hospitalization and overall clinical status.

We are aware of only 1 other study that evaluated re-admissions up to 1 year after PCI [5]. That study was conducted in Denmark, where the National Health Service guarantees free hospital access. In the Danish cohort 50% of patients were re-admitted within 1 year compared to 44% in our study. Similar to our findings, the Denmark investigators concluded that readmission is common in the year following PCI, that many of the re-admissions are due to ischemic heart disease, that co-morbidities correlate most closely with readmission, and that we could identify few modifiable correlates of readmission. Both studies point to the importance of secondary risk factor modification and careful follow-up after PCI. Differences may be due in part to our inability to identify re-admissions to hospitals outside of our 13-hospital system, although we excluded patients lost-to follow-up from our initial cohort. Half of the Denmark patients were readmitted due to angina or myocardial infarction whereas two-thirds of our patients were readmitted with ischemia-related diagnoses. Both studies identified age, Charlson Comorbidity Index </=3, and diabetes as correlates of readmission. The Denmark study identified female gender as a correlate of readmission although our study did not, perhaps because of closer association with other demographic variables that were not available to the Denmark investigators. However, our study showed a 25% increased risk of readmission for women in the first 30 days that equalized over the next 11 months.

Readmission rates after PCI within 30 days have been extensively studied, perhaps because 30 days is the time window considered by the Center for Medicare and Medicaid Services Hospital Re-admission Reduction Program (HRRP). However, this focus may result in lack of focus on care of post-PCI patients over the next 11 months. Attendance at cardiac rehabilitation sessions, adherence to medications, and control of risk factors have all been shown to decrease morbidity and/or mortality after PCI [8-9]. Close follow-up by cardiovascular specialists is important to ensure these goals are met.

Limitations

Our study has several limitations. We were unable to identify re-admissions to a non-Geisinger hospital, although Geisinger operates 13 hospitals in central and northeastern Pennsylvania where the population is very stable and where most patients treated at Geisinger return to Geisinger. The population included in this study was 98% Caucasian, so results may not be generalizable to other more heterogeneous populations. We only considered the first re-admission for each patient, so we are underestimating the total burden of re-admission for this population. We did not identify patients readmitted for elective (staged) PCI, although most of these were assigned “observation” status and thus not counted as readmissions.

In summary, re-admission is common in the first year after PCI. Two-thirds of readmissions occur after the first 30 days. The common focus on readmissions in the first 30 days may result in under-attention to treatments and behaviors known to correlate with reductions in subsequent ischemic events. Providers should focus not just on the first 30 days after PCI but on continuing care and management of these ischemia-prone individuals.

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DOI: 10.31579/2641-0419/253