**Timing and causes of unplanned readmissions after percutaneous coronary intervention: Insights from the Nationwide Readmission Database**

Running title: Timing and causes of readmissions after PCI

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**Abstract**

**Objective:** This study aims to describe the rates and causes of unplanned readmissions at different time periods following percutaneous coronary interventions (PCI).

**Background:** The rates and causes of readmission at different time periods after PCI remain incompletely elucidated.

**Methods:** Patients undergoing PCI between 2010 and 2014 in the U.S. Nationwide Readmission Database were evaluated for the rate, causes, predictors, and cost of unplanned readmission between 0 and 7 days, 8 and 30 days, 31 and 90 days and 91 and 180 days after index discharge.

**Results:** This analysis included 2,412,000 patients; 2.5% were readmitted between 0-7 days, 7.6% between 8 and 30 days, 8.9% between 31 and 90 days, and 8.0% between 91 and 180 days (cumulative rate 2.5%, 9.9%, 18.0% and 24.8%, respectively). Majority of readmissions during each time period were due to non-cardiac causes (53.1%-59.6%). Non-specific chest pain was the most common identifiable non-cardiac cause for readmission during each time period (14.2%-22.7% of non-cardiac readmissions). Coronary artery disease including angina was the most common cardiac cause for readmission during each time period (37.4%-39.3% of cardiac readmissions). The second most common cardiac cause for readmission was acute myocardial infarction (AMI) between 0 and 7 days (27.6% of cardiac readmissions) and heart failure during all subsequent time periods (22.2%-23.7% of cardiac readmission).

**Conclusions:** Approximately one-in-four patients following PCI have an unplanned readmission within 6 months. Causes of readmission depend on the timing at which they are assessed with non-cardiovascular causes becoming more important at longer timepoints.

**Condensed abstract**

The rates and causes of readmission at different time periods after PCI remain incompletely elucidated. Among the 2,412,000 patients, 2.5% were readmitted between 0-7 days, 7.6% between 8 and 30 days, 8.9% between 31 and 90 days, and 8.0% between 91 and 180 days (cumulative rate 2.5%, 9.9%, 18.0% and 24.8%, respectively). Majority of readmissions during each time period were due to non-cardiac causes (53.1% to 59.6%). Non-specific chest pain was the most common identifiable non-cardiac cause for readmission during each time period (12.0% to 22.7% of non-cardiac readmissions). Coronary artery disease including angina was the most common cardiac cause for readmission during each time period (36.8% to 41.2% of cardiac readmissions).

**List of abbreviations**

PCI = percutaneous coronary intervention

DAPT = dual antiplatelet therapy

NRD = Nationwide readmission database

ICD-9 = International Classification of Disease-9th Revision

CABG = coronary artery bypass graft

TIA = transient ischemic attack

AMI = acute myocardial infarction

**Clinical Perspective**

**What's known?** The rates and causes of readmission at different time periods after PCI remain incompletely elucidated.

**What's new?** Our analysis of 2,412,000 patients reveals that approximately one in four patients who undergo PCI had an unplanned readmission within 6 months and the time point at which patients are at greatest risk is at 7-days post discharge with the majority of unplanned readmissions occurring within 30 days. For cardiac causes of readmission, readmissions for acute myocardial infarction is highest 0-7 days post discharge whilst for heart failure the peak is 8-30 days post discharge.

**What's next?** Any interventions developed to reduce unplanned readmissions should consider the important differences in causes of readmission at different time-points after the PCI procedure.

**Introduction**

Percutaneous coronary intervention (PCI) is the most common mode of revascularization in the United States in patients with coronary artery disease.1 With advances in stent technology, pharmacotherapy and changes in interventional practices, procedural outcomes post-PCI have improved over time resulting in low in-hospital mortality and complication rates.2,3 This has led to a growing interest in the study of unplanned readmissions both as a quality metric as well as to help inform healthcare resources and utilization for patients following PCI.4-6

Unplanned readmissions after PCI are important for several reasons. First, they may result from actions taken or omitted during the initial hospitalization7 such as incomplete treatment or poor quality care often reflective of poor coordination between services at time of discharge or ongoing care.8 Secondly, unplanned readmissions can be considered an adverse outcome for patients.9 Complications such as bleeding from dual antiplatelet therapy (DAPT) have been shown to increase mortality when they occur after PCI. 10,11 Thirdly, readmissions may represent an unnecessary cost, which drains both bed capacity and financial resources from other hospital services. Finally, early readmissions are recognized as a quality metric with financial penalties for hospitals under the Affordable Care Act if risk-adjusted readmission rates for specific conditions exceed benchmarks.12

While multiple studies have evaluated readmissions after PCI at 30 days,3-5 less well known are the causes at longer time-points than the 30-day cut off used as a metric in the Affordable Care Act. “In addition, the recently proposed CMS bundle payment models extend the period of monitoring for readmissions to 90 days after PCI.13” Understanding these causes is crucial in helping to plan the delivery of healthcare services and adopting measures to reduce readmissions since the only intervention shown to reduce readmissions is to target specific causes.14 Therefore, this retrospective cohort study of patients who underwent PCI in the Nationwide Readmission Database (NRD) examines the rates, causes, predictors, and costs of readmissions following PCI at different time periods after index discharge.

**Methods**

The NRD is a nationally representative sample of all-age, all-payer discharges from the United States non-federal hospitals produced by the Healthcare Cost and Utilization Project of the Agency for Healthcare Research and Quality.15 This database is composed of discharge-level hospitalization data from 21 geographically dispersed states. The dataset used in the current study was constructed to represent 49.3% of all United States population and 49.1% of all U.S. hospitalizations.4-6 Within a calendar year, hospitalization and rehospitalizations can be determined using a deidentified unique patient linkage number assigned to each patient, which enables tracking of patients across hospitals within a state.

Individual patients in the NRD are assigned up to 15 procedure codes for each hospitalization. We defined PCI with the procedure code 0066 (PTCA OR: CORONARY ATHER), 3606 (INSERT CORON ART STENT), and 3607 (INSERT DRUG ELUTING CRNRY AR).

The primary outcome was first readmission after a PCI performed between 2010 and 2014 with index discharge dates stratified into the following groups: 0-7 days, 8-30 days, 31-90 days, and 91-180 days of index discharge. Patients who died during their initial hospitalization or planned elective readmissions for PCI were excluded. A problem that has been identified with the NRD dataset is bias related to inadequate follow up because of the nature of the annualized dataset. For example, for 30-days of follow up, the cohort patients admitted in the month of December have to be excluded as they may not have 30 days follow up leading to immortal time bias. This is particularly problematic when considering multiple time points of follow up as in the case of the current study (7-days, 30-days, 90-days and 180-days). In order to reduce the likelihood of biases we excluded patients in December for the analysis of 7-days and 30-days (cohort from January to November). We similarly excluded patients from October to December for the analysis of 90-days (cohort from January to September) and excluded patients from July to December for the analysis of 180-days (cohort from January to June). This is shown in Figure 1. The costs were determined by multiplying the hospital charges with the Agency for Healthcare Research and Quality’s all-payer cost-to-charge ratios for each hospital.

The International Classification of Diseases-9th Revision (ICD-9) codes was used to define clinical variables including smoking status, dyslipidemia, coronary artery disease, previous myocardial infarction, previous PCI, previous coronary artery bypass grafting (CABG), previous stroke or transient ischemic attack (TIA), atrial fibrillation, dementia, and receipt of circulatory support. Other comorbidity variables in the analysis were available via the Elixhauser comorbidities and included alcohol misuse, chronic lung disease, heart failure, diabetes, valvular heart disease, peptic ulcer disease, hypertension, renal failure, obesity, cancer, fluid and electrolyte disorders, depression, peripheral vascular disease, hypothyroidism, liver disease and anemia. The Charlson Comorbidity Index was calculated as previously described.4-6 Procedural ICD-9 codes were used to define multivessel disease, bifurcation disease, circulatory support, vasopressor use, intra-aortic balloon pump use, fractional flow reserve use, intravascular ultrasound, and drug eluting stent use. Diagnostic ICD-9 codes were used to define in-hospital outcomes including complete heart block, TIA or stroke, cardiogenic shock, cardiac arrest, major bleeding, blood transfusion, vascular complication, and emergency CABG. Additional data were collected on length of stay in hospital, hospital bed size, hospital location and hospital teaching status, and discharge destination. Major bleeding was defined by ICD-9 codes 4590\* (unspecified hemorrhage), 56681 (hemoperitoneum), 5789\* (gastrointestinal hemorrhage), V582\* (blood transfusion), 431\* (intracerebral hemorrhage) and 4329\* (intracranial hemorrhage). The causes of readmission were determined by the first diagnosis based on Clinical Classification Software codes presented in Supplementary Table 1.

Statistical analysis was performed on Stata 15 (College Station, Texas). The incidence of unplanned readmissions according to time after PCI was graphically examined using a histogram. Bar graphs were used to examine rates of readmissions within the time periods 0-7 days, 8-30 days, 31-90 days, and 91-180 days post PCI. Rates were also determined according to whether patients had acute ischemic syndrome or stable ischemic heart disease. As there were an unequal number of days within each period we further considered the rate of readmission per day within each time period by considering the overall rate and dividing by the number of days in the time period examined. A Kaplan Meier survival curve was plotted to show the cumulative rate of readmission over time using the month of admission to estimate the follow up for the control group that was not readmitted. Within the time periods, baseline characteristics of participants were examined and tested for statistical differences using t-test for continuous variables and chi2 test for categorical variables with no readmission as the reference group. Multiple logistic regressions were used to determine the predictors of readmission within each time periods with adjustments for all variables except for elective variables. The elective variable was not adjusted for because we adjusted for diagnosis of acute myocardial infarction (AMI) which is not an elective case. The causes of unplanned readmissions were examined with a graph and a table of rates. Total costs were also analyzed graphically.

**Results**

A total of 2,412,000 patients were included in the analysis after excluding patients who died during their index hospitalization and those with planned readmissions (Figure 1). The percentage of readmissions that occurred between 0-7 days was 2.5%, which increased to 24.8% at 91-180 days (Figure 2) although there appears to be a decline in readmissions between 2011 and 2014 for all groups. The median time to readmission was 35 days (interquartile range was 14 to 79 days). The peak readmission rate occurred at 7 days (Figure 3). The daily readmission rates were 0.35% for 0-7 days, 0.33% for 8-30 days, 0.15% for 31-90 days and 0.09% for 91-180 days. The Kaplan Meier curve for the proportion of free from readmissions is shown in Figure 4, with a cumulative readmission rate at 6 months of 25%. The rates for unplanned readmissions at each individual time point as well as cumulative rates are shown in Supplementary Table 2a and 2b, respectively, for the cohort with and without a diagnosis of acute myocardial infarction. At 0-7 days the rate of readmission, for acute myocardial infarction and no diagnosis of acute myocardial infarction were 2.41% and 2.49%, respectively (p=0.011). At later time points between 91-180 days, unplanned readmissions occurred in 6.83% and 9.24% in the acute myocardial infarction and no diagnosis of acute myocardial infarction group, respectively (p<0.001). The corresponding cumulative rate up to 180 days were 22.86% and 26.84% (p<0.001), respectively.

Table 1 shows the characteristics of patients according to the time of readmission. Overall, patients who were readmitted were older and more likely to be female. Of the patients readmitted after index discharge, the average age and proportion of female gender were numerically similar across each readmission time period. There was also a greater prevalence of hypertension, diabetes mellitus, chronic lung disease, renal failure and anemia among patients who were readmitted compared to those who were not across all time periods. The burden of comorbidity as measured by the Charlson Comorbidity Index was on average 1.4, 1.9, 2.0 and 1.8 for patients with a readmission between 0-7 days, 8-30 days, 31-90 days and 91-180 days, respectively. This was significantly higher than patients who had no readmission during each of these time periods. The average length of stay during the index admission was shorter among patients who were readmitted between 0 and 7 days (2.4 days) compared to all other time points (5.2 days, 6.2 days and 4.8 days for 8-30 days, 31-90 days, and 91-180 days, respectively). The index admission cost was $18,631, $25,018, $27,292 and $23,797 among patients who were readmitted between 0-7 days, 8-30 days, 31-90 days, and 91-180, respectively. Considering the cost of readmissions, the total cost increased from $29,767 in readmitted within 0-7 days group to $40,186 in the 31 to 90 days group (Supplementary Figure 1).

Table 2 describes the significant predictors of readmissions within the four time periods, after multivariable adjustment for baseline characteristics. The strongest predictors of readmission were diabetes mellitus, chronic lung disease, renal failure, liver disease, anemia, cancer, and discharge to another hospital, care home or discharge against medical advice.

Non-cardiac readmissions were the most common causes of readmission at all time points studied, increasing from 53.1% at 0-7 days to 59.6% between 91-180 days (Figure 5). The causes of readmissions at different readmission time periods are shown in Table 3 and Figure 6. Non-specific chest pain was the most common cause of non-cardiac readmission early post discharge at 22.7% in the period 0-7 days but declined to 12.0% in the period 90-180 days. Readmissions for gastrointestinal (excluding gastrointestinal bleeding) and infectious causes for readmissions increased from 10.7% to 11.9% and from 8.4% to 12.9%, respectively, at 90-180 days. Major bleeding (6.3%) and renal failure (3.9%) readmission rates peaked at 8 to 30 days post index discharge. For cardiac causes, at the early time point of 0-7 days, the rate of acute myocardial infarction (AMI) was 27.9% whilst for heart failure it was 15.6%. These rates for AMI decreased to 18.7% whereas increased for heart failure to 26.3% between 8 to 30 days.

**Discussion**

This large retrospective analysis demonstrates that approximately one in four patients who undergo PCI had an unplanned readmission within 6 months. The time point at which patients are at greatest risk is at 7-days post discharge with the majority of unplanned readmissions occurring within 30 days. Thereafter, the daily rate of unplanned readmissions declines over the time. In addition, the causes of readmissions vary depending on the time periods of readmission, with non-cardiac chest pain as an important cause at early time points and gastrointestinal bleeding and infections more important at longer time points (91-180 days). For cardiac causes of readmission, readmissions for acute myocardial infarction is highest 0-7 days post discharge whilst for heart failure the peak is 8-30 days post discharge.

These results have differences and similarities to a recent 2-centre study reported the incidence and causes of rehospitalization within 1-year after PCI in 17,111 patients from Denmark.16 First, although the authors reported a higher 1-year readmission rate of 50.4%, this included planned staged procedures. The authors also reported that the majority of readmissions occur within the first month, and the current study suggests that it actually peaks in the first 7 days. Secondly, at 1 year the most common cause of readmission in Denmark was either acute myocardial infarction or angina / chest pain (49.7%) whereas the 2nd most common cause of readmission was heart failure (5.5%). In contrast, in the current study, the most common cause of readmission varied according to the time period evaluated, although non-cardiac causes are consistently more prevalent at all time periods studied. The Denmark study may reflect that non-cardiac diagnoses are more likely to be managed by primary care, whilst in the United States are more likely to present in the emergency department, likely due to a less developed primary care services. Third, the current study has a far larger sample size that is reflective of the whole country rather than 2 centers, with more demographic, comorbidity, hospital, and procedural variables so it is not surprising that we identified additional strong predictors including chronic lung disease, renal failure, liver disease, anemia, cancer and discharge to another hospital, nursing facility or discharge against medical advice. Finally, we have evaluated rates of readmissions follow diagnosis of acute ischemic syndrome and stable ischemic heart diseases within time periods while the Danish study reported cumulative rates with survival curves.

We observed differences in readmission rates comparing patients who had a diagnosis of acute myocardial infarction and patients without a diagnosis of acute myocardial infarction and interestingly, after adjustments, there was an increased odds ratio for readmission for patients with acute myocardial infarction in the early follow up period (0-7 days). Patients presenting with acute coronary syndrome tend to be older, more comorbid and have more complex disease that are independent predictors of unplanned readmissions.17 Patients presenting with acute coronary syndrome have a higher incidence of complications which may also contribute to the higher rate of unplanned readmissions. Data from the NOBORI-2 study suggests that patients with acute coronary syndromes have double the major adverse cardiovascular events at 180 days compared to stable angina.17 Similarly, data derived from the CathPCI Registry suggests that major bleeding complications were significantly greater in patients undergoing PCI for acute coronary syndrome compared to elective patients18 with similar findings reported for acute kidney injury and requirement for dialysis.19 We have previously shown that both ischemic and hemorrhagic stroke complications occur between two to five times more commonly in acute coronary syndrome patients compared to elective patients.20 Finally, presentation with acute coronary syndromes is associated with an increased risk of heart failure readmission post discharge, recent data from the nationwide readmission dataset suggests that this may be as high as 13.9% in patients with STEMI.21We observed that gastrointestinal causes for readmissions is common and increases in rate over time. Dyspepsia may mimic symptoms of heart disease. Studies have suggested that gastroesophageal reflux disease is twice as common in patients with coronary heart disease compared to the general population.22 At the same time, the DAPT given to patients may cause or exacerbate dyspepsia.23 Use of proton pump inhibitor may reduce some of these gastrointestinal-related readmissions.

A common complication following PCI is bleeding related to DAPT, with gastrointestinal bleeding one of the most common. The ADAPT-DES (Assessment of Dual AntiPlatelet Therapy With Drug Eluting Stents) study suggests that gastrointestinal bleeding was the most common source of post discharge bleeding after PCI.24 Our study reveals that bleeding causing hospitalization peaks at 8 to 30 days and declines with time despite DAPT that may last for up to 1 year. This may relate to the fact that many bleeds occurring at later time points may be nuisance bleeds that do not require hospital readmission or are fatal bleeds that do not survive to hospital readmission. It is not clear the extent to which these types of bleeding episodes could have been prevented, although there may be a potential role for gastrointestinal prophylaxis in PCI as observational studies have suggested that less than half of acute coronary syndrome patients at high risk of bleeding on DAPT are provided with gastrointestinal prophylaxis.25

Readmission risk could be assessed using risk scores26 and high-risk individuals scheduled for early follow up. As non-cardiac readmissions remain prevalent beyond 90-days clinicians should consider appropriate referral to hospital specialists or community care for continuing care of comorbid conditions with close liaison with primary care. Many of the patients that undergo PCI are comorbid and these comorbidities drive the readmissions.

The only intervention to date which has been shown to reduce readmissions after PCI has used short-video patient education materials which specifically target heart failure and chest discomfort.14 The videos described in the study by Tangeturi et al provided education around the different types of chest discomfort, how to contact cardiologists by phone to evaluate low-risk symptoms, how to use nitroglycerin to treat angina, the role of anxiety after PCI and information about heart failure symptoms after PCI. According to the authors, these videos are provided as web-based links in their discharge instructions, which allows patients to view the videos as often as needed. Our current study supports such interventions as non-specific chest pain is a common non-cardiac cause of unplanned readmission between 0 to 7 days and heart failure is a major cause of readmissions between 8 to 90 days. There are also admission avoidance strategies such as notification systems in the emergency department, which flag up patients who return to hospital who have been recently admitted to hospital. The use of an automated notification system has been shown to reduce readmission rates from 14% to 12%27 through rapid assessment by the cardiac team leading to fewer re-hospitalizations after PCI for low risk patients.14 In addition, there are also other measures which may be implemented to reduce readmissions such as the use of a discharge toolkit,28 multifaceted interventions to improve medication adherence,29 programs to reduce medication errors30 and increased role of pharmacist and social worker.31

**Limitations of the study**

Our study has several limitations. Firstly, the NRD is constructed in a format that precludes linkage of between years, so it is possible that the same patient appears in more than one year, and it is not possible follow up patients across years. Secondly, because of the nature of the annualized data each patient could only have a maximum follow up of 1 year, with the numbers at risk decreasing with time. Thirdly, the NRD is not designed to allow for determining regional variations within the dataset, and our results may only be generalizable to the United States healthcare system. Fourthly, we excluded patients admitted during the month of December and there were further exclusions for the last 6 months of the year so seasonal effects may not be captured. One of the limitations of using administrative data is uncertainty in classification of non-specific chest pain as a reason for readmission. This code is derived from codes for chest pain, unspecified, precordial pain and other chest pain and in the current analysis it was classified as non-cardiac. While there is the potential that the pain coded using these terms may potentially have been cardiac in origin, we are unable to explore this further. In addition, the current dataset is further limited because it lacks outpatient PCI procedures and only represents hospital admissions. Finally, as with any observational data it would be incorrect to make causal inferences with data and there are the limitations related to unmeasured confounders.

In conclusion, we show that readmissions after PCI are common, occurring in one in four of patients, with the highest risk of readmissions at 7-days post procedure. The time period where there are the most readmissions is up to 30-days. Although there is a decline in readmissions beyond 30-days, readmission related to non-cardiac causes increases. The most common cause for readmission in the early period is non-cardiac chest pain. Other important causes for readmissions include heart failure, gastrointestinal disease and infections. Any interventions developed to reduce unplanned readmissions should consider the important differences in causes of readmission at different time-points after the PCI procedure.

**Contributorship**

CSK and MAM were responsible for the study design and concept. CSK performed the data cleaning and analysis. CSK wrote the first draft of the manuscript and all authors contributed to the writing of the paper.

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**Table 1:** Characteristics of participants

A) Readmitted between 0-7 days and 8-30 days of index discharge after percutaneous coronary intervention

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Variable | Available 30-day follow up with no readmission between 0-7 days | Readmission between 0-7 days | | Available 30-day follow up with no readmission between 8-30 days | Readmission between 8-30 days | |
| Mean/% | p-value\* | Mean/% | p-value\* |
| Age (years) | 65±12 | 66±13 | <0.001 | 64±12 | 67±13 | <0.001 |
| Female sex | 32.4% | 38.3% | <0.001 | 31.8% | 40.4% | <0.001 |
| Elective | 16.0% | 13.4% | <0.001 | 16.4% | 10.7% | <0.001 |
| Diagnosis of acute myocardial infarction | 51.8% | 51.0% | 0.011 | 51.9% | 50.5% | <0.001 |
| Primary expected payer  Medicare  Medicaid  Private  Self-pay  No charge  Other | 52.3%  7.5%  30.1%  5.7%  0.8%  3.7% | 59.6%  8.5%  23.0%  4.8%  0.8%  3.4% | <0.001 | 51.3%  7.3%  31.0%  5.8%  0.8%  3.7% | 64.9%  9.3%  18.3%  3.9%  0.6%  3.0% | <0.001 |
| Quartile of median household income  0-25th  26th-50th  51st-75th  76th-100th | 28.8%  25.3%  24.0%  22.0% | 29.3%  25.2%  24.0%  21.5% | 0.23 | 28.6%  25.3%  24.1%  22.1% | 31.2%  25.5%  23.2%  20.1% | <0.001 |
| Smoker | 41.5% | 39.8% | <0.001 | 41.7% | 39.1% | <0.001 |
| Alcohol misuse | 2.7% | 2.4% | 0.016 | 2.6% | 2.9% | <0.001 |
| Dyslipidemia | 71.4% | 71.2% | 0.56 | 71.7% | 67.3% | <0.001 |
| Hypertension | 74.6% | 77.6% | <0.001 | 74.3% | 78.1% | <0.001 |
| Diabetes | 36.7% | 40.3% | <0.001 | 35.9% | 45.7% | <0.001 |
| Obesity | 16.0% | 15.2% | 0.001 | 15.9% | 16.3% | 0.007 |
| Heart failure | 1.6% | 0.5% | <0.001 | 1.4% | 3.1% | <0.001 |
| Coronary artery disease | 94.1% | 94.8% | <0.001 | 94.1% | 93.9% | 0.013 |
| Previous myocardial infarction | 14.2% | 15.1% | <0.001 | 14.1% | 15.8% | <0.001 |
| Previous PCI | 20.9% | 22.1% | <0.001 | 20.8% | 21.3% | 0.004 |
| Previous CABG | 7.8% | 9.0% | <0.001 | 7.6% | 9.3% | <0.001 |
| Valvular heart disease | 0.5% | 0.2% | <0.001 | 0.4% | 1.0% | <0.001 |
| Atrial fibrillation | 11.6% | 12.8% | <0.001 | 10.9% | 19.5% | <0.001 |
| Previous stroke or TIA | 6.9% | 8.6% | <0.001 | 6.6% | 10.3% | <0.001 |
| Peripheral vascular disease | 11.0% | 12.7% | <0.001 | 10.5% | 16.7% | <0.001 |
| Pulmonary circulatory disorders | 0.3% | 0.1% | <0.001 | 0.3% | 0.6% | <0.001 |
| Peptic ulcer disease | 0.02% | 0.02% | 0.50 | 0.02% | 0.03% | 0.22 |
| Chronic lung disease | 16.7% | 19.5% | <0.001 | 16.0% | 25.8% | <0.001 |
| Renal failure | 13.4% | 16.2% | <0.001 | 12.4% | 25.4% | <0.001 |
| Liver disease | 1.3% | 1.6% | <0.001 | 1.2% | 2.0% | <0.001 |
| Hypothyroidism | 9.2% | 10.5% | <0.001 | 9.0% | 11.9% | <0.001 |
| Fluid and electrolyte disorder | 12.6% | 11.1% | <0.001 | 11.9% | 21.2% | <0.001 |
| Anemia | 10.8% | 11.8% | <0.001 | 9.9% | 21.1% | <0.001 |
| Cancer | 1.7% | 2.0% | 0.006 | 1.6% | 3.1% | <0.001 |
| Depression | 6.6% | 8.2% | <0.001 | 6.4% | 9.3% | <0.001 |
| Dementia | 1.9% | 2.6% | <0.001 | 1.8% | 3.5% | <0.001 |
| Charlson score | 1.3±1.4 | 1.4±1.5 | <0.001 | 1.2±1.4 | 1.9±1.7 | <0.001 |
| Hospital bed size  Small  Medium  Large | 5.6%  20.7%  73.7% | 5.6%  21.3%  73.1% | 0.10 | 5.7%  20.8%  73.6% | 4.8%  20.4%  74.8% | <0.001 |
| Urban hospital | 95.8% | 95.7% | 0.56 | 95.8% | 95.9% | 0.029 |
| Teaching hospital | 54.6% | 52.4% | <0.001 | 54.7% | 54.2% | 0.022 |
| Multi-vessel | 16.1% | 16.8% | 0.004 | 16.1% | 16.1% | 0.59 |
| Bifurcation lesion | 2.9% | 2.8% | 0.45 | 2.9% | 2.7% | 0.045 |
| Circulatory support | 3.0% | 1.9% | <0.001 | 2.9% | 4.9% | <0.001 |
| Vasopressor use | 0.5% | 0.3% | 0.002 | 0.4% | 0.7% | <0.001 |
| Intra-aortic balloon pump | 2.7% | 1.7% | <0.001 | 2.6% | 4.4% | <0.001 |
| Fractional flow reserve | 1.9% | 2.1% | 0.14 | 1.9% | 2.0% | 0.066 |
| Intra-vascular ultrasound | 7.0% | 6.8% | 0.20 | 7.0% | 7.0% | 0.87 |
| Drug-eluting stent | 74.2% | 71.7% | <0.001 | 74.8% | 67.0% | <0.001 |
| In-hospital complete heart blocks | 1.0% | 0.7% | <0.001 | 1.0% | 1.3% | <0.001 |
| In-hospital stroke/TIA | 2.9% | 2.7% | 0.036 | 2.9% | 4.1% | <0.001 |
| Cardiogenic shock | 2.8% | 1.5% | <0.001 | 2.6% | 4.6% | <0.001 |
| Cardiac arrest | 1.8% | 1.0% | <0.001 | 1.8% | 2.3% | <0.001 |
| In-hospital bleeding | 0.7% | 0.4% | <0.001 | 0.6% | 1.3% | <0.001 |
| In-hospital vascular complications | 0.8% | 0.6% | 0.003 | 0.8% | 1.2% | <0.001 |
| In-hospital emergency CABG | 1.4% | 0.1% | <0.001 | 1.4% | 1.9% | <0.001 |
| Index admission length of stay (days) | 3.8±5.2 | 2.4±1.3 | <0.001 | 3.7±5.3 | 5.2±4.3 | <0.001 |
| Index admission cost (USD) | $21,958±17,906 | $18,631±8,616 | <0.001 | $21,704±18,026 | $25,018±16,072 | <0.001 |
| Discharge destination  Home/self-care  Transfer to other hospital  Care home  Discharge against medical advice | 87.7%  4.9%  7.0%  0.4% | 88.2%  3.9%  6.8%  1.1% | <0.001 | 88.8%  4.4%  6.4%  0.4% | 74.6%  10.2%  14.6%  0.7% | <0.001 |
| Readmission length of stay (days) | - | 3.6±4.7 | - | - | 4.5±5.6 | - |
| Readmission cost ($ USD) | - | $11,258±16,472 | - | - | $12,191±16,939 | - |
| Readmission death | - | 2.3% | - | - | 2.9% | - |
| Total cost (index and readmission) | $21,958±17,906 | $29,767±19,548 | <0.001 | $21,704±18,026 | $37,155±25,312 | <0.001 |

\*p-value compared to no readmission

B) Readmitted between 31-90 days and 91-180 days of index discharge after percutaneous coronary intervention

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Variable | Available 90-day follow up with no readmission between 31-90 days | Readmission between 31-90 days | | Available 180-day follow up with no readmission 90-180 days | Readmission between 91-180 days | |
| Mean/% | p-value\* | Mean/% | p-value\* |
| Age (years) | 64±12 | 67±13 | <0.001 | 64±12 | 66±13 | <0.001 |
| Female sex | 30.8% | 40.4% | <0.001 | 30.1% | 38.8% | <0.001 |
| Elective | 17.0% | 12.5% | <0.001 | 17.4% | 14.6% | <0.001 |
| Diagnosis of acute myocardial infarction | 51.9% | 45.1% | <0.001 | 51.9% | 43.8% | <0.001 |
| Primary expected payer  Medicare  Medicaid  Private  Self-pay  No charge  Other | 50.0%  7.0%  32.4%  6.0%  0.8%  3.8% | 64.6%  9.9%  17.8%  4.0%  0.7%  2.9% | <0.001 | 49.0%  6.8%  33.5%  6.0%  0.8%  3.8% | 62.3%  9.4%  19.6%  4.7%  0.8%  3.2% | <0.001 |
| Quartile of median household income  0-25th  26th-50th  51st-75th  76th-100th | 28.3%  25.2%  24.2%  22.4% | 31.9%  25.4%  22.9%  19.9% | <0.001 | 27.9%  25.2%  24.3%  22.6% | 32.0%  25.0%  22.7%  20.3% | <0.001 |
| Smoker | 41.9% | 38.7% | <0.001 | 41.8% | 39.5% | <0.001 |
| Alcohol misuse | 2.6% | 3.1% | <0.001 | 2.5% | 2.8% | 0.005 |
| Dyslipidemia | 72.2% | 67.2% | <0.001 | 72.5% | 70.3% | <0.001 |
| Hypertension | 73.8% | 78.5% | <0.001 | 73.4% | 79.1% | <0.001 |
| Diabetes | 34.9% | 46.9% | <0.001 | 33.9% | 46.1% | <0.001 |
| Obesity | 15.8% | 16.7% | <0.001 | 15.7% | 17.0% | <0.001 |
| Heart failure | 1.2% | 4.1% | <0.001 | 1.0% | 2.7% | <0.001 |
| Coronary artery disease | 94.2% | 93.9% | 0.001 | 94.2% | 94.9% | <0.001 |
| Previous myocardial infarction | 14.0% | 16.6% | <0.001 | 13.8% | 17.8% | <0.001 |
| Previous PCI | 20.8% | 23.5% | <0.001 | 20.7% | 26.1% | <0.001 |
| Previous CABG | 7.5% | 10.1% | <0.001 | 7.3% | 11.0% | <0.001 |
| Valvular heart disease | 0.4% | 1.2% | <0.001 | 0.3% | 0.8% | <0.001 |
| Atrial fibrillation | 10.1% | 18.6% | <0.001 | 9.7% | 15.3% | <0.001 |
| Previous stroke or TIA | 6.1% | 10.6% | <0.001 | 5.7% | 10.1% | <0.001 |
| Peripheral vascular disease | 9.8% | 17.0% | <0.001 | 9.3% | 15.5% | <0.001 |
| Pulmonary circulatory disorders | 0.2% | 0.8% | <0.001 | 0.2% | 0.5% | <0.001 |
| Peptic ulcer disease | 0.02% | 0.03% | 0.20 | 0.02% | 0.03% | 0.16 |
| Chronic lung disease | 15.0% | 25.4% | <0.001 | 14.5% | 22.8% | <0.001 |
| Renal failure | 11.0% | 25.8% | <0.001 | 10.1% | 21.9% | <0.001 |
| Liver disease | 1.1% | 2.0% | <0.001 | 1.0% | 1.7% | <0.001 |
| Hypothyroidism | 8.7% | 11.5% | <0.001 | 8.4% | 10.9% | <0.001 |
| Fluid and electrolyte disorder | 10.9% | 20.8% | <0.001 | 10.3% | 16.1% | <0.001 |
| Anemia | 8.8% | 21.0% | <0.001 | 8.1% | 16.9% | <0.001 |
| Cancer | 1.5% | 3.1% | <0.001 | 1.4% | 2.4% | <0.001 |
| Depression | 6.1% | 9.1% | <0.001 | 5.8% | 8.8% | <0.001 |
| Dementia | 1.6% | 3.5% | <0.001 | 1.5% | 2.8% | <0.001 |
| Charlson score | 1.1±1.3 | 2.0±1.7 | <0.001 | 1.1±1.3 | 1.8±1.6 | <0.001 |
| Hospital bed size  Small  Medium  Large | 5.8%  20.8%  73.4% | 4.8%  19.7%  75.4% | <0.001 | 5.9%  20.8%  73.3% | 5.1%  20.2%  74.7% | <0.001 |
| Urban hospital | 95.8% | 95.9% | 0.25 | 95.8% | 96.0% | 0.039 |
| Teaching hospital | 54.7% | 54.8% | 0.54 | 54.8% | 55.0% | 0.42 |
| Multi-vessel | 16.0% | 16.4% | 0.003 | 16.0% | 17.0% | <0.001 |
| Bifurcation lesion | 2.9% | 2.8% | 0.33 | 2.9% | 2.8% | 0.23 |
| Circulatory support | 2.7% | 4.7% | <0.001 | 2.6% | 3.3% | <0.001 |
| Vasopressor use | 0.4% | 0.6% | <0.001 | 0.4% | 0.4% | 0.57 |
| Intra-aortic balloon pump | 2.4% | 4.1% | <0.001 | 2.3% | 2.8% | <0.001 |
| Fractional flow reserve | 1.8% | 1.9% | 0.96 | 1.8% | 1.9% | 0.12 |
| Intra-vascular ultrasound | 7.0% | 7.1% | 0.58 | 7.1% | 7.5% | 0.006 |
| Drug-eluting stent | 75.7% | 65.8% | <0.001 | 76.2% | 69.3% | <0.001 |
| In-hospital complete heart blocks | 1.0% | 1.2% | <0.001 | 0.9% | 1.0% | 0.32 |
| In-hospital stroke/TIA | 2.7% | 4.4% | <0.001 | 2.6% | 3.6% | <0.001 |
| Cardiogenic shock | 2.4% | 4.6% | <0.001 | 2.3% | 2.9% | <0.001 |
| Cardiac arrest | 1.7% | 2.3% | <0.001 | 1.6% | 1.6% | 0.38 |
| In-hospital bleeding | 0.5% | 1.3% | <0.001 | 0.5% | 0.9% | <0.001 |
| In-hospital vascular complications | 0.7% | 1.2% | <0.001 | 0.7% | 0.9% | <0.001 |
| In-hospital emergency CABG | 1.3% | 1.6% | <0.001 | 1.4% | 1.2% | 0.001 |
| Index admission length of stay (days) | 3.4±4.8 | 6.2±7.8 | <0.001 | 3.3±4.5 | 4.8±7.3 | <0.001 |
| Index admission cost (USD) | $20,978±16,664 | $27,292±26,175 | <0.001 | $20,645±15,983 | $23,797±23,480 | <0.001 |
| Discharge destination  Home/self-care  Transfer to other hospital  Care home  Discharge against medical advice | 90.3%  3.6%  5.7%  0.4% | 74.9%  11.8%  12.8%  0.5% | <0.001 | 91.0%  3.3%  5.3%  0.4% | 82.0%  7.1%  10.3%  0.5% | <0.001 |
| Readmission length of stay (days) | - | 4.7±6.2 | - | - | 4.3±5.5 | - |
| Readmission cost ($ USD) | - | $12,960±17,858 | - | - | $13,175±17,810 | - |
| Readmission death | - | 2.6% | - | - | 2.1% | - |
| Total cost (index and readmission) | $20,978±16,664 | $40,186±34,142 | <0.001 | $20,645±15,983 | $36,905±31,858 | <0.001 |

\*p-value compared to no readmission

**Table 2:** Significant predictors of readmissions at different time periods after index discharge for percutaneous coronary intervention

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable | Readmission between 0-7 days (odds ratio (95% CI)) | Readmission between 8-30 days  (odds ratio (95% CI)) | Readmission between 31-90 days  (odds ratio (95% CI)) | Readmission between 90-180 days  (odds ratio (95% CI)) |
| Age (per year increase) | - | 1.00 (1.00-1.00) | 1.00 (1.00-1.00) | 1.00 (1.00-1.00) |
| Female sex | 1.28 (1.23-1.32) | 1.20 (1.18-1.23) | 1.23 (1.20-1.26) | 1.26 (1.22-1.30) |
| Diagnosis of acute myocardial infarction | 1.18 (1.14-1.23) | - | 0.81 (0.79-0.83) | 0.80 (0.77-0.82) |
| Primary expected payer vs Medicare  Medicaid  Private  Self-pay  No charge  Other | 1.11 (1.04-1.19)  0.73 (0.69-0.76)  0.82 (0.75-0.89)  -  0.90 (0.82-0.99) | 1.18 (1.13-1.22)  0.69 (0.67-0.71)  0.74 (0.70-0.78)  0.85 (0.75-0.97)  0.79 (0.75-0.84) | 1.19 (1.14-1.25)  0.63 (0.61-0.65)  0.75 (0.70-0.79)  0.84 (0.75-0.93)  0.76 (0.72-0.81) | 1.18 (1.11-1.25)  0.64 (0.61-0.67)  0.81 (0.76-0.87)  -  0.78 (0.72-0.85) |
| Quartile of median household income vs 0-25th  26th-50th  51st-75th  76th-100th | -  -  - | 0.96 (0.93-0.99)  0.94 (0.91-0.97)  0.94 (0.91-0.98) | 0.94 (0.91-0.97)  0.92 (0.89-0.95)  0.93 (0.90-0.96) | 0.89 (0.85-0.93)  0.90 (0.86-0.94)  0.90 (0.86-0.95) |
| Smoker | 0.92 (0.89-0.96) | 0.97 (0.95-1.00) | - | 0.97 (0.94-1.00) |
| Alcohol misuse | - | 1.14 (1.07-1.21) | 1.17 (1.10-1.24) | 1.16 (1.06-1.27) |
| Dyslipidemia | 0.91 (0.88-0.95) | 0.87 (0.85-0.89) | 0.85 (0.83-0.87) | 0.87 (0.85-0.90) |
| Hypertension | 1.07 (1.02-1.11) | 1.06 (1.03-1.08) | 1.07 (1.04-1.10) | 1.09 (1.05-1.12) |
| Diabetes | 1.15 (1.11-1.19) | 1.24 (1.21-1.26) | 1.31 (1.28-1.35) | 1.34 (1.30-1.37) |
| Obesity | 0.95 (0.91-0.99) | 0.94 (0.91-0.96) | 0.95 (0.93-0.98) | - |
| Heart failure | - | - | - | - |
| Coronary artery disease | - | - | - | - |
| Previous myocardial infarction | - | 1.06 (1.03-1.09) | 1.08 (1.04-1.11) | 1.14 (1.10-1.19) |
| Previous PCI | - | - | 1.11 (1.08-1.14) | 1.21 (1.17-1.25) |
| Previous CABG | - | 1.11 (1.07-1.14) | 1.16 (1.12-1.20) | 1.31 (1.25-1.37) |
| Valvular heart disease | - | - | 1.18 (1.03-1.35) | - |
| Atrial fibrillation | 1.30 (1.23-1.37) | 1.45 (1.41-1.49) | 1.37 (1.33-1.42) | 1.25 (1.20-1.30) |
| Previous stroke or TIA | 1.17 (1.10-1.24) | 1.17 (1.13-1.21) | 1.23 (1.18-1.27) | 1.33 (1.27-1.40) |
| Peripheral vascular disease | 1.18 (1.12-1.25) | 1.19 (1.16-1.22) | 1.25 (1.21-1.29) | 1.24 (1.19-1.30) |
| Pulmonary circulatory disorders | - | - | - | - |
| Peptic ulcer disease | - | - | - | - |
| Chronic lung disease | 1.27 (1.22-1.33) | 1.42 (1.38-1.45) | 1.43 (1.39-1.47) | 1.35 (1.30-1.40) |
| Renal failure | 1.36 (1.30-1.43) | 1.51 (1.47-1.55) | 1.57 (1.52-1.61) | 1.59 (1.53-1.66) |
| Liver disease | 1.36 (1.30-1.65) | 1.34 (1.25-1.44) | 1.37 (1.33-1.42) | 1.25 (1.12-1.40) |
| Hypothyroidism | - | - | - | - |
| Fluid and electrolyte disorder | 1.16 (1.10-1.23) | 1.24 (1.21-1.28) | 1.17 (1.14-1.21) | 1.11 (1.06-1.16) |
| Anemia | 1.26 (1.19-1.34) | 1.37 (1.33-1.41) | 1.39 (1.35-1.43) | 1.32 (1.26-1.38) |
| Cancer | 1.19 (1.05-1.35) | 1.45 (1.37-1.54) | 1.59 (1.48-1.69) | 1.45 (1.31-1.61) |
| Depression | 1.23 (1.16-1.31) | 1.23 (1.19-1.27) | 1.20 (1.15-1.25) | 1.28 (1.21-1.35) |
| Dementia | 1.23 (1.10-1.38) | 1.12 (1.06-1.19) | 1.16 (1.09-1.25) | 1.11 (1.00-1.23) |
| Hospital bed size vs small  Medium  Large | -  - | -  - | -  1.10 (1.01-1.19) | -  - |
| Urban hospital | 1.12 (1.03-1.22) | 1.09 (1.03-1.15) | 1.09 (1.04-1.15) | 1.14 (1.07-1.21) |
| Teaching hospital | 0.91 (0.88-0.95) | - | - | 0.96 (0.93-1.00) |
| Multi-vessel | 1.05 (1.01-1.10) | - | - | 1.07 (1.03-1.11) |
| Bifurcation lesion | - | - | - | 0.90 (0.83-0.98) |
| Circulatory support | - | - | - | - |
| Vasopressor use | - | - | - | - |
| Intra-aortic balloon pump | - | 1.28 (1.09-1.51) | - | - |
| Fractional flow reserve | - | 1.10 (1.03-1.19) | - | - |
| Intra-vascular ultrasound | - | - | - | - |
| Drug-eluting stent | 0.82 (0.79-0.85) | 0.81 (0.80-0.83) | 0.73 (0.71-0.74) | 0.76 (0.74-0.79) |
| In-hospital complete heart blocks | - | - | - | - |
| In-hospital stroke/TIA | - | - | - | - |
| Cardiogenic shock | - | - | - | - |
| Cardiac arrest | - | - | 0.83 (0.76-0.90) | 0.73 (0.65-0.82) |
| In-hospital bleeding | - | 1.15 (1.04-1.28) | 1.21 (1.08-1.35) | - |
| In-hospital vascular complications | - | 1.14 (1.04-1.24) | - | - |
| In-hospital emergency CABG | 0.30 (0.19-0.46) | 0.84 (0.78-0.92) | 0.62 (0.57-0.68) | 0.52 (0.46-0.59) |
| Index admission length of stay (days) | 0.76 (0.75-0.77) | 1.00 (1.00-1.00) | 1.03 (1.02-1.03) | 1.02 (1.01-1.02) |
| Discharge destination vs home/self-care  Transfer to other hospital  Care home  Discharge against medical advice | 1.47 (1.32-1.64)  1.38 (1.29-1.48)  2.16 (1.86-2.52) | 1.52 (1.45-1.59)  1.69 (1.63-1.74)  1.70 (1.51-1.92) | 1.74 (1.66-1.83)  1.47 (1.42-1.53)  1.38 (1.20-1.60) | 1.30 (1.21-1.40)  1.32 (1.26-1.39)  1.42 (1.18-1.71) |

**Table 3:** Non-cardiac and cardiac causes of readmissions at different time periods after index discharge for percutaneous coronary intervention

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Non-cardiac cause for readmission | Readmission between 0-7 days (%) | Readmission between 8-30 days (%) | Readmission between 31-90 days (%) | Readmission 90-180 days (%) |
| Non-specific chest pain | 22.7 | 15.6 | 12.5 | 12.0 |
| Gastrointestinal | 10.7 | 10.8 | 11.4 | 11.9 |
| Infections | 8.4 | 12.0 | 13.4 | 12.9 |
| Respiratory | 6.4 | 8.6 | 8.6 | 7.6 |
| TIA/stroke | 5.4 | 4.1 | 4.7 | 5.4 |
| Peripheral vascular disease | 4.2 | 4.4 | 3.8 | 3.2 |
| Bleeding | 3.6 | 6.3 | 5.2 | 4.5 |
| Renal failure | 2.6 | 3.9 | 3.6 | 2.8 |
| Genitourinary | 2.6 | 2.9 | 3.4 | 3.6 |
| Neuropsychiatric | 2.3 | 2.5 | 2.9 | 3.5 |
| Trauma | 1.9 | 2.4 | 4.3 | 5.7 |
| Hematological/neoplasm | 1.7 | 3.3 | 4.2 | 3.8 |
| Endocrine/metabolic | 1.3 | 2.9 | 3.4 | 3.1 |
| Other non-cardiac | 26.1 | 20.4 | 18.5 | 19.9 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Cardiac cause for readmission | Readmission between 0-7 days (%) | Readmission between 8-30 days (%) | Readmission between 31-90 days (%) | Readmission >90 days (%) |
| Coronary artery disease including angina | 39.3 | 36.8 | 38.3 | 41.2 |
| Acute myocardial infarction | 27.6 | 16.3 | 17.4 | 24.1 |
| Heart failure | 15.6 | 26.3 | 24.0 | 17.2 |
| Arrhythmias | 12.5 | 15.3 | 16.1 | 14.4 |
| Other cardiac cause | 5.1 | 5.2 | 4.2 | 3.0 |

**Figure 1:** Flow diagram of patient inclusion



**Figure 2:** Rate of readmissions during different time periods

****

**Figure 3:** Histogram and temporal trends according to time to readmission

****

**Figure 4:** Kaplan Meier Curve for cumulative readmissions over time



**Figure 5:** Rate of non-cardiac readmissions at different time points

****

**Figure 6:** Causes of readmissions at different time points

****

**Supplementary Table 1:** Classification of Clinic Classification Software codes for Readmissions Causes

|  |  |  |
| --- | --- | --- |
| Causes of readmission | CCS code | Diagnosis |
| Respiratory | 127 | Chronic obstructive pulmonary disease and bronchiectasis |
| 128 | Asthma |
| 130 | Pleurisy, pneumothorax, pulmonary collapse |
| 131 | Respiratory failure, insufficiency and arrest |
| 132 | Lung disease due to external agents |
| 133 | Other lower respiratory disease |
| 134 | Other upper respiratory disease |
| 221 | Respiratory distress syndrome |
| Infection | 1 | Tuberculosis |
| 2 | Septicemia |
| 3 | Bacterial infection |
| 4 | Mycoses |
| 5 | HIV infection |
| 6 | Hepatitis |
| 7 | Viral infection |
| 8 | Other infection |
| 9 | Sexually transmitted infection |
| 76 | Meningitis |
| 77 | Encephalitis |
| 78 | Other CNS infection and poliomyelitis |
| 90 | Inflammation or infection of eye |
| 122 | Pneumonia |
| 123 | Influenza |
| 124 | Acute and chronic tonsillitis |
| 125 | Acute bronchitis |
| 126 | Other upper respiratory infections |
| 129 | Aspiration pneumonitis |
| 135 | Intestinal infection |
| 197 | Skin and subcutaneous tissue infections |
| 201 | Infective arthritis and osteomyelitis (except that caused by tuberculosis or sexually transmitted disease) |
| Bleeding | 60 | Acute posthemorrhagic anemia |
| 153 | Gastrointestinal hemorrhage |
| 182 | Hemorrhage during pregnancy; abrutio placenta; placenta previa |
| Peripheral vascular disease | 114 | Peripheral and visceral atherosclerosis |
| 115 | Aortic, peripheral and visceral artery aneurysms |
| 116 | Aortic and peripheral arterial embolism or thrombosis |
| 117 | Other circulatory disease |
| 118 | Phlebitis, thrombophlebitis and thromboembolism |
| 119 | Varicose veins of lower extremities |
| Genitourinary | 159 | Urinary tract infection |
| 160 | Calculus of the urinary tract |
| 161 | Other diseases of kidney and ureters |
| 162 | Other diseases of bladder and urethra |
| 163 | Genitourinary symptoms and ill-defined conditions |
| 164 | Hyperplasia of prostate |
| 165 | Inflammatory conditions of the male genital organs |
| 166 | Other male genital disorders |
| 170 | Prolapse of female genital organs |
| 175 | Other female genital disorders |
| 215 | Genitourinary congenital anomalies |
| Renal disease | 156 | Nephritis; nephrosis; renal sclerosis |
| 157 | Acute and unspecified renal failure |
| 158 | Chronic kidney disease |
| Gastrointestinal | 138 | Esophageal disorders |
| 139 | Gastroduodenal ulcer (except hemorrhage) |
| 140 | Gastritis and duodenitis |
| 141 | Other disorders of stomach and duodenum |
| 142 | Appendicitis and other appendiceal conditions |
| 143 | Abdominal hernia |
| 144 | Regional enteritis and ulcerative colitis |
| 145 | Intestinal obstruction without hernia |
| 146 | Diverticulosis and diverticulitis |
| 147 | Anal and rectal conditions |
| 148 | Peritonitis and intestinal abscess |
| 149 | Biliary tract disease |
| 150 | Liver disease; alcohol-related |
| 151 | Other liver diseases |
| 152 | Pancreatic disorders (not diabetes) |
| 154 | Noninfectious gastroenteritis |
| 155 | Other gastrointestinal disorders |
| 214 | Digestive congenital anomalies |
| 222 | Hemolytic jaundice and perinatal jaundice |
| 250 | Nausea and vomiting |
| 251 | Abdominal pain |
| TIA/stroke | 109 | Acute cerebrovascular disease |
| 110 | Occlusion of stenosis of precerebral arteries |
| 111 | Other and ill-defined cerebrovascular disease |
| 112 | Transient cerebral ischemia |
| 113 | Late effects of cerebrovascular disease |
| Trauma | 207 | Pathological fracture |
| 225 | Joint disorders and dislocations; trauma-related |
| 226 | Fracture of neck of femur (hip) |
| 227 | Spinal cord injury |
| 228 | Skull and face fractures |
| 229 | Fracture of upper limb |
| 230 | Fracture of lower limb |
| 231 | Other fractures |
| 232 | Sprains and strains |
| 233 | Intracranial injury |
| 234 | Crushing injury or internal injury |
| 235 | Open wounds of head; neck; and trunk |
| 236 | Open wounds of extremities |
| 239 | Superficial injury; contusion |
| 244 | Other injuries and conditions due to external causes |
| 260 | All (external causes of injury and poisoning) |
| Endocrine/metabolic | 48 | Thyroid disorders |
| 49 | Diabetes mellitus without complication |
| 50 | Diabetes mellitus with complication |
| 51 | Other endocrine disorders |
| 53 | Disorders of lipid metabolism |
| 58 | Other nutritional and endocrine/metabolic disorders |
| 186 | Diabetes or abnormal glucose tolerance complicating pregnancy; childbirth; or the puerperium |
| Neuropsychiatric | 650 | Adjustment disorders |
| 651 | Anxiety disorders |
| 652 | Attention-deficit, conduct, and disruptive behavior disorders |
| 653 | Delirium, dementia, and amnestic and other cognitive disorders |
| 654 | Developmental disorders |
| 655 | Disorders usually diagnosed in infancy and childhood or adolescence |
| 656 | Impulse control disorders, NEC |
| 657 | Mood disorders |
| 658 | Personality disorders |
| 659 | Schizophrenia and other psychotic disorders |
| 660 | Alcohol-related disorders |
| 661 | Substance-related disorders |
| 662 | Suicide and intentional self-inflicted injury |
| 663 | Screening and history of mental health and substance abuse codes |
| 670 | Miscellaneous mental health disorders |
| 79 | Parkinson's disease |
| 80 | Multiple sclerosis |
| 81 | Other hereditary and degenerative nervous system conditions |
| 82 | Paralysis |
| 83 | Epilepsy, convulsions |
| 84 | Headache including migraine |
| 85 | Coma, stupor and brain damage |
| 95 | Other nervous system disorders |
| 216 | Nervous system congenital anomalies |
| 650 | Adjustment disorders |
| 651 | Anxiety disorders |
| 652 | Attention-deficit, conduct, and disruptive behavior disorders |
| 653 | Delirium, dementia, and amnestic and other cognitive disorders |
| 654 | Developmental disorders |
| 655 | Disorders usually diagnosed in infancy and childhood or adolescence |
| 656 | Impulse control disorders |
| 657 | Mood disorders |
| 658 | Personality disorders |
| 659 | Schizophrenia and other psychotic disorders |
| 660 | Alcohol-related disorders |
| 661 | Substance-related disorders |
| 662 | Suicide and intentional self-inflicted injury |
| 663 | Screening and history of mental health and substance abuse codes |
| 670 | Miscellaneous mental health disorders |
| Hematological/neoplastic | 11 | Cancer of head and neck |
| 12 | Cancer of esophagus |
| 13 | Cancer of stomach |
| 14 | Cancer of colon |
| 15 | Cancer of rectum and anus |
| 16 | Cancer of liver and intrahepatic bile ducts |
| 17 | Cancer of pancreas |
| 18 | Cancer of other gastrointestinal organs, peritoneum |
| 19 | Cancer of bronchus, lung |
| 20 | Cancer of other respiratory and intrathoracic |
| 21 | Cancer of bone and connective tissue |
| 22 | Melanoma of skin |
| 23 | Other non-epithelial cancer of skin |
| 24 | Cancer of breast |
| 25 | Cancer of uterus |
| 26 | Cancer of cervix |
| 27 | Cancer of ovary |
| 28 | Cancer of other female genital organs |
| 29 | Cancer of prostate |
| 30 | Cancer of testis |
| 31 | Cancer of other male genital organs |
| 32 | Cancer of bladder |
| 33 | Cancer of kidney and renal pelvis |
| 34 | Cancer of other urinary organs |
| 35 | Cancer of brain and nervous system |
| 36 | Cancer of thyroid |
| 37 | Hodgkin's disease |
| 38 | Non-Hodgkin's lymphoma |
| 39 | Leukemias |
| 40 | Multiple myeloma |
| 41 | Cancer, other and unspecified primary |
| 42 | Secondary malignancies |
| 43 | Malignant neoplasm without specification of site |
| 44 | Neoplasm of unspecified nature or uncertain behavior |
| 46 | Benign neoplasm of uterus |
| 47 | Other and unspecified benign neoplasm |
| 59 | Deficiency and other anemias |
| 61 | Sickle cell anemia |
| 62 | Coagulation and hemorrhagic disorders |
| 63 | Disease of white blood cells |
| 64 | Other hematologic conditions |
| Rheumatology problem | 54 | Gout and other crystal arthropathies |
| Opthalmology problem | 86 | Cataract |
| 87 | Retinal detachment defects, vascular occlusion and retinopathy |
| 88 | Glaucoma |
| 89 | Blindness and vision defects |
| 91 | Other eye disorders |
| ENT problem | 92 | Otitis media and related conditions |
| 93 | Conditions associate with dizziness or vertigo |
| 94 | Other ear and sense organ disorder |
| Non-specific chest pain | 102 | Non-specific chest pain |
| Oral health problem | 136 | Disorders of teeth and jaw |
| 137 | Diseases of mouth; excluding dental |
| Obstetric admission including pregnancy | 174 | Female infertility |
| 176 | Contraceptive and procreative management |
| 177 | Spontaneous abortion |
| 178 | Induced abortion |
| 179 | Postabortion complication |
| 180 | Ectopic pregnancy |
| 181 | Other complications of pregnancy |
| 184 | Early or threatened labor |
| 185 | Prolonged pregnancy |
| 187 | Malposition; malpresentation |
| 188 | Fetopelvic disproportion; obstruction |
| 189 | Previous C-section |
| 190 | Fetal distress and abnormal forces of labor |
| 191 | Polyhydramnios and other problems of amniotic cavity |
| 192 | Umbilical cord complication |
| 193 | OB-related trauma to perineum and vulva |
| 194 | Forceps delivery |
| 195 | Other complications of birth; puerperium affecting management of mother |
| 196 | Other pregnancy and deliver including normal |
| 218 | Liveborn |
| 219 | Short gestation; low birth weight; and fetal growth retardation |
| 220 | Intrauterine hypoxia and birth asphyxia |
| 223 | Birth trauma |
| 224 | Other perinatal conditions |
| Dermatology problem | 198 | Other inflammatory condition of skin |
| 199 | Chronic ulcer of skin |
| 200 | Other skin disorders |
| Poisoning | 241 | Poisoning by psychotrophic agents |
| 242 | Poisoning by other medication and drugs |
| 243 | Poisoning by nonmedical substances |
| Syncope | 245 | Syncope |
| Other non-cardiac | 10 | Immunization and screening for infectious disease |
| 45 | Maintenance chemotherapy, radiotherapy |
| 52 | Nutritional deficiencies |
| 55 | Fluid and electrolyte disorders |
| 56 | Cystic fibrosis |
| 57 | Immunity disorder |
| 120 | Hemorrhoids |
| 121 | Other diseases of veins and lymphatics |
| 167 | Nonmalignant breast conditions |
| 168 | Inflammatory disease of female pelvic organs |
| 169 | Endometriosis |
| 172 | Ovarian cyst |
| 173 | Menopausal disorders |
| 202 | Rheumatoid arthritis and related disease |
| 203 | Osteoarthritis |
| 204 | Other non-traumatic joint disorders |
| 205 | Spondylosis; intervertebral disc disorders; other back problems |
| 206 | Osteoporosis |
| 208 | Acquired foot deformities |
| 209 | Other acquired deformities |
| 210 | Systemic lupus erythematosus and connective tissue disorders |
| 211 | Other connective tissue disease |
| 212 | Other bone disease and musculoskeletal deformities |
| 217 | Other congenital anomalies |
| 237 | Complication of device; implant or graft |
| 238 | Complications of surgical procedure or medical care |
| 240 | Burns |
| 246 | Fever of unknown origin |
| 247 | Lymphadenitis |
| 248 | Gangrene |
| 252 | Malaise and fatigue |
| 253 | Allergic reactions |
| 254 | Rehabilitation care; fitting of prostheses; and adjustment of devices |
| 255 | Administrative/social admission |
| 256 | Medical examination/evaluation |
| 257 | Other aftercare |
| 258 | Other screening for suspected conditions (not mental disorders or infectious disease) |
| 259 | Residual codes; unclassified |
| Heart failure | 108 | Congestive heart failure non-hypertensive |
| Arrhythmia | 106 | Cardiac dysrhythmias |
| 107 | Cardiac arrest and ventricular fibrillation |
| Conduction disorder | 105 | Conduction disorders |
| Valve disorders | 96 | Heart valve disorder |
| Hyper/hypotension | 98 | Essential hypertension |
| 99 | Hypertension with complications and secondary hypertension |
| 183 | Hypertension complicating pregnancy; childbirth and the puerperium |
| 249 | Shock |
| Pericarditis | 97 | Peri-, endo- and myocarditis, cardiomyopathy |
| Coronary artery disease including angina | 101 | Coronary atherosclerosis and other heart disease includes angina |
| Acute myocardial infarction | 100 | Acute myocardial infarction |
| Others (cardiac) | 103 | Pulmonary heart disease |
| 104 | Other and ill-defined heart disease |
| 213 | Cardiac and circulatory congenital anomalies |

**Supplementary Table 2:** Rates of unplanned readmissions within each timepoint (a) and cumulative rates (b) for acute coronary syndrome and stable ischemic heart disease cohorts.

(a)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Group | 0-7 day (n=2,215,514) | 8-30 days (n=2,161,213) | 31-90 days (n=1,651,393) | 91-180 days (n=1,023,324) |
| No diagnosis of acute myocardial infarction readmissions | 26,620 (2.49%) | 81,693 (7.85%) | 80,871 (10.06%) | 35,851 (9.24%) |
| Diagnosis of acute myocardial infarction readmissions | 27,681 (2.41%) | 83,210 (7.43%) | 66,501 (7.85%) | 46,046 (6.83%) |
| Total readmitted | 54,301 (2.45%) | 164,903 (7.63%) | 147,372 (8.92%) | 81,897 (8.00%) |
| Total not readmitted | 2,161,213 (97.55%) | 1,996,310 (92.37%) | 1,504,021 (91.18%) | 941,427 (92.00%) |
| p-value for difference between acute myocardial infarction and not a diagnosis of acute myocardial infarction | 0.011 | <0.001 | <0.001 | <0.001 |

(b)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Group | 0-7 days (n=2,215,514) | 0-30 days (n=2,215,514) | 0-90 days (n=1,834,667) | 0-180 days (n=1,252,384) |
| No diagnosis of acute myocardial infarction | 26,620 (2.49%) | 108,313 (10.14%) | 172,332 (19.25%) | 166,054 (26.84%) |
| Diagnosis of acute myocardial infarction | 27,681 (2.41%) | 110,891 (9.66%) | 158,313 (16.85%) | 144,904 (22.86%) |
| Total readmitted | 54,301 (2.45%) | 219,204 (9.89%) | 330,645 (18.02%) | 310,958 (24.83%) |
| Total not readmitted | 2,161,213 (97.55%) | 1,996,310 (91.11%) | 1,504,022 (81.98%) | 941,426 (75.17%) |
| p-value for difference between acute myocardial infarction and not a diagnosis of acute myocardial infarction | 0.011 | <0.001 | <0.001 | <0.001 |

**Supplementary Figure 1:** Cost associated with readmissions at different time points

