**Multiple unplanned readmissions after discharge for an admission with percutaneous coronary intervention**

Short title: Multiple readmissions after PCI

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**Word count:** 3,582

**Keywords:** percutaneous coronary intervention; readmissions; cost

**Abstract**

**Objective:** This study aims to describe temporal trends, characteristics and clinical outcomes of patients with more than one unplanned readmission within 30 and 180 days after admission with percutaneous coronary intervention (PCI).

**Background:** There is limited understanding of multiple readmissions after PCI.

**Methods:** Patients undergoing PCI between 2010 and 2014 in the U.S. Nationwide Readmission Database were evaluated for unplanned readmissions at 30 days and 180 days after discharge. Trends in multiple readmissions, characteristics of patients and causes of first readmissions are described.

**Results:** A total of 2,324,194 patients were included in the analysis of 30 day unplanned readmissions and 1,327,799 patients in the analysis of 180 day unplanned readmission. The proportion of patients with a single readmission and multiple readmissions within 30 days were 8.5% and 1.0%, and at 180 days were 15.4% and 9.1%, respectively. Common reasons for first readmission among patients with multiple readmissions were coronary artery disease including angina, heart failure and acute myocardial infarction. Factors associated with multiple readmissions, were discharge against medical advice, discharge to care home, renal failure and liver failure. The total cost of multiple readmissions is significant with an increase from ~$20,000 for no readmission to over $60,000 at 30 days follow up and $86,000 at 180 days follow up.

**Conclusions:** Multiple readmissions are rare within 30 days after PCI but increase to nearly 1 in 10 patients at 180 days and 20-25% of patients who have multiple readmissions are readmitted for the same cause for first and second readmission.

**Introduction**

Percutaneous coronary intervention (PCI) is the most common modality of coronary revascularization in the United States1. Procedural and periprocedural care has evolved over time with technological, pharmacological and clinical practice advancements resulting in reduced in-hospital mortality and complication rates2,3. There is emerging interest in unplanned readmissions which is a burden to patients and healthcare services as well as a quality metric.4 There have been numerous reports on early hospital readmissions after PCI5-8 and a more recent study of readmissions up to 180 days. There have been no sizable studies which have looked at the vulnerable populations with repeated readmissions after PCI.

Multiple unplanned readmissions after PCI are important because they are associated with a significant financial impact. With each hospital admission actions may potentially be taken to favorably impact risk of subsequent readmissions-specifically if similar in nature to the etiology of the index admission. These actions may represent opportunities to mitigate future hospitalizations. There are expectations for hospitals to adequately manage acute medical and surgical problems prior to discharge and for the patient to be safely cared for within the community with appropriate outpatient services. Multiple hospitalizations can therefore be considered a reflection of poor quality of care or inadequate coordination of community and hospital services. For the patient unplanned readmissions are generally considered a poor outcome reflective of patient care such as unmanaged comorbidities, lack of reconciliation of medications or complications undetected at time of discharge or developed in the community but related to inpatient care such as stent thrombosis / re-infarction due to stent malapposition. Furthermore, from a healthcare perspective, they are a burden to healthcare providers and potentially an unnecessary cost, which diverts resources away from other hospital services.

Despite reviews of unplanned readmissions after PCI9,10 there are currently no studies of multiple readmissions after PCI. We therefore evaluated multiple unplanned readmissions within 30 days and 180 days specifically addressing rates and predictors of multiple readmissions, change in rates over time and the degree to which patients are readmitted for similar causes for first and second readmission.

**Methods**

The Nationwide Readmission Database (NRD) is a dataset produced by the Healthcare Cost and Utilization Project (HCUP), which was designed to address the lack of a nationally representative information on hospital readmissions for all ages11. The 2010 to 2014 dataset contains discharge-level hospitalization data from 21 geographically disperse states which is representative of 49.3% of all United States population and 49.1% of all U.S. hospitalizations5. Within each year, hospitalization and rehospitalization can be determined using a de identified unique patient linkage number which enables tracking of patients across hospitals within a state.

At each admission episode within the NRD there are up to 15 International Classification of Disease, Ninth-Revision (ICD-9) procedural codes. We defined the population with first admission for PCI as patients with the procedural code 0066 (PTCA OR CORONARY ATHER), 3606 (INSERT CORON ART STENT), and 3607 (INSERT DRUG ELUTING CRNRY AR).

The outcome of interest in this study was unplanned readmissions within 30 days and 180 days which were further stratified by single readmission and multiple readmissions. Patients who died during their initial hospitalization for PCI were excluded. Using methods as described previously4, the annualized design of NRD made it necessary to split the population into two groups one having 30 days of follow up (January to November within each calendar year) and 180 days of follow up (January to June within each calendar year) in order to reduce immortal time bias.

ICD-9 codes were used to defined the clinical variables for smokers, dyslipidemia, coronary artery disease, previous myocardial infarction, previous PCI, previous coronary artery bypass graft (CABG), previous stroke or transient ischemic attack (TIA), atrial fibrillation, dementia and receipt of circulatory support. Elixhauser comorbidities codes were used to define 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. In addition, the Charlson comorbidity index was derived as previously describe.12 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 further used to define in-hospital complete heart block, TIA or stroke, cardiogenic shock, cardiac arrest, bleeding, vascular complication and emergency CABG. Further data was collected on length of stay in hospital, hospital bed size, hospital location, hospital teaching status and patient discharge destination. The causes of readmissions were determined by the first diagnosis based on Clinical Classification Software codes presented in Supplementary Table 1. Full descriptions of variables in the analysis are shown in Supplementary Table 2.

Statistical analysis was performed on Stata 15 (College Station, Texas). A flow diagram was used to illustrate patient inclusion and exclusion. The trend in proportion of patients with more than one unplanned readmission within 30 days and 180 days was examined graphically. Descriptive statistics for baseline variables of the participants according to no readmission, one readmission and more than one readmission are shown in tables with the use of one-way analysis of variance to compare continuous variables and Chi2 test to compare for difference for categorical variables. The causes of first readmission among patients with more than one readmission are shown graphically and we determined the extent to which the cause of readmission was similar for the first and second readmissions. We further graphically examined the proportion of patients with 0, 1, 2, 3, 4 and 5+ readmissions in the cohort. Multiple logistic regressions with adjustments for baseline variables were used to identify variables associated with increased odds of multiple readmissions at 30 days and 180 days with no readmissions as the reference group. The cost of index and readmissions were determined by multiplying the hospital charges by the Agency for Healthcare Research and Quality’s all-payer cost-to-charge ratios for each hospital. The average cost at 30 days and 180 days were determined for patients according to number of readmissions which was graphically presented.

**Results**

A total of 2,324,194 patients were included in the analysis of 30 day unplanned readmissions and 1,327,799 patients in the analysis of 180 day unplanned readmission (Figure 1). The proportion of patients with a single readmission and multiple readmissions within 30 days were 8.5% and 1.0%, respectively. The corresponding proportions for readmissions within 180 days were 15.4% and 8.9%, respectively.

Considering trends in multiple readmissions, the rates remained static at 30 days, ranging from 1.01% to 0.98% between 2010 and 2014 (Figure 2); no major changes were observed for 180-day readmissions.

Table 1 shows the characteristics of patients at index PCI according to unplanned readmission status at 30 days. Patients who were readmitted were older (67.1 years for single readmission, 66.8 years for multiple readmissions compared to 64.6 years with no readmissions). A greater proportion of readmitted patients were female with (39.9% for single and multiple readmissions compared to 31.8% with no readmission). With respect to comorbidities, readmitted patients were more likely to be diabetic (single readmission 43.8%, multiple readmission 48.7%, no readmission 36.1%), have atrial fibrillation (single readmission 17.1%, multiple readmission 18.8%, no readmission 11.1%), peripheral vascular disease (single readmission 15.5%, multiple readmission 18.0%, no readmission 10.9%), chronic lung disease (single readmission 23.8%, multiple readmission 27.8%, no readmission 16.1%), renal failure (single readmission 22.6%, multiple readmission 27.0%, no readmission 12.7%), fluid and electrolyte disorder (single readmission 18.5%, multiple readmission 19.7%, no readmission 11.9%) and anemia (single readmission 18.4%, multiple readmission 22.1%, no readmission 10.0%). The increase in comorbidity is reflected in the greater average Charlson score of 1.2, 1.8 and 2.0 for the groups with no readmission, single readmission and multiple readmissions, respectively. The proportion of patients that were discharge to home/self-care with readmission was 88.7%, 78.1%, 77.7% for no readmission, single readmission and multiple readmissions, respectively. Table 2 shows the characteristics of patients at index PCI according to unplanned readmission status at 180 days, which shows similar trends as Table 1.

The causes for first unplanned readmissions among patients with more than one readmission at 30 and 180 days are shown in Figure 3. Patients with first readmission for coronary artery disease including angina, heart failure and acute myocardial infarction were commonly readmitted again within 30 days and 180 days. Compared to the causes for first readmission at 30-day, patients with 180 day readmissions had more first readmissions for gastrointestinal disease, infections and respiratory disease. Comparing the patient’s cause of first readmission and second readmission, 24.1% of patients had the same cause for readmissions within 30 days and the most common reason for the same cause for readmission was heart failure (18.0%), coronary artery disease including angina (16.9%) and non-specific chest pain (9.8%). At 180 days, 21.6% of patients had the same cause for first and second readmission and the three most common reasons for the same cause for readmission were coronary artery disease including angina (19.1%), heart failure (16.0%) and infections (7.9%).

Figure 4 shows the number of unplanned readmissions at 30 and 180 days. Among those patients with an unplanned readmission at 30 days, 8.5% are readmitted once while 1.0% are readmitted two or more times. Within 180 days, 15%, 5% and 3% have one, two and three or more unplanned readmissions respectively.

Tables 3 and 4 evaluate variables associated with multiple readmissions at 30 and 180 days. For 30 day multiple readmissions, the strongest factors were discharge against medical advice (OR 2.76 95%CI 2.17-3.49) followed by discharge to care home (OR 1.68 95%CI 1.55-1.84), renal failure (OR 1.65 95%CI 1.55-1.76) and liver failure (OR 1.62 95%CI 1.38-1.89) in decreasing order of strength of association. Variables associated with decreased odds of 30 day multiple readmissions included private payer (OR 0.49 95%CI 0.45-0.54), and drug eluting stent (OR 0.79 95%CI 0.75-0.84). At 180 days multiple readmissions were associated with renal failure (OR 2.03 95%CI 1.97-2.10), transfer to other hospital (OR 1.86 95%CI 1.76-1.96), discharge against medical advice (OR 1.81 95%CI 1.56-2.10) and cancer (OR 1.76 95%CI 1.61-1.93). Similar to 30 day multiple readmissions, private payers were associated with reduction in multiple readmissions at 180 days. The total cost significantly increases with a greater number of readmission (Figure 5). At 30 days, the cost increases from $20,281 for no readmissions to $62,755 for five readmissions while at 180 days the cost increases from $19,958 to $86,365 for five readmissions.

**Discussion**

Our study of multiple unplanned readmissions following PCI highlighting several novel findings. First, within 30 days 1% of patients have more than one unplanned readmission that increases to 9% at 180 days. Second, patients who have multiple readmissions tend to be older, of female gender and more comorbid compared to those who are not readmitted. Third, among patients who are readmitted multiple times, those who are readmitted once for coronary artery disease including angina, heart failure and acute myocardial infarction have the greatest proportion of multiple readmissions at 30-days and 180 days. Fourth, nearly 1 in 4 patients with multiple readmissions are readmitted for the same reason within 30 days and more than 1 in 5 have multiple readmissions for the same reason at 180 days. While the number of multiple readmissions is low at 30-days, it rises to more than 5% for 2 readmissions and 3% for 3 or more readmissions within 180 days. Finally, the total cost of multiple readmissions is significant with costs increasing from ~$20,000 for no readmission to over $60,000 at 30 days follow up and $86,000 at 180 days follow up for those patients with multiple readmissions. These findings suggest that multiple readmissions are not uncommon and have an important health economic and clinical impact to healthcare services, with a need for interventions to reduce multiple readmissions among PCI patients.

Factors associated with multiple readmissions are similar to those reported in the literature for first readmission after PCI. There are a greater proportion of readmitted patients who are of older age, female and comorbid. In addition, a strong predictor of 30 day unplanned readmission in our previous study was discharge against medical advice13 and this was an important predictor of readmission in both this 30 day and 180 multiple readmission analyses. In the longer term follow up period, cancer was a predictor of unplanned readmission. While we have excluded patients that died in hospital in our readmission analysis, our previous analysis of PCI patients revealed that patients with cancer both historically and with current cancer have poor outcomes14.

An important issue with readmissions is whether they are preventable. While there are no previous studies of preventability of multiple readmissions, a study by Wasfy et al in which medical records were reviewed independently by two physicians led to the conclusion that nearly half of all 30-day readmissions after PCI may have been prevented by changes in clinical decision making.15 They reported that the common causes for preventable readmissions were staged PCI within new symptoms (14.7%), vascular/bleeding complications of PCI (10.0%) and congestive heart failure (9.7%). In the current study, we have made efforts to eliminate staged PCI by excluding elective readmissions and we have extended the follow up beyond 30 days to 180 days. It has been suggested that categories of readmissions provide clear opportunities for care improvement in relation to preventing readmissions. For example, heart failure as a cause for first readmission is associated with further readmissions at both 30 days and 180 days and these admissions could be considered as preventable with careful titration of medications before discharge and early follow up. Additional actions that may avert subsequent heart failure admissions include review during PCI admission by heart failure specialists prior to discharge and early follow up in heart failure specialist clinics. Furthermore, it has been suggested that chest pain after PCI may have limited preventability. Nevertheless, there may be interventions that could potentially reduce readmissions including patient education videos about chest pain, instructions on seeking help, early follow up and notification systems for cardiologists for prompt input when patients return to the emergency department.

We have shown that among patients with 30 day multiple readmissions nearly 1 in 4 are readmitted for the same reason as their first admission and more than 1 in 5 are readmitted for the same reason as their first admission at 180 days. The major causes for these repeated readmissions should be targeted for interventions to reduce readmissions. To date only one study has been published demonstrating a means to reduce preventable readmission after PCI by employing a multi-intervention strategy16. During hospitalization for PCI, patients are assessed for readmission risk using a validated score, a discharge checklist is used to ensure they have access to appropriate medications and close follow up is arranged for high risk patients. In addition, this intervention involved specific patient education videos on chest discomfort and heart failure. In the outpatient space, a new follow up clinic led by cardiology fellows was established and in the emergency department, a computerized notification system was developed to notify cardiologists if patients presented to emergency department within 30 days. Together this reduced readmission from 9.6% to 5.3%. It is likely that this type of multimodal intervention may reduce multiple readmissions after PCI but it should be clear that the resource investment in implementing these interventions should not outweigh the benefits in readmission reduction.

A key issue related to readmissions is the availability of community services that may care for patients after PCI. A report by the National Association of Community Health Centers suggest that 62 million Americans have no or inadequate access to primary care due to shortage of physicians17. In addition, there is a population of Americans who live in rural areas that may find it challenging to access specialist cardiology services once discharged. A report from the American College of Cardiology has found a shortfall of cardiologists and the impact is likely to impact low income and rural communities most profoundly18. One study of visiting attending clinics has shown that outreach cardiology in Iowa can reduce average driving time to cardiologist from 42.2 to 14.7 minutes and can improve geographic access to office-based cardiology care for more than 1 million Iowans19. While more studies are needed to demonstrate that outreach programs reduce hospitalizations, it is likely that better access and integration of hospital and community services would improve patient care and potentially reduce readmissions especially in the rural population.

There are several limitations with the current study. First, a key limitation of the study is that the hospital admission cohort of PCI patients is likely to under capture low risk outpatient PCI as we have observed previously that rates of same day discharge are low.20 Therefore, the cohort studied may be sicker and be at greater risk of readmission compared to a cohort which includes low risk day case PCI patients. Secondly, the NRD cannot accommodate linkage of patients between years so it is therefore possible that patients may appear in more than one year and it is not possible to track patients across years. Third,, the NRD is not designed to allow for determination of regional differences within the dataset and seasonal effects may not be captured as we excluded patients in December and those in the last 6 months of the year. Fourth, the data is limited to discharge level records and there is no individual patient level data about medications and follow up plans once discharged. Fifth, a portion of patients those having been discharged in the month of December and those discharged between July and December had to be excluded in order to ensure that all patients had at least 30 days or 180 days for readmissions. Finally, while this is a dataset of actual clinical practice, the observational nature precludes assessment of causality and there are limitations related to unmeasured confounders.

In conclusion, multiple readmissions are rare within 30 days after PCI but increase to nearly 1 in 10 patients at 180 days. There are a greater proportion of patients who are older, female and more comorbid who have multiple readmissions and 20-25% of patients who have multiple readmissions are readmitted for the same cause for first and second readmission. More studies are needed to determine if there are interventions that may better mitigate unnecessary readmissions.

**List of Supports/Grants Information:** The study was supported by a grant from the Research and Development Department at the Royal Stoke Hospital. This work is conducted as a part of PhD for CSK which is supported by Biosensors International.

**Acknowledgements:** We are grateful to the Healthcare Cost and Utilization Project (HCUP) and the HCUP Data Partners for providing the data used in the analysis.

**Conflicts of interest disclosures:** The authors have no conflicts of interest to declare.

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**Table 1:** Characteristics of patients at index PCI admission with no readmission, single unplanned readmission and multiple readmissions within 30 days

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable | No readmission (n=2,103,697) | Single 30-day unplanned readmission (n=197,304) | Multiple readmissions (n=23,193) | p-value |
| Age (year) | 64.6±12.3 | 67.1±12.8 | 66.8±13.2 | <0.001 |
| Female sex | 31.8% | 39.9% | 39.9% | <0.001 |
| Elective admission for index PCI | 17.3% | 11.6% | 10.4% | <0.001 |
| Diagnosis of acute myocardial infarction | 51.3% | 50.6% | 49.5% | <0.001 |
| Primary expected payer  Medicare  Medicaid  Private  Self-pay  No charge  Other | 51.9%  7.2%  30.8%  5.7%  0.8%  3.7% | 63.2%  8.8%  20.1%  4.1%  0.7%  3.1% | 66.7%  11.5%  14.5%  3.8%  0.6%  3.1% | <0.001 |
| Quartile of median household income  0-25th  26-50th  51-75th  76th-100th | 28.8%  25.3%  24.0%  22.0% | 30.5%  25.5%  23.4%  20.6% | 32.7%  25.2%  23.3%  18.8% | <0.001 |
| Smoker | 41.5% | 39.1% | 40.6% | <0.001 |
| Alcohol misuse | 2.6% | 2.7% | 3.3% | <0.001 |
| Dyslipidemia | 71.7% | 68.3% | 68.0% | <0.001 |
| Hypertension | 74.4% | 77.7% | 80.3% | <0.001 |
| Diabetes | 36.1% | 43.8% | 48.7% | <0.001 |
| Obesity | 15.9% | 16.0% | 16.2% | 0.28 |
| Heart failure | 1.5% | 2.5% | 2.5% | <0.001 |
| Coronary artery disease | 94.2% | 94.0% | 94.6% | 0.060 |
| Previous myocardial infarction | 14.1% | 15.4% | 17.4% | <0.001 |
| Previous PCI | 20.8% | 21.3% | 23.1% | <0.001 |
| Previous CABG | 7.7% | 9.1% | 10.0% | <0.001 |
| Valvular heart disease | 0.5% | 0.8% | 0.8% | <0.001 |
| Atrial fibrillation | 11.1% | 17.7% | 18.8% | <0.001 |
| Previous stroke or TIA | 6.6% | 9.7% | 11.6% | <0.001 |
| Peripheral vascular disease | 10.9% | 15.5% | 18.0% | <0.001 |
| Pulmonary circulatory disorder | 0.3% | 0.5% | 0.5% | <0.001 |
| Peptic ulcer disease | 0.02% | 0.03% | 0.03% | 0.71 |
| Chronic lung disease | 16.1% | 23.8% | 27.8% | <0.001 |
| Renal failure | 12.7% | 22.6% | 27.0% | <0.001 |
| Liver disease | 1.2% | 1.8% | 2.5% | <0.001 |
| Hypothyroidism | 9.0% | 11.4% | 12.3% | <0.001 |
| Fluid and electrolyte disorder | 11.9% | 18.5% | 19.7% | <0.001 |
| Anemia | 10.0% | 18.4% | 22.1% | <0.001 |
| Cancer | 1.7% | 2.7% | 3.3% | <0.001 |
| Depression | 6.3% | 8.8% | 10.2% | <0.001 |
| Dementia | 1.8% | 3.3% | 3.5% | <0.001 |
| Charlson score | 1.2±1.4 | 1.8±1.6 | 2.0±1.7 | <0.001 |
| Hospital bed size  Small  Medium  Large | 5.8%  20.7%  73.6% | 5.0%  20.5%  74.5% | 5.1%  21.3%  73.6% | <0.001 |
| Urban hospital | 95.7% | 95.9% | 95.9% | <0.001 |
| Teaching hospital | 54.7% | 53.8% | 53.1% | <0.001 |
| Multivessel disease | 16.1% | 16.2% | 16.9% | 0.092 |
| Bifurcation lesion | 2.9% | 2.8% | 2.7% | 0.073 |
| Circulatory support | 2.9% | 4.2% | 3.7% | <0.001 |
| Vasopressor use | 0.4% | 0.6% | 0.4% | <0.001 |
| Intra-aortic balloon pump | 2.6% | 3.8% | 3.2% | <0.001 |
| Fractional flow reserve | 1.9% | 2.0% | 2.2% | 0.020 |
| Intravascular ultrasound | 7.0% | 7.0% | 6.7% | 0.30 |
| Drug-eluting stent | 74.3% | 68.3% | 66.6% | <0.001 |
| In-hospital complete heart block | 1.0% | 1.2% | 1.0% | <0.001 |
| In-hospital stroke/TIA | 3.0% | 3.8% | 3.9% | <0.001 |
| Cardiogenic shock | 2.7% | 3.9% | 3.3% | <0.001 |
| Cardiac arrest | 1.8% | 2.0% | 1.4% | <0.001 |
| In-hospital bleeding | 0.6% | 1.1% | 0.9% | <0.001 |
| In-hospital vascular complication | 0.8% | 1.1% | 0.8% | <0.001 |
| In-hospital emergency CABG | 1.3% | 1.5% | 1.1% | <0.001 |
| Length of stay | 3.7±5.3 | 4.6±4.0 | 4.3±3.2 | <0.001 |
| Discharge destination  Home/self-care  Transfer to other hospital  Care home  Discharge against medical advice | 88.7%  4.4%  6.5%  0.4% | 78.1%  8.7%  12.5% 0.7% | 77.7%  7.7%  13.4%  1.2% | <0.001 |

PCI=percutaneous coronary intervention, CABG=coronary artery bypass graft, TIA=transient ischemic attack

**Table 2:** Characteristics of patients at index PCI admission with no readmission, single readmission and multiple readmissions within 180 days

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable | No readmission (n=1,004,705) | Single 30-day unplanned readmission (n=204,878) | Multiple readmissions (n=118,216) | p-value |
| Age (year) | 64.2±12.2 | 66.7±12.7 | 67.4±12.8 | <0.001 |
| Female sex | 30.3% | 38.3% | 41.8% |  |
| Elective admission for index PCI | 18.4% | 13.7% | 12.6% |  |
| Diagnosis of acute myocardial infarction | 51.1% | 47.3% | 44.2% |  |
| Primary expected payer  Medicare  Medicaid  Private  Self-pay  No charge  Other | 49.8%  6.7%  33.2%  5.8%  0.8%  3.7% | 61.0%  8.7%  21.7%  4.5%  0.8%  3.3% | 68.9%  10.4%  14.2%  3.4%  0.6%  2.6% | <0.001 |
| Quartile of median household income  0-25th  26-50th  51-75th  76th-100th | 28.1%  25.2%  24.2%  22.5% | 30.4%  25.2%  23.5%  20.9% | 33.6%  25.2%  22.3%  18.9% | <0.001 |
| Smoker | 41.6% | 39.2% | 38.1% | <0.001 |
| Alcohol misuse | 2.5% | 2.7% | 3.0% | <0.001 |
| Dyslipidemia | 72.4% | 69.6% | 66.2% | <0.001 |
| Hypertension | 73.6% | 77.5% | 79.7% | <0.001 |
| Diabetes | 34.2% | 43.1% | 50.7% | <0.001 |
| Obesity | 15.6% | 16.2% | 16.8% | <0.001 |
| Heart failure | 1.1% | 2.6% | 4.0% | <0.001 |
| Coronary artery disease | 94.3% | 94.5% | 94.2% | 0.14 |
| Previous myocardial infarction | 13.8% | 16.0% | 17.8% | <0.001 |
| Previous PCI | 20.8% | 23.1% | 24.8% | <0.001 |
| Previous CABG | 7.4% | 9.5% | 11.2% | <0.001 |
| Valvular heart disease | 0.3% | 0.8% | 1.1% | <0.001 |
| Atrial fibrillation | 9.9% | 16.0% | 19.9% | <0.001 |
| Previous stroke or TIA | 5.8% | 9.2% | 11.8% | <0.001 |
| Peripheral vascular disease | 9.8% | 14.6% | 19.8% | <0.001 |
| Pulmonary circulatory disorder | 0.2% | 0.5% | 0.8% | <0.001 |
| Peptic ulcer disease | 0.02% | 0.03% | 0.04% | 0.14 |
| Chronic lung disease | 14.6% | 21.8% | 28.8% | <0.001 |
| Renal failure | 10.3% | 19.5% | 31.0% | <0.001 |
| Liver disease | 1.0% | 1.6% | 2.4% | <0.001 |
| Hypothyroidism | 8.5% | 10.9% | 12.0% | <0.001 |
| Fluid and electrolyte disorder | 10.3% | 16.4% | 21.9% | <0.001 |
| Anemia | 8.3% | 16.1% | 24.4% | <0.001 |
| Cancer | 1.5% | 2.5% | 3.4% | <0.001 |
| Depression | 5.8% | 8.2% | 10.0% | <0.001 |
| Dementia | 1.5% | 2.9% | 3.6% | <0.001 |
| Charlson score | 1.1±1.3 | 1.6±1.6 | 2.2±1.7 | <0.001 |
| Hospital bed size  Small  Medium  Large | 6.0%  20.7%  73.3% | 5.1%  20.2%  74.8% | 5.1%  20.2%  74.7% | <0.001 |
| Urban hospital | 95.8% | 95.9% | 96.1% | 0.002 |
| Teaching hospital | 54.9% | 54.5% | 54.8% | 0.084 |
| Multivessel disease | 16.1% | 16.6% | 16.7% | <0.001 |
| Bifurcation lesion | 2.9% | 2.9% | 2.7% | 0.041 |
| Circulatory support | 2.6% | 3.8% | 4.4% | <0.001 |
| Vasopressor use | 0.4% | 0.5% | 0.6% | <0.001 |
| Intra-aortic balloon pump | 2.4% | 3.4% | 3.8% | <0.001 |
| Fractional flow reserve | 1.8% | 1.8% | 2.0% | <0.001 |
| Intravascular ultrasound | 7.1% | 7.3% | 7.2% | 0.14 |
| Drug-eluting stent | 75.5% | 69.1% | 63.9% | <0.001 |
| In-hospital complete heart block | 0.9% | 1.1% | 1.2% | <0.001 |
| In-hospital stroke/TIA | 2.7% | 3.7% | 4.6% | <0.001 |
| Cardiogenic shock | 2.4% | 3.6% | 4.1% | <0.001 |
| Cardiac arrest | 1.6% | 1.9% | 1.9% | <0.001 |
| In-hospital bleeding | 0.5% | 0.9% | 1.4% | <0.001 |
| In-hospital vascular complication | 0.7% | 1.0% | 1.1% | <0.001 |
| In-hospital emergency CABG | 1.3% | 1.5% | 1.3% | <0.001 |
| Length of stay | 3.3±4.6 | 4.7±6.1 | 6.0±6.8 | <0.001 |
| Discharge destination  Home/self-care  Transfer to other hospital  Care home  Discharge against medical advice | 90.9%  3.3%  5.4%  0.4% | 81.3%  7.8%  10.4%  0.5% | 72.9%  11.5%  14.9%  0.7% | <0.001 |

PCI=percutaneous coronary intervention, CABG=coronary artery bypass graft, TIA=transient ischemic attack

**Table 3:** Variables associated with multiple readmissions within 30 days

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable | OR | 95%CI | | p-value |
| Age (per year) | 0.99 | 0.99 | 0.99 | <0.001 |
| Female sex | 1.18 | 1.12 | 1.25 | <0.001 |
| Diagnosis of AMI | 1.01 | 0.96 | 1.07 | 0.69 |
| Primary expected payer vs Medicare | | | | |
| Medicaid | 1.28 | 1.16 | 1.41 | <0.001 |
| Private | 0.49 | 0.45 | 0.54 | <0.001 |
| Self-pay | 0.64 | 0.55 | 0.73 | <0.001 |
| No charge | 0.84 | 0.60 | 1.18 | 0.31 |
| Other | 0.75 | 0.64 | 0.87 | <0.001 |
| Quartile of median household income vs 0-25th | | | | |
| 26th-50th | 0.90 | 0.85 | 0.97 | 0.004 |
| 51st-75th | 0.97 | 0.91 | 1.04 | 0.43 |
| 76th-100th | 0.92 | 0.86 | 1.00 | 0.044 |
| Smoker | 0.96 | 0.91 | 1.01 | 0.12 |
| Alcohol misuse | 1.28 | 1.11 | 1.47 | 0.001 |
| Dyslipidemia | 0.84 | 0.80 | 0.89 | <0.001 |
| Hypertension | 1.15 | 1.07 | 1.23 | <0.001 |
| Diabetes | 1.32 | 1.25 | 1.39 | <0.001 |
| Obesity | 0.89 | 0.83 | 0.95 | 0.001 |
| Heart failure | 0.94 | 0.77 | 1.15 | 0.52 |
| Coronary artery disease | 1.04 | 0.93 | 1.16 | 0.46 |
| Previous myocardial infarction | 1.07 | 1.00 | 1.15 | 0.036 |
| Previous PCI | 1.03 | 0.97 | 1.10 | 0.3 |
| Previous CABG | 1.15 | 1.06 | 1.25 | 0.001 |
| Vavular heart disease | 1.32 | 0.90 | 1.95 | 0.16 |
| Atrial fibrillation | 1.49 | 1.39 | 1.59 | <0.001 |
| Previous stroke or TIA | 1.23 | 1.14 | 1.33 | <0.001 |
| Peripheral vascular disease | 1.23 | 1.15 | 1.32 | <0.001 |
| Pulmonary circulatory disorder | 1.14 | 0.75 | 1.73 | 0.54 |
| Peptic ulcer disease | 0.83 | 0.26 | 2.67 | 0.76 |
| Chronic lung disease | 1.57 | 1.48 | 1.67 | <0.001 |
| Renal failure | 1.65 | 1.55 | 1.76 | <0.001 |
| Liver failure | 1.62 | 1.38 | 1.89 | <0.001 |
| Hypothyroidism | 1.10 | 1.02 | 1.18 | 0.01 |
| Fluid and electrolyte disorder | 1.25 | 1.16 | 1.34 | <0.001 |
| Anemia | 1.52 | 1.42 | 1.64 | <0.001 |
| Cancer | 1.55 | 1.34 | 1.79 | <0.001 |
| Depression | 1.41 | 1.29 | 1.54 | <0.001 |
| Dementia | 1.19 | 1.03 | 1.37 | 0.019 |
| Bed size versus small | | | | |
| Medium | 0.98 | 0.84 | 1.14 | 0.78 |
| Large | 0.97 | 0.84 | 1.12 | 0.66 |
| Urban hospital | 1.14 | 1.00 | 1.31 | 0.059 |
| Teaching hospital | 0.92 | 0.87 | 0.97 | 0.003 |
| Multivessel | 1.07 | 1.00 | 1.14 | 0.049 |
| Bifurcation | 0.99 | 0.84 | 1.16 | 0.87 |
| Circulatory support | 1.21 | 0.87 | 1.68 | 0.27 |
| Vasopressor use | 0.98 | 0.63 | 1.52 | 0.94 |
| Intra-aortic balloon pump | 1.14 | 0.80 | 1.64 | 0.46 |
| Fractional flow reserve | 1.10 | 0.91 | 1.32 | 0.31 |
| Intravascular ultrasound | 0.97 | 0.87 | 1.08 | 0.59 |
| Drug eluting stent | 0.79 | 0.75 | 0.84 | <0.001 |
| In-hospital complete heart block | 0.86 | 0.66 | 1.12 | 0.26 |
| In-hospital stroke/TIA | 0.97 | 0.85 | 1.11 | 0.65 |
| Cardiogenic shock | 1.03 | 0.86 | 1.24 | 0.72 |
| Cardiac arrest | 0.75 | 0.60 | 0.95 | 0.017 |
| In-hospital bleeding | 0.98 | 0.76 | 1.26 | 0.85 |
| In-hospital vascular complication | 0.83 | 0.63 | 1.08 | 0.16 |
| In-hospital emergency CABG | 0.62 | 0.49 | 0.78 | <0.001 |
| Length of stay | 0.96 | 0.95 | 0.97 | <0.001 |
| Discharge location vs home/self-care | | | | |
| Transfer to other hospital | 1.37 | 1.22 | 1.55 | <0.001 |
| Care home | 1.68 | 1.55 | 1.84 | <0.001 |
| Discharge against medical advice | 2.76 | 2.17 | 3.49 | <0.001 |

CABG=coronary artery bypass graft, TIA=transient ischemic attack

**Table 4:** Variables associated with multiple readmissions within 180 days

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable | OR | 95%CI | | p-value |
| Age (per year) | 0.99 | 0.99 | 0.99 | <0.001 |
| Female sex | 1.29 | 1.25 | 1.32 | <0.001 |
| Diagnosis of AMI | 0.82 | 0.80 | 0.85 | <0.001 |
| Primary expected payer vs Medicare | | | | |
| Medicaid | 1.22 | 1.16 | 1.28 | <0.001 |
| Private | 0.48 | 0.46 | 0.50 | <0.001 |
| Self-pay | 0.62 | 0.58 | 0.66 | <0.001 |
| No charge | 0.72 | 0.62 | 0.84 | <0.001 |
| Other | 0.64 | 0.59 | 0.69 | <0.001 |
| Quartile of median household income vs 0-25th | | | | |
| 26th-50th | 0.87 | 0.84 | 0.90 | <0.001 |
| 51st-75th | 0.88 | 0.84 | 0.91 | <0.001 |
| 76th-100th | 0.88 | 0.84 | 0.91 | <0.001 |
| Smoker | 0.92 | 0.90 | 0.95 | <0.001 |
| Alcohol misuse | 1.25 | 1.15 | 1.36 | <0.001 |
| Dyslipidemia | 0.78 | 0.76 | 0.81 | <0.001 |
| Hypertension | 1.08 | 1.05 | 1.12 | <0.001 |
| Diabetes | 1.47 | 1.43 | 1.51 | <0.001 |
| Obesity | 0.93 | 0.90 | 0.96 | <0.001 |
| Heart failure | 0.96 | 0.87 | 1.06 | 0.46 |
| Coronary artery disease | 0.97 | 0.91 | 1.03 | 0.35 |
| Previous myocardial infarction | 1.14 | 1.10 | 1.18 | <0.001 |
| Previous PCI | 1.17 | 1.13 | 1.21 | <0.001 |
| Previous CABG | 1.26 | 1.21 | 1.32 | <0.001 |
| Vavular heart disease | 1.11 | 0.94 | 1.30 | 0.22 |
| Atrial fibrillation | 1.52 | 1.46 | 1.57 | <0.001 |
| Previous stroke or TIA | 1.37 | 1.32 | 1.43 | <0.001 |
| Peripheral vascular disease | 1.37 | 1.33 | 1.42 | <0.001 |
| Pulmonary circulatory disorder | 1.00 | 0.82 | 1.23 | 0.99 |
| Peptic ulcer disease | 0.85 | 0.44 | 1.65 | 0.63 |
| Chronic lung disease | 1.68 | 1.63 | 1.73 | <0.001 |
| Renal failure | 2.03 | 1.97 | 2.10 | <0.001 |
| Liver failure | 1.51 | 1.38 | 1.66 | <0.001 |
| Hypothyroidism | 1.04 | 1.00 | 1.08 | 0.066 |
| Fluid and electrolyte disorder | 1.24 | 1.19 | 1.28 | <0.001 |
| Anemia | 1.58 | 1.52 | 1.64 | <0.001 |
| Cancer | 1.76 | 1.61 | 1.93 | <0.001 |
| Depression | 1.35 | 1.29 | 1.42 | <0.001 |
| Dementia | 1.17 | 1.09 | 1.27 | <0.001 |
| Bed size versus small | | | | |
| Medium | 1.05 | 0.94 | 1.16 | 0.4 |
| Large | 1.06 | 0.96 | 1.16 | 0.28 |
| Urban hospital | 1.20 | 1.12 | 1.29 | <0.001 |
| Teaching hospital | 0.96 | 0.93 | 0.99 | 0.021 |
| Multivessel | 1.03 | 0.99 | 1.06 | 0.11 |
| Bifurcation | 0.92 | 0.85 | 1.00 | 0.043 |
| Circulatory support | 1.06 | 0.88 | 1.29 | 0.54 |
| Vasopressor use | 0.96 | 0.78 | 1.18 | 0.71 |
| Intra-aortic balloon pump | 1.16 | 0.94 | 1.43 | 0.17 |
| Fractional flow reserve | 1.15 | 1.05 | 1.26 | 0.003 |
| Intravascular ultrasound | 1.02 | 0.97 | 1.07 | 0.37 |
| Drug eluting stent | 0.68 | 0.66 | 0.70 | <0.001 |
| In-hospital complete heart block | 0.94 | 0.83 | 1.06 | 0.3 |
| In-hospital stroke/TIA | 0.99 | 0.92 | 1.05 | 0.67 |
| Cardiogenic shock | 0.89 | 0.81 | 0.97 | 0.009 |
| Cardiac arrest | 0.69 | 0.63 | 0.76 | <0.001 |
| In-hospital bleeding | 1.26 | 1.10 | 1.45 | 0.001 |
| In-hospital vascular complication | 0.89 | 0.78 | 1.01 | 0.07 |
| In-hospital emergency CABG | 0.43 | 0.38 | 0.49 | <0.001 |
| Length of stay | 1.02 | 1.02 | 1.02 | <0.001 |
| Discharge location vs home/self-care | | | | |
| Transfer to other hospital | 1.86 | 1.76 | 1.96 | <0.001 |
| Care home | 1.76 | 1.69 | 1.84 | <0.001 |
| Discharge against medical advice | 1.81 | 1.56 | 2.10 | <0.001 |

CABG=coronary artery bypass graft, TIA=transient ischemic attack

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



**Figure 2:** Trends in proportion of patients with multiple unplanned readmissions at 30 days and 180 days

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**Figure 3:** Frequent causes of first unplanned readmission among patients with more than one readmission at 30 days and 180 days follow up

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**Figure 4:** Number of unplanned readmissions at 30 and 180 days

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**Figure 5:** Cost of unplanned readmissions at 30 and 180 days



**Supplementary Table 1:** Classification of Clinical Classifications Software (CCS) 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 | Human Immunodeficiency Virus (HIV) infection |
| 6 | Hepatitis |
| 7 | Viral infection |
| 8 | Other infection |
| 9 | Sexually transmitted infection |
| 76 | Meningitis |
| 77 | Encephalitis |
| 78 | Other central nervous system 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; placental abruption; 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 |
| Transient ischemic attack/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 | 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, 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 |
| 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 GI 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 | Leukemia |
| 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 |
| Ophthalmology 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 |
| 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:** Sources for data

|  |  |  |
| --- | --- | --- |
| Variable | Data source | Codes |
| PCI | ICD-9 procedural codes | 0066 3606 3607 |
| Age | NRD dataset | AGE |
| Female sex | NRD dataset | SEX |
| Elective admission for index PCI | NRD dataset | ELECTIVE |
| Diagnosis of acute myocardial infarction | Primary ICD-9 diagnostic codes | 410\*1 4111 |
| Primary expected payer | NRD dataset | PAY1 |
| Quartile of median household income | NRD dataset | ZIPINC\_QRTL |
| Smoker | ICD-9 diagnostic codes | V1582 305.1 |
| Alcohol misuse | AHRQ comorbidity software | cm\_alchol |
| Dyslipidemia | ICD-9 diagnostic codes | 272.0/272.4 |
| Hypertension | AHRQ comorbidity software | cm\_htn\_c |
| Diabetes | AHRQ comorbidity software | cm\_dm cm\_dmcx |
| Obesity | AHRQ comorbidity software | cm\_obese |
| Heart failure | AHRQ comorbidity software | cm\_chf |
| Coronary artery disease | ICD-9 diagnostic codes | 414.00/414.07 |
| Previous myocardial infarction | ICD-9 diagnostic codes | 412 |
| Previous PCI | ICD-9 diagnostic codes | V4582 |
| Previous CABG | ICD-9 diagnostic codes | V4581 |
| Valvular heart disease | AHRQ comorbidity software | cm\_valve |
| Atrial fibrillation | ICD-9 diagnostic codes | 42731 |
| Previous stroke or TIA | ICD-9 diagnostic codes | V1254 438\* |
| Peripheral vascular disease | AHRQ comorbidity software | cm\_perivasc |
| Pulmonary circulatory disorder | AHRQ comorbidity software | cm\_pulmcirc |
| Peptic ulcer disease | AHRQ comorbidity software | cm\_ulcer |
| Chronic lung disease | AHRQ comorbidity software | cm\_chrnlung |
| Renal failure | ICD-9 diagnostic codes | 584\* |
| Liver disease | AHRQ comorbidity software | cm\_liver |
| Hypothyroidism | AHRQ comorbidity software | cm\_hypothy |
| Fluid and electrolyte disorder | AHRQ comorbidity software | cm\_lytes |
| Anemia | AHRQ comorbidity software | cm\_anemdef |
| Cancer | AHRQ comorbidity software | cm\_tumor cm\_mets cm\_lymph |
| Depression | AHRQ comorbidity software | cm\_depress |
| Dementia | ICD-9 diagnostic codes | 290\* 2941\* 2942\* 2948 3310/3312 33182 797 |
| Hospital bed size | NRD dataset | HOSP\_BEDSIZE |
| Urban hospital | NRD dataset | HOSP\_LOCATION |
| Teaching hospital | NRD dataset | HOSP\_LOCTEACH |
| Multivessel disease | ICD-9 procedure codes | 0041 0042 0043 0046 0047 0048 |
| Bifurcation lesion | ICD-9 procedure codes | 0044 |
| Circulatory support | ICD-9 procedure codes | 3761 3768 3965 |
| Vasopressor use | ICD-9 procedure codes | 0017 |
| Intra-aortic balloon pump | ICD-9 procedure codes | 3761 |
| Fractional flow reserve | ICD-9 procedure codes | 0059 |
| Intravascular ultrasound | ICD-9 procedure codes | 0024 |
| Drug-eluting stent | ICD-9 procedure codes | 3607 |
| In-hospital complete heart block | ICD-9 diagnostic codes | 4260 |
| In-hospital stroke/TIA | ICD-9 diagnostic codes | 431 433\*1 434\*1 435\* 4336\* 99701 |
| Cardiogenic shock | ICD-9 diagnostic codes | 78551 |
| Cardiac arrest | ICD-9 diagnostic codes | 4275 |
| In-hospital bleeding | ICD-9 diagnostic codes/procedural codes | 4590\* 56881 5789\* V582\* 431\* 4329\* (diagnostic)  9900 (procedure) |
| In-hospital vascular complication | ICD-9 diagnostic codes | 4470 86604 900/904 9977 998 9992 |
| In-hospital emergency CABG | ICD-9 procedural code | 361\* 3620 3632 369\* |
| Length of stay | NRD dataset | LOS |
| Discharge destination | NRD dataset | DISPUNIFORM |