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ORIGINAL RESEARCH

Understanding Readmissions in Medicare Beneficiaries During the 90-Day Follow-Up Period of an Acute Myocardial Infarction Admission

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***Background*—**Medicare has a voluntary episodic payment model for Medicare beneficiaries that bundles payment for the index acute myocardial infarction (AMI) hospitalization and all post-discharge services for a 90-day follow-up period. The purpose of this study is to report on the types and frequency of readmissions and identify demographic and clinical factors associated with readmission of Medicare beneficiaries that survived their AMI hospitalization.

***Methods and Results*—**This retrospective study used the Inpatient Standard Analytical File for 2014. There were 143 286 Medicare beneficiaries with AMI who were discharged alive from 3619 hospitals. All readmissions occurring in any hospital within 90 days of the index AMI discharge date were identified. Of 143 286 Medicare beneficiaries discharged alive from their index AMI hospitalization, 28% (40 145) experienced at least 1 readmission within 90 days and 8% (11 477) had >1 readmission. Readmission rates were higher among Medicare beneficiaries who did not undergo a percutaneous coronary intervention in their index AMI admission (34%) compared with those that underwent a percutaneous coronary intervention (20.2%). Using all Medicare beneficiary's index AMI, 27 comorbid conditions were significantly associated with the likelihood of a Medicare beneficiary having a readmission during the follow-up period. The strongest clinical characteristics associated with readmissions were dialysis dependence, type 1 diabetes mellitus, and heart failure.

***Conclusions*—**This study provides benchmark information on the types of hospital readmissions Medicare beneficiaries experience during a 90-day AMI bundle. This paper also suggests that interventions are needed to alleviate the need for readmissions in high-risk populations, such as, those managed medically and those at risk of heart failure. **(*J Am Heart Assoc*. 2019;8:e013513. DOI: 10.1161/JAHA.119.013513.)**

Key Words: Medicare bundled payments • myocardial infarction • readmission

Advances in the management of acute myocardial infarction (AMI) have reduced morbidity and mortality, resulting in a higher number of hospital discharges, and therefore, a greater potential for hospital readmission.[1,2] In 2009, the Centers for Medicare and Medicaid Services targeted hospital readmissions following AMI for reduction through public reporting of readmission as a measure of quality, and in 2012 for cost savings through penalties for higher than expected readmission rates.[2–7] As a result, readmission within the 30-day follow-up period after an index AMI hospitalization has been studied for measures including: cause, type, rate, timing, predictability, prevention, relation to mortality, and use for hospital profiling.[2,3,5,8–20]

In a movement toward value-based payment, Centers for Medicare and Medicaid Services has new voluntary episodic payment models for AMI. Under these episodes hospitals will assume financial responsibility for Medicare beneficiaries admitted with AMI, encompassing the period from the index hospitalization through 90 days following discharge.[1] Under this initiative, Medicare beneficiaries experiencing AMI will be segregated into 2 populations: those treated with percutaneous coronary intervention (PCI) during the index hospitalization, and those managed medically (no PCI during index hospitalization).[1] Hospitals will be paid a fixed target price per AMI episode, adjusted for quality and resource intensive care.[1] It is anticipated that hospital readmissions during the

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Clinical Perspective

What Is New?

- This study provides insights into readmission rates, timing, and reasons for readmission which provide clinicians with benchmarks that can be used for improvement strategies.

What Are the Clinical Implications?

- This study has significant clinical implications. It highlights the need to optimize patients' cardiac function befor discharge as well as closely monitoring them after discharge to minimize readmissions, especially for heart failure which is the number 1 reason for readmission.

90-day follow-up period will significantly impact the amount of medical care Medicare beneficiaries receive, as well as costs.

The aim of this study was to identify the causes, frequency, clinical predictors, and timing of readmissions occurring within the 90-day follow-up period in Medicare beneficiaries after an index AMI hospitalization. This analysis assessed the population of Medicare beneficiaries experiencing AMI as a whole, as well as within the 2 Centers for Medicare and Medicaid Services defined cohorts; those Medicare beneficiaries with and without PCI during the index hospitalization. Enhanced understanding of readmission in Medicare beneficiaries extending to 90-days post index hospitalization is warranted for hospitals and providers to navigate the shared risk inherent in the AMI episodic payment model.

Methods

Data Source

Centers for Medicare and Medicaid Services' Inpatient Standard Analytical File for 2014 was the primary data source for this retrospective analysis. All data in the Inpatient Standard Analytical File are publicly available from https://www.cms.gov/. The authors have data disclosures and data use agreements to allow them to publish articles using the 2014 Inpatient Standard Analytical File. As a result, no institutional review board approval is required for this study. The Inpatient Standard Analytical File is an administrative database that contains all claims submitted by acute care hospitals for services provided to Medicare beneficiaries in the Medicare free-for-service program. The Inpatient Standard Analytical File contains a unique identifier code for each Medicare beneficiary that allows one to link all hospitalizations during a time period to an individual Medicare beneficiary. The 2014 Inpatient Standard Analytical File includes patient information (age, sex, and race), the principal diagnosis code, up to 24 secondary diagnoses codes, a flag indication if each diagnosis code was present on admission, primary procedure code, up to 24 additional procedure codes, length of hospital stay in days, discharge status, the diagnosis related group (DRG) for the admission, total reimbursement and total charges, and the cost for that episode of care.

Study Population

The population in this study consists of Medicare beneficiaries who experienced an AMI hospitalization in a US hospital with a discharge date during the first 9 months of 2014. A Medicare beneficiary's AMI was identified if the DRG category for that hospitalization was one of the following DRGs: 246, 247, 248, 249, 250, 251, 280, 281, or 282. The first AMI hospitalization for each Medicare beneficiary during the study period was considered the index hospitalization. If a Medicare beneficiary had an additional AMI hospitalization after the 90-day index admission, the additional AMI was not considered, so each patient is in the data set one time for an index hospitalization. A Medicare beneficiary was excluded from the study population for 2 reasons: (1) their first 2 AMI hospital admissions occurred on the same date (n=946) which was interpreted as a transfer patient or (2) they died during their index AMI hospitalization (n=1717).

Unit of Analysis and 90-Day Follow-Up

The unit of analysis was a Medicare beneficiary. The analytical data file was constructed as follows. First, the Inpatient Standard Analytical File was searched to identify each Medicare beneficiary's index AMI hospitalization, including all relevant utilization and reimbursement information associated with the index AMI hospitalization. Next, the Inpatient Standard Analytical File was searched for all hospitalizations that match each study patient's unique patient key. All follow-up hospitalizations were included in the study if the admission date occurred ≤90 days after the discharge date of the index admission. The relevant information for each Medicare beneficiary's hospital readmission was then merged onto the Medicare beneficiary's index AMI hospital claim. If a Medicare beneficiary did not have a second hospitalization during the 90-day follow-up period, all readmission information was set equal to zero.

Statistical Analysis

Univariate differences between Medicare beneficiaries were assessed using χ^2 analysis or the Fisher exact test for discrete variables and 2-sample Student *t*-test for continuous variables. Observed readmission rates are reported as the proportion of Medicare beneficiaries with at least 1 readmission during the 90-day follow-up period. Multivariate logistic

regression models were used to estimate risk-adjusted odds ratios of a Medicare beneficiaries experiencing at least 1 hospital readmission during the 90-day follow-up period. The logistic regression models controlled for demographic characteristics, selected comorbid characteristics during the index hospitalization; and if the index AMI hospitalization included a PCI or 1 of 11 complications identified in the study. The logistic regression models were estimated for the entire study population and separately, depending on whether or not the Medicare beneficiary underwent a PCI during their index AMI hospitalization. Differences between study groups were considered statistically different if the *P* value was ≤0.01. All analyses were performed with SAS 9.4 (SAS Institute, Cary, North Carolina).

Clinical Covariates

The risk-adjusted total 90-day Medicare reimbursement regression models adjusted for difference in the demographic and comorbid conditions of Medicare beneficiaries. All demographic and comorbid covariates were created based on information contained in the claim for the index AMI hospitalization. Demographic variables of interest included: age group (<65, 65–69, 70–74, 75–79, and ≥80 years); sex (men or women), and race (white or non-white). Comorbidities of interest included: obesity, body mass index <19, malnutrition, depression, dementia, current smoker, history of smoking, type 1 diabetes mellitus, type 2 diabetes mellitus, heart failure, acute respiratory failure present on admission, chronic respiratory failure, prior myocardial infarction, ST-segment–elevation myocardial infarction present on admission, non–ST-segment–elevation myocardial infarction present on admission, hypertension, cardiogenic shock present on admission, cardiac arrest present on admission, mild chronic kidney disease, moderate chronic kidney disease, severe chronic kidney disease, chronic kidney disease unspecified, dialysis dependent renal failure present on admission, chronic obstruction pulmonary disease, chronic liver disease, aortic aneurysm, hyperlipidemia, peripheral vascular disease, cardiomyopathy, valvular heart disease, atrial fibrillation present on admission, ventricular fibrillation present on admission, heart block present on admission, prior valve surgery, prior cerebral vascular accident, prior venous thromboembolism, prior percutaneous coronary intervention, prior coronary artery bypass grafting (CABG), prior implantation of permanent pacemaker, prior implantation of defibrillator, anemia present on admission, and cancer.

Reasons for Readmission

This study uses diagnosis-related groups (DRG) to identify the type of readmissions during the 90-day follow-up period. Fourteen high volume DRG categories were defined as follows: (1) heart failure/pulmonary edema—(DRG=189, 291, 292, or 293); (2) cardiac surgery—(DRG=231, 232, 233, 234, 235, 236, 216, 217, 218, 219, 220, or 221); (3) sepsis—(DRG=870, 871, or 872); (4) chronic obstructive pulmonary disease/pneumonia—(DRG=190, 191, 192, 193, 194, or 195); (5) angina or chest pain—(DRG=311, 313, 314, 315, or 316); (6) renal failure—(DRG=682, 683, or 684); (7) arrhythmia—(DRG=308, 309, or 310); (8) GI bleed with hemorrhage—(DRG=377, 378, or 379); (9) cardiac catheterization—(DRG=286 or 287); (10) PCI—(DRG=246, 247, 248, 249, 250, or 251); (11) recurrent AMI—(DRG=280, 281, 282, 283, 284, or 285); (12) stroke—(DRG=064, 065, or 066); (13) respiratory failure with ventilator—(DRG=207, or 208); or (14) internal cardiac defibrillator implant—(DRG=222, 223, 224, 225, 226, 0227). For each DRG category, readmission information was reported both as the share of all Medicare beneficiaries with ≥1 readmissions in each category and as the total number of hospitalization in the 90-day follow-up period with a DRG code in that DRG category.

Definitions of Adverse Events

Eleven adverse events of interest that occurred during the index AMI hospitalization were defined for this study: (1) acute renal failure (not present on admission); (2) new onset hemodialysis; (3) postoperative respiratory distress syndrome; (4) infection (postoperative infection or sepsis); (5) cardiogenic shock (not present on admission); (6) cardiac arrest (not present on admission); (7) acute respiratory failure (not present on admission); (8) pneumonia (not present on admission); (9) vascular complication; (10) heart block (not present on admission); and (11) postoperative stroke. A dichotomous variable was set to 1 if a Medicare beneficiary experienced any of the 11 adverse events during their index AMI hospitalization.

Results

A total of 145 949 Medicare beneficiaries were identified as having an index AMI hospitalization between January 1, 2014 and September 30, 2014. After excluding patients who died before hospital discharge, the final study sample includes 143 286 Medicare beneficiaries treated in 3619 different hospitals. Of the 143 286 Medicare beneficiaries with an index AMI hospitalization, 61 980 (43.26%) underwent a PCI and 81 306 (56.74%) did not undergo PCI during the index admission (Table 1). At the 1720 hospitals performing PCI, 46.7% of Medicare beneficiaries received a PCI during their index AMI hospitalizations (range: 2.3%–100%). Another 1899 hospitals did not perform PCI on any index AMI Medicare beneficiaries.

Table 1. Baseline Demographic and Preexistent Comorbid Conditions of All AMI Admissions and by Whether or Not the Medicare Beneficiaries Underwent a PCI During Their Index Hospital

Variables	All Medicare Beneficiaries (n=143 286)	AMI Without PCI (n=81 306)	AMI With PCI (n=61 980)	*P* Value
Age (age categories)				
<65 y, %	13.61	11.65	16.18	
65–69 y, %	18.00	13.16	24.35	
70–74 y, %	16.34	13.63	19.90	
75–79 y, %	15.11	14.32	16.16	
≥80 y, %	36.93	47.24	23.41	<0.001
Sex				
Men, %	53.76	47.66	61.75	<0.001
Race				
White, %	83.97	82.43	86.00	
Non-white, %	16.03	17.57	14.00	<0.001
Comorbidities present on admission				
Obesity, %	13.08	11.92	14.60	<0.001
Body mass index <19, %	0.97	1.47	0.31	<0.001
Malnutrition, %	2.12	2.99	0.98	<0.001
Anemia, %	23.45	29.11	16.04	<0.001
Type 1 diabetes mellitus, %	0.88	0.94	0.81	0.007
Type 2 diabetes mellitus, %	39.56	40.95	37.75	<0.001
Current smoker, %	15.75	12.20	20.41	<0.001
History of smoking, %	21.78	21.15	22.61	<0.001
Acute respiratory failure, %	8.79	10.97	4.28	<0.001
Chronic respiratory failure, %	0.87	1.16	0.49	<0.001
Chronic obstructive pulmonary disease, %	25.84	29.28	21.33	<0.001
Mild chronic kidney disease, %	0.10	0.10	0.10	0.940
Moderate chronic kidney disease, %	11.77	14.09	8.73	<0.001
Severe chronic kidney disease, %	4.11	5.79	1.91	<0.001
Dialysis dependent/end stage kidney disease, %	5.95	6.87	4.75	<0.001
Chronic kidney disease, unspecified, %	8.79	10.90	6.01	<0.001
Chronic liver disease, %	1.16	1.39	0.86	<0.001
Aortic aneurysm, %	2.14	2.40	1.80	<0.001
Peripheral vascular disease, %	13.51	14.58	12.12	<0.001
Prior myocardial infarction, %	14.57	15.24	13.69	<0.001
Chronic ischemic heart disease, %	80.24	70.29	93.29	<0.001
Heart failure, %	40.99	52.73	25.58	<0.001
Hypertension, %	82.67	83.70	81.31	<0.001
Hyperlipidemia, %	65.26	59.91	72.28	<0.001
Cardiomyopathy, %	7.18	9.37	4.31	<0.001
Cardiogenic shock, %	1.72	1.55	1.95	<0.001
Cardiac arrest, %	0.84	0.59	1.17	<0.001
Primary STEMI, %	16.87	5.17	32.22	<0.001

Continued

Table 1. Continued

Variables	All Medicare Beneficiaries (n=143 286)	AMI Without PCI (n=81 306)	AMI With PCI (n=61 980)	*P* Value
Valvular heart disease, %	16.87	21.10	11.32	<0.001
Atrial fibrillation, %	23.21	29.59	14.85	<0.001
Ventricular fibrillation, %	0.89	0.43	1.50	<0.001
Heart block, %	9.49	10.43	8.26	<0.001
Prior valve surgery, %	1.47	1.91	0.88	<0.001
Prior PCI, %	18.74	16.90	21.16	0.640
Prior CABG, %	18.00	19.07	16.60	<0.001
Prior pacemaker implantation, %	4.95	6.32	3.16	<0.001
Prior implantable cardioverter-defibrillator, %	3.19	3.90	2.25	<0.001
Prior cerebral vascular accident, %	10.28	11.79	8.30	<0.001
Prior venous thromboembolism, %	3.03	3.45	2.48	<0.001
Cancer, %	1.30	1.52	1.02	<0.001
Dementia, %	9.54	14.04	3.64	<0.001
Depression, %	1.86	2.00	1.68	<0.001

AMI indicates acute myocardial infarction; CABG, coronary artery bypass grafting; PCI, percutaneous coronary intervention; STEMI, ST-segment–elevation myocardial infarction.

As shown in Table 1, whites and men were significantly more likely to undergo PCI during their index AMI than non-whites or women. In addition, Medicare beneficiaries aged <80 years were significantly more likely to undergo a PCI during their index AMI than those aged ≥80 years. The distribution of comorbid conditions varied significantly between those Medicare beneficiaries with and without PCI during their index AMI: Medicare beneficiaries not undergoing PCI had a significantly higher prevalence of most of the comorbid conditions assessed. Of these, heart failure (52.7% versus 25.6%) and chronic ischemic heart disease (70.3% versus 93.3%) were the 2 conditions with the greatest absolute differences.

A total of 40 145 Medicare beneficiaries (28.0%) had ≥1 hospital readmissions during the 90-day follow-up period (Table 2). Medicare beneficiaries not undergoing a PCI during their index hospitalization were significantly more likely (34.0% versus 20.3%) to experience at least 1 readmission. Women and non-whites were significantly more likely to be readmitted than men and whites for the overall population. Table 2 also reports the percentage of Medicare beneficiaries that had each of 42 comorbid conditions by whether or not the Medicare beneficiaries experienced a readmission during the 90-day follow-up period for both all MIs and by whether or not they underwent PCI during the index admission. Of the 42 preexisting comorbidities assessed, 35 were significantly associated with readmission for the overall AMI population.

There was a total of 56 549 hospital readmissions among the 40 145 Medicare beneficiaries that had at least 1 readmission during the 90-day follow-up period. Of the Medicare beneficiaries with at least 1 readmission, 28 668 (71.4%) had only 1 readmission during the follow-up period (Table 3), while 97.5% had ≤3. For those with readmissions, more than a single readmission was marginally more common among those without PCI (29% versus 27.6%).

As shown in Table 3, heart failure, CABG or valve surgery, sepsis, renal failure, and arrhythmia were the 5 most common reasons for readmission for the overall cohort, as well as those patients who did not undergo PCI during the index hospitalization. For those that did undergo PCI, heart failure and cardiac surgery were the 2 most common reasons for readmission, with gastrointestinal bleeding, sepsis, and PCI completing the top 5 reasons for readmission. The incidence rate was much lower among the sub-population group of AMI with PCI for CABG or valve surgery (4.8% versus 12.5%). Hospital readmission for recurrent AMI occurred in 2.1% of all Medicare beneficiaries, but only 1.0% in the PCI sub-population versus 2.6% of those without PCI.

Table 3 also reports the average number of days from discharge to selected events that occurred anytime during the 90-day follow-up period. For example, the average number of days until in-hospital death was 28.2±26.7 for Medicare beneficiaries that died during a readmission. The average number of days until the first hospital readmission was 26.3±25.5 for the overall population and (29.5±25.6 days for the PCI subpopulation compared with 24.9±25.4 days for the AMI without PCI sub-population). The average length of time to a second re-admission, (11 477 Medicare beneficiaries) was 46.3±23.6, or 20 days after the first readmission. The average time from the second to the third readmissions

Table 2. Baseline Demographic and Preexistent Comorbid Conditions of Medicare Beneficiaries With at Least 1 Readmission for All AMIs and by PCI Versus No PCI During the Index Hospitalization

	All AMIs			AMI Without PCI			AMI With PCI		
	At Least 1 Readmission	No Readmission	*P* Value	At Least 1 Readmission	No Readmission	*P* Value	At Least 1 Readmission	No Readmission	*P* Value
Number of Medicare beneficiaries	40 145	103 141	-NA-	27 640	53 666	-NA-	12 505	49 475	-NA-
Age (age categories)									
<65 y, %	15.03	13.06		13.71	10.59		17.94	15.74	
65–69 y, %	15.16	19.11		13.70	12.88		18.38	25.87	
70–74 y, %	15.95	16.49		14.95	12.95		18.18	20.33	
75–79 y, %	15.56	14.94		15.10	13.91		16.57	16.05	
≥80 y, %	38.30	36.40	<0.001	42.54	49.67	<0.001	28.92	22.01	<0.001
Sex									
Men, %	51.64	54.58	<0.001	49.93	46.50	<0.001	55.42	63.36	<0.001
Race									
White, %	81.44	84.96		80.56	83.39	<0.001	83.37	86.66	<0.001
Non-white, %	18.56	15.04	<0.001	19.44	16.61	<0.001	16.63	13.34	<0.001
Comorbidities present on admission									
Obesity, %	13.48	12.92	0.006	12.83	11.45	<0.001	14.91	14.53	0.283
Body mass index <19, %	1.09	0.93	0.006	1.32	1.55	0.009	0.57	0.25	<0.001
Malnutrition, %	2.76	1.88	<0.001	3.19	2.89	0.019	1.79	0.78	<0.001
Anemia, %	31.93	20.16	<0.001	33.81	26.69	<0.001	27.77	13.07	<0.001
Type 1 diabetes mellitus, %	1.28	0.73	<0.001	1.20	0.81	<0.001	1.45	0.64	<0.001
Type 2 diabetes mellitus, %	45.92	37.09	<0.001	46.10	38.29	<0.001	45.49	35.79	<0.001
Current smoker, %	15.03	16.03	<0.001	13.30	11.63	<0.001	18.86	20.81	<0.001
History of smoking, %	22.02	21.69	0.174	21.72	20.86	0.004	22.68	22.59	0.838
Acute respiratory failure, %	10.48	7.14	<0.001	11.90	10.50	<0.001	7.36	3.50	<0.001
Chronic respiratory failure, %	1.20	0.75	<0.001	1.35	1.07	<0.001	0.85	0.40	<0.001
Chronic obstructive pulmonary disease, %	31.66	23.58	<0.001	32.91	27.41	<0.001	28.92	19.41	<0.001
Mild chronic kidney disease, %	0.13	0.09	0.068	0.11	0.10	0.630	0.17	0.09	0.012
Moderate chronic kidney disease, %	14.35	10.77	<0.001	15.21	13.51	<0.001	12.45	7.79	<0.001
Severe chronic kidney disease, %	5.70	3.49	<0.001	6.84	5.24	<0.001	3.19	1.58	<0.001
Dialysis dependent/end stage kidney disease, %	10.24	4.28	<0.001	9.89	5.31	<0.001	11.00	3.17	<0.001
Chronic kidney disease, unspecified, %	10.61	8.08	<0.001	11.56	10.56	<0.001	8.51	5.38	<0.001
Chronic liver disease, %	1.54	1.02	<0.001	1.66	1.25	<0.001	1.29	0.76	<0.001
Aortic aneurysm, %	2.50	2.00	<0.001	2.51	2.34	0.116	2.46	1.64	<0.001
Peripheral vascular disease, %	17.36	12.02	<0.001	16.90	13.38	<0.001	18.38	10.53	<0.001
Prior myocardial infarction, %	15.22	14.32	<0.001	15.33	15.20	0.646	14.99	13.36	<0.001
Chronic ischemic heart disease, %	79.10	80.69	<0.001	72.42	69.19	<0.001	93.84	93.15	0.006
Heart failure, %	52.95	36.33	<0.001	58.19	49.92	<0.001	41.38	21.59	<0.001
Hypertension, %	84.58	81.92	<0.001	84.33	83.37	<0.001	85.12	80.35	<0.001
Hyperlipidemia, %	62.49	66.34	<0.001	59.51	60.11	0.098	69.07	73.09	<0.001

Continued

Table 2. Continued

	All AMIs			AMI Without PCI			AMI With PCI		
	At Least 1 Readmission	No Readmission	*P* Value	At Least 1 Readmission	No Readmission	*P* Value	At Least 1 Readmission	No Readmission	*P* Value
Cardiomyopathy, %	8.85	6.53	<0.001	10.13	8.97	<0.001	6.00	3.88	<0.001
Cardiogenic shock, %	1.86	1.67	0.017	1.53	1.57	0.674	2.58	1.78	<0.001
Cardiac arrest, %	0.91	0.81	0.082	0.79	0.53	0.002	1.36	1.12	0.027
Primary STEMI, %	11.69	18.89	<0.001	4.51	5.52	<0.001	27.56	33.40	<0.001
Valvular heart disease, %	20.68	15.39	<0.001	22.96	20.14	<0.001	15.64	10.23	<0.001
Atrial fibrillation, %	28.07	21.33	<0.001	30.78	28.98	<0.001	22.07	13.02	<0.001
Ventricular fibrillation, %	0.83	0.92	0.111	0.53	0.38	0.003	1.50	1.50	0.958
Heart block, %	9.82	9.36	0.008	10.40	10.45	0.844	8.55	8.19	0.188
Prior valve surgery, %	1.76	1.36	<0.001	1.95	1.89	0.539	1.32	0.77	<0.001
Prior PCI, %	18.82	18.71	0.640	17.20	16.75	0.099	22.39	20.84	<0.001
Prior CABG, %	18.74	17.71	<0.001	18.73	19.24	0.078	18.78	16.05	<0.001
Prior pacemaker im plantation, %	5.90	4.58	<0.001	6.54	6.20	0.059	4.49	2.82	<0.001
Prior implantable cardioverter-defibrillator, %	4.16	2.81	<0.001	4.50	3.60	<0.001	3.41	1.96	<0.001
Prior cerebral vascular accident, %	11.71	9.72	<0.001	12.17	11.59	0.014	10.69	7.70	<0.001
Prior venous thromboembolism, %	3.67	2.79	<0.001	3.80	3.27	<0.001	3.41	2.25	<0.001
Cancer	1.62	1.18	<0.001	1.72	1.41	<0.001	1.41	0.92	<0.001
Dementia, %	`9.64	9.50	0.423	11.56	15.32	<0.001	5.41	3.19	<0.001
Depression, %	2.25	1.71	<0.001	2.27	1.86	<0.001	2.22	1.54	<0.001

AMI indicates acute myocardial infarction; CABG, coronary artery bypass grafting; PCI, percutaneous coronary intervention; STEMI, ST-segment–elevation myocardial infarction.

decreased to 11.7 days and the average time from the third to the fourth readmission was only 5.9 days. Compared with the AMI without PCI group, Medicare beneficiaries in the AMI with PCI group had significantly longer average time before any readmission for additional cardiac-related procedures: PCI (44.5 versus 25.0 days), CABG or valve surgery (33.7 versus 10.7), and implantable cardioverter defibrillator (32.8 versus 21.9), as well as recurrent MI (40.8 versus 34.4).

The first column of Table 4 reports logistic regression analysis predicting readmission during the 90-day follow up period for all Medicare beneficiaries. For the overall population, women were 1.03 times more likely to have a readmission than men and non-whites were 1.09 times more likely than whites to have a readmission. In addition, after risk adjustment, all age groups were significantly less likely to have a readmission than Medicare beneficiaries aged <65 years (the estimated odds ratios across age groups ranged between 0.83 [age 65–69] to 0.94–3 [age 70–74]). Table 4 also reports the risk-adjusted odds ratios for the 27 preexisting comorbid conditions that were significantly associated with predicting a readmission during the follow-up period for all Medicare beneficiaries. The 3 preexisting conditions with the highest estimated odds ratios were: dialysis dependent end stage renal failure (odds ratio [OR] =1.80), type 1 diabetes mellitus (OR=1.58), and heart failure (OR=1.34). Four of the comorbid conditions were associated with a significant reduction in likelihood of having a readmission during the follow-up period: primary ST-segment–elevation myocardial infarction in the index AMI (OR=0.92), prior CABG surgery (OR=0.91), hyperlipidemia (OR=0.90) and dementia (OR=0.86).

The last 2 columns of Table 4 report the estimated odds ratio from the logistic regression estimated separately for Medicare beneficiaries with and without PCI during their index AMI. In all cases, the estimated odds ratios from the 2 subpopulations bracket the estimated odds ratio for the entire sample. Nevertheless, the individual estimated odds ratio indicates different impact for selected demographic and comorbid conditions. For example, female sex increased the likelihood of a hospital readmission by 1.24 times among

Table 3. Readmission Information for All AMIs and by PCI Versus No PCI During the Index Hospitalization

	All AMI	AMI Without PCI	AMI With PCI
Number of Medicare beneficiaries	143 286	81 306	61 980
Readmissions by maximum number of readmissions for each Medicare beneficiaries			
0 readmissions,% (n=count)	71.98% (103 141)	66.00% (53 666)	79.82% (49 475)
Any readmission, % (n)	28.02% (40 145)	34.00% (27 640)	20.18% (12 505)
1 readmission, % (n)	20.01% (28 668)	24.13% (19 618)	14.60% (9050)
2 readmissions, % (n)	5.63% (8064)	6.89% (5600)	3.98% (2464)
3 readmissions, % (n)	1.68% (2404)	2.11% (1714)	1.11% (690)
4 readmissions, % (n)	0.49% (702)	0.60% (482)	0.35% (218)
5 readmissions, % (n)	0.14% (196)	0.17% (141)	0.09% (55)
6 readmissions, % (n)	0.05% (69)	0.06% (45)	0.04% (24)
7 readmissions, % (n)	0.02% (22)	0.02% (20)	0.00% (2)
8 readmissions, % (n)	0.01% (9)	0.01% (9)	NA (0)
9+ readmissions, % (n)	0.00% (11)	0.01% (9)	0.00% (2)
Reason for first readmission (using selected DRG categories)			
Number of Medicare beneficiaries, n	40 145	27 640	12 505
Heart failure/pulmonary edema, % (n)	15.32% (6149)	15.92% (4399)	13.99% (1750)
CABG/valve surgery, % (n)	10.13% (4067)	12.53% (3462)	4.84% (605)
Sepsis, % (n)	5.10% (2049)	5.56% (1539)	4.09% (511)
Renal failure, % (n)	3.68% (1478)	3.86% (1068)	3.38% (410)
Arrhythmia, % (n)	3.45% (1386)	3.21% (887)	3.99% (499)
Gastrointestinal bleed, % (n)	3.24% (1300)	2.54% (703)	4.77% (597)
PCI, % (n)	2.82% (1131)	2.26% (624)	4.05% (507)
Recurrent AMI, % (n)	2.11% (846)	2.60% (720)	1.01% (126)
Stroke, % (n)	1.93% (774)	1.79% (494)	2.24% (280)
Implantable cardioverter defibrillator, % (n)	1.17% (471)	1.17% (323)	1.18% (148)
Days from index AMI discharge to selected event			
Death during a readmission, % (n)	28.2±26.7 (3822)	27.4±26.5 (3122)	31.4±27.1 (700)
1st readmission, % (n)	26.3±25.5 (40 145)	24.9±25.4 (27 640)	29.5±25.6 (12 505)
2nd readmission, % (n)	46.3±23.6 (11 477)	46.1±23.6 (8022)	46.6±23.7 (3455)
3rd readmission, % (n)	58.0±20.6 (3413)	58.1±20.8 (2422)	57.7±20.2 (991)
4th readmission, % (n)	63.9±16.6 (1009)	63.4±17.6 (708)	64.8±16.9 (301)
Days from index discharge to readmission for selected procedures or recurrent MI			
Readmission for recurrent AMI, % (n)	35.3±29.7 (1193)	34.4±29.6 (1014)	40.8±30.2 (179)
Readmission for PCI, % (n)	33.6±28.9 (1459)	25.0±27.5 (813)	44.5±26.9 (646)
Readmission for CABG or valve surgery, % (n)	14.3±22.5 (4426)	10.7±20.0 (3730)	33.7±25.0 (696)
Readmission for an implantable cardioverter-defibrillator, % (n)	25.5±27.9 (584)	21.9±27.0 (391)	32.8±28.3 (193)
Days from index discharge to readmission during follow-up period (using selected DRG categories)			
Stroke, % (n)	32.1±27.3 (1015)	33.6±27.3 (664)	29.3±26.8 (351)
Gastrointestinal bleed, % (n)	34.0±25.4 (1895)	34.4±25.7 (1063)	33.3±24.9 (832)
Sepsis, % (n)	35.6±26.4 (3075)	35.1±26.3 (2310)	36.9±26.5 (765)
Renal failure, % (n)	35.6±26.2 (2159)	35.6±26.0 (1576)	35.4±26.7 (583)
Arrhythmia, % (n)	32.7±26.1 (1948)	33.9±26.4 (1286)	30.2±25.3 (662)
Heart failure or pulmonary edema, % (n)	36.0±26.6 (9322)	36.7±26.4 (6750)	34.0±27.1 (2572)

AMI indicates acute myocardial infarction; CABG, coronary artery bypass grafting; DRG; diagnosis related group; MI, myocardial infarction; PCI, percutaneous coronary intervention; STEMI, ST-segment–elevation myocardial infarction.

Table 4. Estimated Odds Ratio and 99% CI for Significant Variables* Predicting a Readmission During the 90-Day Follow-Up Period for All Study Populations and by Whether or Not the Medicare Beneficiaries Underwent a PCI During Index AMI

Variables	All Medicare Beneficiaries Estimated OR (99% CI)	Medicare Beneficiaries Without PCI Estimated OR (99% CI)	Medicare Beneficiaries With PCI Estimated OR (99% CI)
Demographic variables			
Age 65 to 69 y	0.83 (0.78–0.88)	0.91 (0.85–0.99)	0.76 (0.70–0.84)
Age 70 to 74 y	0.94 (0.88–0.99)	-NS-	0.87 (0.80–0.96)
Age 75 to 79 y	0.93 (0.87–0.99)	0.92 (0.85–0.99)	-NS-
Age ≥80 y	0.84 (0.80–0.89)	0.76 (0.71–0.82)	-NS-
Women	1.03 (1.00–1.07)	0.92 (0.89–0.96)	1.24 (1.17–1.31)
Non-white	1.09 (1.04–1.13)	1.07 (1.02–1.13)	1.10 (1.02–1.19)
Index hospitalization			
No PCI during index, complication	1.78 (1.67–1.89)	-NA-	-NA-
PCI during index, complication	1.54 (1.44–1.66)	-NA-	-NA-
No PCI during index, no complication	1.77 (1.70–1.84)	-NA-	-NA-
Experienced a complication	-NA-	1.08 (1.02–1.14)	1.26 (1.17–1.36)
Preexistent comorbidities			
Dialysis dependent	1.80 (1.69–1.92)	1.55 (1.43–1.68)	2.24 (2.00–2.52)
Type 1 diabetes mellitus	1.58 (1.35–1.84)	1.39 (1.14–1.69)	1.79 (1.38–2.32)
Heart failure	1.34 (1.29–1.39)	1.23 (1.18–1.28)	1.59 (1.49–1.70)
Chronic obstructive pulmonary disease	1.28 (1.23–1.32)	1.20 (1.15–1.25)	1.40 (1.31–1.50)
Anemia	1.27 (1.22–1.32)	1.19 (1.13–1.24)	1.44 (1.34–1.55)
Depression	1.25 (1.12–1.39)	1.16 (1.01–1.33)	1.40 (1.15–1.70)
Type 2 diabetes mellitus	1.25 (1.21–1.29)	1.24 (1.19–1.29)	1.21 (1.14–1.29)
Peripheral vascular disease	1.23 (1.17–1.28)	1.14 (1.08–1.20)	1.35 (1.25–1.46)
Cancer	1.24 (1.09–1.42)	-NS-	1.44 (1.13–1.83)
Chronic liver disease	1.21 (1.05–1.39)	-NS-	1.35 (1.04–1.75)
Prior venous thromboembolism	1.19 (1.10–1.30)	1.15 (1.03–1.27)	1.30 (1.11–1.52)
Atrial fibrillation	1.18 (1.14–1.23)	1.09 (1.04–1.14)	1.46 (1.36–1.56)
Aortic aneurysm	1.17 (1.05–1.30)	-NS-	1.38 (1.15–1.66)
Severe chronic kidney disease	1.17 (1.09–1.27)	1.18 (1.09–1.29)	1.21 (1.02–1.44)
Valvular heart disease	1.17 (1.13–1.22)	1.17 (1.12–1.23)	1.17 (1.08–1.27)
Chronic kidney disease, unspecified	1.15 (1.09–1.22)	1.10 (1.03–1.18)	1.33 (1.20–1.48)
Moderate chronic kidney disease	1.15 (1.09–1.21)	1.11 (1.05–1.18)	1.24 (1.13–1.36)
Prior implantable cardioverter-defibrillator	1.15 (1.06–1.26)	-NS-	1.24 (1.05–1.46)
Prior pacemaker implantation	1.11 (1.03–1.19)	1.10 (1.01–1.19)	1.16 (1.01–1.33)
Prior cerebral vascular accident	1.11 (1.05–1.17)	1.07 (1.01–1.14)	1.16 (1.06–1.27)
Acute renal failure present on admission	1.09 (1.04–1.15)	1.08 (1.03–1.14)	1.20 (1.09–1.32)
Chronic ischemic heart disease	1.09 (1.04–1.14)	1.10 (1.05–1.15)	-NS-
Obesity	0.95 (0.90–1.00)	-NS-	0.92 (0.85–1.00)
Primary STEMI	0.92 (0.88–0.97)	0.91 (0.83–1.00)	-NS-
Prior coronary artery bypass grafting	0.91 (0.87–0.95)	0.84 (0.80–0.89)	-NS-
Hyperlipidemia	0.90 (0.87–0.94)	0.94 (0.90–0.98)	0.83 (0.78–0.88)

Continued

Table 4. Continued

Variables	All Medicare Beneficiaries Estimated OR (99% CI)	Medicare Beneficiaries Without PCI Estimated OR (99% CI)	Medicare Beneficiaries With PCI Estimated OR (99% CI)
Dementia	0.86 (0.81–0.91)	0.81 (0.76–0.86)	1.31 (1.15–1.49)
Body mass index <19	-NS-	-NS-	1.51 (1.01–2.28)
Prior valve surgery	-NS-	-NS-	1.33 (1.03–1.72)
Acute respiratory failure	-NS-	-NS-	1.18 (1.04–1.34)
Hypertension	-NS-	-NS-	1.13 (1.04–1.22)
Cardiogenic shock	-NS-	0.83 (0.71–0.98)	-NS-
Prior myocardial infarction	-NS-	0.94 (0.89–0.99)	-NS-

PCI indicates percutaneous coronary intervention; OR, odds ratio; STEMI, ST-segment–elevation myocardial infarction.
*Ten of the comorbid controls listed in Table 1 were not significant in any of the 3 logistic regression equations: malnutrition, smoker, history of smoking, chronic respiratory failure, mild chronic kidney disease, cardiac arrest, cardiomyopathy, ventricular dysrhythmia, heart block, and prior PCI.

Medicare beneficiaries with PCI during index AMI, but not following AMI without PCI (OR=0.92).

Discussion

This study provides several contemporary national benchmarks around acute myocardial infarction admissions among the patients in the fee-for-service Medicare program, as well as hospital readmissions during the 90 days following discharge for the index AMI. First, 43% of Medicare beneficiaries who survived their index AMI hospitalization in the Medicare fee-for-service program had a PCI during the index AMI hospitalization. Medicare beneficiaries surviving their index AMI and undergoing a PCI had lower rates of comorbid conditions for all but 9 of the 42 conditions studied, as well as were less likely to be aged ≥80 years compared with Medicare beneficiaries not receiving a PCI. However, it should be noted that Medicare beneficiaries undergoing a PCI were also more likely to have had a history of chronic ischemic heart disease, hyperlipidemia, and a prior PCI indicating that these patients were more likely to be known by a cardiologist than Medicare beneficiaries in the non-PCI study arm.

A total of 28.2% of Medicare beneficiaries with an index AMI hospitalization had at least 1 hospital readmission within 90 days of the discharge date of the index hospitalization. This compares to 30-day readmission rates of 18.6% to 34%, reported previously.[10–12] In addition, our 90-day readmission rate is nearly identical to the 27.5% reported among Medicare beneficiaries using data from the National Cardiovascular Data ACTION Registry between 2008 and 2014.[21] Medicare beneficiaries with a readmission during the follow-up period were significantly more likely to have had nearly every preexisting comorbid condition compared with those without a readmission. Preexisting comorbid conditions with the largest observed differences in incidence rates between Medicare beneficiaries with and without a readmission included: heart failure, anemia, type 2 diabetes mellitus, and chronic obstructive pulmonary disease.

This study provides insights concerning the reasons for readmissions and the incidence of repeated readmissions. For example, those patients with any readmission had an average of 1.4 readmissions within 90 days. The leading reason for readmissions for all cohorts was heart failure or pulmonary edema. For the overall cohort, and the subpopulation that did not undergo PCI during the index hospitalization, CABG or valve surgery, sepsis, renal failure, and arrhythmia were the next 4 most common reasons for readmission. In the PCI population, like the non-PCI population, CABG or valve surgery was the second most common cause for readmission. GI bleeding was the third most common reason for readmission, presumably related to dual antiplatelet therapy. The fourth and fifth readmission reasons were sepsis and repeat PCI, respectively. Recurrent myocardial infarction was not among the most common reasons for readmission, which differs from earlier 30-day readmission reports.[11,13]

The average number of days to the first readmission was 26.3±25.5 days. This is similar (24 days) reported for 30-day readmissions.[10] The average time to additional readmission declined between each readmission: 20 days to the second readmission and 11.7 until the third readmission. The average number of days to death was 28.2±26.7 days among the 3822 Medicare beneficiaries (2.7%) that died in a hospital during the follow-up period.

After risk adjusting, we identified 27 comorbid conditions that were significant predictors of Medicare beneficiaries having a hospital readmission within 90 days. Seven comorbid conditions were estimated to increase the likelihood of a readmission by >25%: dialysis dependence; type 1 diabetes mellitus; heart failure; chronic obstructive pulmonary disease;

anemia present on admission; depression; and type 2 diabetes mellitus. In addition, after controlling for all demographic and comorbid conditions, Medicare beneficiaries whose index AMI hospitalization did not include a PCI or a complication were 1.77 times more likely to have a readmission during the follow-up period than those Medicare beneficiaries undergoing a PCI without a complication during their index AMI hospitalization.

The results of the current analysis have some straightforward clinical implications. Heart failure clearly plays a highly important role in the outcomes of these patients, as over half of our sample had heart failure documented before their MI or present by the time of admission and heart failure was the most common cause of readmission within 90 days. This suggests that efforts to reduce readmission after MI should focus on optimizing the cardiac status of patients before discharge and ensuring early follow-up to support heart failure management in the outpatient setting. The timing of readmissions suggests targeted efforts in this population should occur early (within the first few weeks following the index discharge). Also, perhaps greater emphasis should be directed at those patients who did not receive a PCI during the index admission.

The fact that cardiac surgery was the second most common cause of readmission after MI also raises potential concerns regarding the impact of changing incentives from new payment models on clinical care. The frequent readmission for cardiac surgery within a few months of AMI implies, first, that clinicians may be staging coronary revascularization procedures in accordance with guidelines, informed by clinical evidence that mortality rates are higher in emergency CABG, then if the procedure is performed electively.[22] One can surmise that some, perhaps many, of these readmissions for cardiac surgery are planned after some period of recovery following AMI, so that patients may be operated upon in stable clinical circumstances. The evidence for non-culprit vessel PCI during the index AMI hospitalization in the most recent studies indicate that in some patients it is appropriate and feasible, but it should be individualized based on the patient's condition.[23] In creating new payment models policymakers should take care to avoid creating financial disincentives for what may be entirely appropriate clinical decisions. Perhaps planned readmissions for staged coronary interventions or bypass surgery should be handled differently under new bundled payment models than readmissions for other reasons.

There are several limitations to this study. This analysis applies only to Medicare beneficiaries in the fee-for service program. No information on Medicare beneficiaries participating in the Medicare Advantage program is included. Second, identification of comorbid conditions and complications were dependent on *International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM)* coding. This limitation is mitigated by the fact that the hospital Inpatient Standard Analytical File contains present on admission codes to differentiate between diagnoses that existed on admission from those diagnoses that occurred during the hospitalization. Third, the author's hospital Inpatient Standard Analytical File started in January 1, 2014, therefore, it is impossible to determine which Medicare beneficiaries may have had an AMI admission in the last 90 days of 2013 which means that the index AMIs for Q1, 2014 might be overstated. Fourth, this study examined Medicare hospital use based on the payment rules and incentives in the Medicare program during 2014. It is not possible to speculate how hospitals and other healthcare providers will change patterns of care, in response to the financial incentives associated with Medicare bundled payment programs. Finally, mortality data are restricted to Medicare beneficiaries who died during hospitalization subsequent to the index AMI hospitalization, and does not include those that died outside of a hospital. Thus, these estimates likely underrepresent mortality in the post AMI population.

Conclusions

This study provides benchmark data on Medicare beneficiaries undergoing AMI with and without PCI in the Medicare fee-for-service programs. It also establishes the frequency and causes for readmissions during the 90-day follow-up period. Finally, the paper identifies demographic, comorbid conditions, and outcome variables that are significant predictors of hospital readmissions during the 90-day period following an AMI hospitalization for all Medicare beneficiaries and separately for those Medicare beneficiaries whose index AMI included PCI or did not include PCI. This study also suggests that interventions are needed to alleviate the need for readmissions in high-risk populations, such as, those initially managed medically and those at risk for heart failure.

Disclosures

Prof. Culler has a data analyst's contract with HealthTrust Purchasing Group, LLP and Conformis. Dr. Cohen has contracts with Edwards Life Science, Medtronic, and Boston Scientific. Dr. Reynolds has contracts with Edwards Life Science, Abbott, and Medtronic. The remaining authors have no disclosures to report.

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