

Review of early hospitalization after percutaneous coronary intervention

Short running title: Early hospitalization after PCI

Chun Shing Kwok,^{1,2} William Hulme,³ Ivan Olier,¹ Eric Holroyd,² Mamas A Mamas^{1,2,3}

1. Keele Cardiovascular Research Group, Keele University, Stoke-on-Trent, UK and University Hospital North Staffordshire, Stoke-on-Trent, UK.

"This author takes responsibility for all aspects of the reliability and freedom from bias of the data presented and their discussed interpretation"

2. University of Manchester, Manchester, UK.

"This author takes responsibility for all aspects of the reliability and freedom from bias of the data presented and their discussed interpretation"

3. Keele Cardiovascular Research Group, Keele University, Stoke-on-Trent, UK.

"This author takes responsibility for all aspects of the reliability and freedom from bias of the data presented and their discussed interpretation"

4. University Hospital North Staffordshire, Stoke-on-Trent, UK.

"This author takes responsibility for all aspects of the reliability and freedom from bias of the data presented and their discussed interpretation"

5. Keele Cardiovascular Research Group, Keele University, Stoke-on-Trent, UK, University Hospital North Staffordshire, Stoke-on-Trent, UK and University of Manchester, Manchester, UK.

"This author takes responsibility for all aspects of the reliability and freedom from bias of the data presented and their discussed interpretation"

Correspondence to:

Chun Shing Kwok, MBBS, MSc, BSc

Keele Cardiovascular Research Group,

Guy Hilton Research Centre,

Thornburrow Drive, Hartshill, Stoke-on-Trent

ST4 7QB United Kingdom

Telephone: +44(0)178267653

Fax: +44 (0)1782 674467

Acknowledgement: We thank the North Staffs Heart Committee for supporting this research.

Conflicts of interest disclosures: The authors report no relationships that could be construed as a conflict of interest.

Keywords: percutaneous coronary intervention; coronary angioplasty; coronary revascularization; readmission; hospitalization

Word count: 3,479

Abstract

Percutaneous coronary intervention (PCI) is the commonest modality of revascularization in patients with coronary artery disease. Data suggests that 30-day readmissions are not uncommon. The rate of readmission after PCI is highly influenced by the cohort and the healthcare system studied, with 30-day readmission rates reported between 4.7-15.6%. Understanding the reasons for readmission is important because it is a quality of care indicator, in addition to being a burden to patients and healthcare services. Studies consistently report that majority of readmissions within 30 days are due to a cardiac related disorders or complication related. While there are many predictors of readmissions it is not known whether any of the modifiable predictors could have prevented the readmission. This review aims to evaluate readmission rates, causes and predictors in the current literature. Furthermore, we explore the cohort inclusion criteria and patient characteristics to better understand the variation in reported readmission rates and causes across different studies.

Keywords: percutaneous coronary intervention; coronary angioplasty; coronary revascularization; readmission; hospitalization

Highlights

- The rate of 30-day readmission after PCI has been reported between 4.7-15.6%.
- The rate is highly influenced by the cohort and the healthcare system studied.
- Majority of readmissions within 30 days are cardiac related.
- There are many predictors of readmission following PCI.
- It is unclear whether targeting patients with predictors could reduce readmissions.

Introduction

Percutaneous coronary intervention (PCI) is the most common form of revascularization undertaken in patients with coronary disease in both the elective and acute setting, accounting for 3.6% of all operating room procedures in USA in 2011.[1] In 2007-2008 in USA, 3,667 PCI were performed per million adults per year.[2] The growth of PCI is a global phenomenon that has been observed in other countries. PCIs performed in the UK have more than doubled over the last decade from over 44,000 procedures in 2002 to over 92,000 in 2013 and the numbers have levelled off since.[3] In Europe, PCI has increased from 184,000 procedures to 733,000 between 1992 to 2003.[4] The rise has also been observed in other countries such as India,[5] China[6] and Japan.[7] With the growth PCI, there has been recent concerns about the common problem of post-procedural hospital readmissions.[8]

Understanding the nature and impact of readmissions is important because of its burden to patients and healthcare services. Hospital readmissions are an indicator of quality of care[9] since they may result from actions taken or omitted during the initial hospital stay.[10] Readmission may be a consequence of incomplete treatment, poor quality care or may reflect poor coordination of services at the time of discharge or during ongoing care.[11,12] Unplanned readmissions can be considered an adverse outcome for patients. Patients may be hospitalised because of complications related to their PCI procedure or in-hospital management. Recognised complications related to the PCI procedure include contrast-induced nephropathy, thrombotic complications and major bleeding.[13,14] Coronary stent implantation during PCI requires dual antiplatelet therapy post procedure which increase the propensity to bleed and may directly contribute to gastrointestinal or intracranial hemorrhage.[15,16] Furthermore, readmissions are costly to healthcare services. In the USA, the Affordable Care Act creates financial penalties for hospitals that have risk

adjusted readmission rates for specific conditions exceeding specific benchmarks.[17] In the USA 20% of Medicare patients are readmitted within 30 days with an associated cost estimated at \$17 billion.[18] The UK government has made a commitment to ensure hospitals are responsible for patients not just during their treatment but also for the 30 days after they are discharged and the hospital will not receive any additional payment for treatment if patients are readmitted within 30 days.[19]

This literature review highlights the current evidence on readmissions after PCI. In particular we will focus on the evidence surrounding early readmission among studies of PCI patients.

Early admissions after PCI

Early readmission after PCI is a more robust marker of quality of care and overall outcome when compared to late readmission. The association with the initial PCI weakens with time, as other confounding variables increasingly influence hospital admission. Table 1 shows a summary of the studies which are described in the manuscript.

Curtis et al conducted the first studies evaluating early admission after PCI in 2005. This study included 315,241 Medicare patients from 1,108 US hospitals. The all-cause 30-day readmission rate was 14.6%.[20] The readmission rates for individual hospitals ranged from 8.9% to 22.0%. Interestingly, the study identified the 10 most frequent diagnostic codes for readmission and report that one-fifth of the cohort returned because of an acute cardiovascular condition, such as acute myocardial infarction, unstable angina, arrhythmia or heart failure. Chronic ischemic heart disease, chest pain and acute cardiovascular conditions together account for 54.7% of all readmissions.

These results must be interpreted in the context of the study cohort. First, the Medicare database is limited to patients older than 65 years and consequently younger, and possibly lower risk patients, were not included. Secondly, hospitals which performed fewer than 50 PCI cases in 2005 were excluded meaning only more experienced operating sites were included. However, the authors did perform an analysis of readmission rates according to different volume of PCI (≤ 200 , 201 to 400 and >400) and it was consistently 14%. Nevertheless, there is evidence elsewhere of cut-off effects where low PCI volumes are associated with inferior clinical outcomes.[21] The authors reported many key differences between those patients readmitted within 30 days and patients that did not experience readmission. Patients who were readmitted were older, more likely to be female and have diabetes, heart failure, renal failure and prior ischemic heart disease. The mortality rate in patients readmitted was greater at 30 days compared to those who did not experience readmission (3.3% vs 0.6%). A total of 30.5% of patients in the cohort had a diagnosis of acute myocardial infarction at baseline and these patients had significantly higher readmission rates (17.5%) compared to those without this diagnosis (13.6%).

Hannan et al retrospectively evaluated 30-day readmissions among patients in the New York State PCI registry in 2007.[22] Analysis of 40,093 patients, recorded that 15.6% (n=6,254) of patients were readmitted within 30 days and 20.5% (n=1,285) out of the 6,254 total readmissions had staged procedures. Excluding these staged procedures readmission rate was 12.4% (n=4,969). This study also reported that patients who underwent PCI for acute myocardial infarction had greater 30-day readmission rates than those who underwent PCI for elective indications (17.3% vs 15.4% respectively). In terms of causes of readmission, out of the 4,969 patients who were readmitted without a staged PCI, 58.0% (n=2,883) had a cardiac diagnosis for readmission. There are a few important considerations for this cohort. This cohort had very low rates of in-hospital mortality of 0.49% (n=195).

This may be explained by the observation that nearly half the cohort (48%) was aged less than 65 years old, a group excluded from the Curtis et al study. With a large cohort of young patients, the rates of acute myocardial infarction at index presentation was nearly half that of Curtis's study (17.3%, n=863). The study identified many predictors of 30-day readmissions including: age greater than 65 years, female gender, reduced ejection fraction and triple vessel disease, and a number of comorbidities including: peripheral vascular disease, COPD, diabetes and renal failure. Prolonged length of stay was also associated with increased odds of readmission.

Khawaja et al studied 30-day readmission rates after PCI. Out of a total of 15,498 cases of PCI between 1998 to 2008 in the Rochester, USA[23] 30-day readmission rates were 9.4% which was highest for emergency procedures (13.8%), then urgent procedures (10.8%) and least for elective procedures (8.0%). More than two thirds of participants readmitted within 30 days were readmitted because of cardiac causes. This was not defined by the study. This study also looked at the prognostic impact of readmission within 30 days and found that it was associated with significantly higher mortality at 1 year.

Compared to the other studies, the study by Khawaja et al had more in-depth analyses of factors that contributed to readmissions. This study included a unselected cohort with 289 (1.8%) in-hospital deaths before initial discharge and there were many independent predictors of re-admissions including female sex (OR 1.32; 95% CI 1.17-1.48), medicare insurance (OR 1.20; 95% CI 1.01-1.43), less than a high school education (OR 1.35; 95% CI 1.17-1.55), congestive heart failure at presentation (OR 1.36; 95% CI 1.15-1.60), CVA/TIA (OR 1.22; 95% CI 1.04-1.44), moderate to severe renal disease (OR 1.46; 95% CI 1.12-1.89), COPD (OR 1.31; 95% CI 1.12-1.54), peptic ulcer disease (OR 1.29; 95% CI 1.05-1.59), metastatic cancer (OR 1.92; 95% CI 1.19-3.09) and length of stay >3 days (OR 1.59; 95% CI 1.37-1.85). These findings reveal the strong influence of comorbidity on readmission rates but

there is no consideration of the effect of combinations of comorbidities and severity of the comorbidities. This study was limited because it did not define the readmission diagnoses aside from 69% for cardiac-related reasons.

Another important factor not considered in this 10-year study was how changes in practice over time might have influenced readmissions. We would expect that over the course of one year in the Curtis and Hannan studies there would not be major changes in practice. However, over a ten-year period one can expect significant changes in operator techniques / practice, clinical demographics of the patients undergoing PCI, equipment and stent platforms used, techniques and pharmacology that all might contribute to readmission rates.

The Guthrie Health Off-label Stent (GHOST) Registry was used as a single-centre study to evaluate early readmissions after PCI in a rural tertiary care setting.[24] This study between 2001 and 2009 evaluated 5,706 patients and the in-hospital mortality rate was 1.7%. Early readmission occurred in 11.4% (n=486) of all patients and 75% (n=366) of all readmission returned for cardiac reasons such as unstable angina, myocardial infarction, repeat revascularization and heart failure. There was no explanation of what defined non-cardiac early readmissions. Unlike other studies, patients with a diagnosis of myocardial infarction at index PCI did not have an increased risk of readmission (45% vs 42%) and this applied for both NSTEMI (24% vs 22%) and STEMI (21% vs 20%). However, non-elective cases were predictive of readmission (72% vs 62%). This study found that mortality rates at one year were significantly higher with 30-day readmission (aHR 2.2; 95% CI 1.4-3.4) but this was the first study to consider one-year major adverse cardiovascular outcome which was also significantly higher (aHR 2.2; 95% CI 1.8-2.8).

Again there were detailed analyses of the association between patient and procedural variables and readmissions. Patients who had readmissions were more likely to be female and had lower body surface area. Comorbidities also had a strong association with readmissions in the cohort as diabetes, cerebrovascular disease, peripheral vascular disease, and previous myocardial infarction were more prevalent in patients re-admitted. Several key angiographic variables were further identified as predictors of readmission including AHA type C lesions, lesion length >28 mm, left ventricular ejection fraction <40% and intra-aortic balloon pump use. This study built on existing studies by evaluating the influence of medical therapy at time of hospital discharge, with aspirin <325 mg (18% vs 14%) and proton pump inhibitor (36% vs 27%) the only drugs associated with greater readmission rates. Similar to the study of Khawaja et al, readmissions were strongly associated with all one-year outcomes of death (7.9% vs 3.2%), myocardial infarction (5.1% vs 2.2%), stent thrombosis (2.8% vs 0.8%) and major adverse cardiovascular events (18% vs 9.7%).

Meadows et al conducted a study of administrative claims in a large US managed care plan that included 30-day readmissions after PCI in 2006.[25] Out of the 6,687 commercially insured patients, 744 (11.1%) recorded an all-cause readmission within 30 days. Nearly half of all admissions were for revascularization procedures (47.6%) and 27.4% had other non-cardiovascular-related hospitalizations.

A more recent American study was published by Wasfy et al, who evaluated readmissions between 2007 to 2011 in 2 hospitals.[8] A total of 9081 patients were included, with 2.2% (n=207) dying during index admission and 893 (9.8%) readmitted within 30 days of discharge. The most common cause for readmission was chest pain (38.1%) and 6.6% of patients returned for staged PCI procedure and 2.5% returned for elective CABG. Several other key reasons were reported including congestive heart failure (5.9%), vascular/bleeding complication of PCI (4.4%), gastrointestinal hemorrhage (3.1%) and stent thrombosis (2.5%).

The cohort had proportionally few elective procedures (18.7%) and access site was predominantly femoral (85.6%). In addition, this study was able to assess whether or not patients were readmitted to the index hospital that undertook the PCI and the reason of readmission. The most common cause for readmission to the same hospital was related to chronic ischemic heart disease (31%). The commonest reason for readmission to non-index hospital was heart failure (13.8%). The next most common cause for admission was symptoms involving respiratory system and other chest symptoms (11%). The high rates of respiratory and other chest symptoms may be due to the higher reported prevalence of COPD (20.7%) in this cohort compared to other cohorts studied (Hannan 6.1%, Khawaja 11%).

Yost et al conducted a study of 3,255 patients who underwent PCI in the American College of Cardiology National Cardiovascular Data Registry.[26] They reported that 30-day readmission rate was 8.0% which can be broken down into 11.9% that had complications related to PCI, 35.6% had non-PCI cardiac causes for readmission, 13% had noncardiac cause for readmission and 39.5% had an admission unrelated to the index admission. The study also found that the independent predictors of 30-day readmission were female sex, advanced age, peripheral vascular disease, prior valvular surgery and PCI complications during index procedure.

Only two studies evaluated early readmissions outside of North America. Moretti et al conducted a study of patients in an Italian cohort who underwent PCI between 2009 and 2011.[27] Their study of 1,192 patients recorded very low readmission rates of 4.7% (n=53) of which 47% of the total readmissions (n=25) were for acute coronary syndromes or heart failure. This is a smaller study compared to previous studies, which may explain why only a few independent predictors of readmission were identified. Age, ejection fraction, diagnosis of acute coronary syndrome, left main disease with implant of stent and periprocedural myocardial infarction were independent predictors of 30-day cardiac readmission. There

were also higher rates of adverse events at 30 days in the readmission group including myocardial infarction (6% vs 0%), PCI (60% vs 0.6%). Out of all readmissions, 10 were staged PCI or staged cardiac surgery that means after excluding these cases the readmission rate is even lower (3.6%). The other study, by Przybysz et al, studied outcomes at a Polish centre between 2008 and 2009.[28] The in-hospital mortality rate was 2% (n=40) and a total of 1897 patients were included in the analysis of which 277 (14.6%) were readmitted at 30 days. The readmitted group was older (67.5 vs 65.3 years) and with a greater prevalence of congestive heart failure (27.8% vs 18.6%) and chronic renal insufficiency (9.4% vs 4.6%). Readmitted patients were also more likely to die at 30 days (3.6% vs 0.3%).

Predictors of readmission

Seven of the include studies described independent predictors of readmission (Table 3a). A few of the predictors were reported in more than one studies and these were pooled in meta-analysis. The results suggest that female sex, peripheral vascular disease, peripheral vascular disease, diabetes mellitus, renal failure and non-elective PCI were predictive of readmission (Table 3b).

Mortality among patients who have early readmission compared to no readmission

Five of the include studies describe mortality associated with patients who had early readmission compared to those who were not readmitted (Table 4). All the studies suggest greater risk of mortality among patients with readmission.

Discussion

The published evidence suggests that 30-day readmission following PCI is important because it is common and is associated with poor outcome. The rate depends on the population studied. The risk profile of the cohort studies is important, as the prevalence of high-risk cases, such as acute coronary syndrome, will affect readmission rates. In addition, there are other more complex factors, such as proportion of older patients and the prevalence of comorbidities influencing the propensity of a patient to be readmitted within 30 days. Furthermore, the processes of care and availability of alternatives to PCI may affect rates of readmission, as different centres may have different thresholds for managing patients conservatively or undertaking PCI or different protocols for referral for coronary bypass. The variation in processes of care is not captured or considered in many studies.

The causes of readmissions are shown in Table 2. They can be divided into cardiac and non-cardiac causes for readmission. We observed variation in the frequency of these causes across each study. We believe this reflects differences in the population studied in terms of factors which influence readmission. However, most studies reported that cardiac causes represent the most common reason for readmission.

The potential reasons for post PCI hospitalisation can be divided into hospital factors, patient factors, pre-existing disease factors, procedural factors and medication related factors and these have been explored in PCI and non-selected elderly cohorts. In terms of hospital factors, lack of documented patient or family education and previous admission within 30 days was associated with increased readmission in a non-selected elderly cohort.[29] For patient factors, Aggarwal et al conducted a study of PCI patients and found a higher readmission rate for patients who were age 65 years or greater, female gender, Medicaid insurance, low median income for zip code and metropolitan areas.[30] The finding that low

income was associated with greater readmission has been also reported in non-selected cohorts.[31] The influence of comorbidities on readmissions has been demonstrated by several PCI studies with diabetes,[32] renal failure,[32,33] chronic obstructive pulmonary disease[33] and hypertension[32,34] associated with greater risk of readmissions. In non-selected elderly studies, readmission is associated with number of comorbidities and having depression.[29,35] The PCI procedure itself can lead to complications such as coronary dissection,[36] coronary perforation,[37] major bleeding,[13] stent thrombosis,[38] stroke,[15] radial artery occlusion[39] and contrast nephropathy[40] and some of these complications may lead to readmission. Medication related factors can also affect readmission as there is increased risk of readmission with any medication dosage change in the 48 hours prior to discharge.[41] Secondary prevention medications after PCI might reduce chest pain and re-infarction but carry side effects. For example, dual antiplatelet drugs can increase the propensity to bleed and cause admissions related to bleeding complications.[42] Use of beta-blockers and ACE inhibitors can low blood pressure and cause postural hypotension that may result in admissions for falls in the elderly.[43]

Stent thrombosis is one of the feared complications following PCI as mortality after this complication may be as high as 45%.[44] The pathophysiology of stent thrombosis involves stent mal-apposition to the vessel wall with subsequent platelet adhesion, activation and thrombus formation.[38] As time progresses after stent implantation, endothelial cells cover the stent and the need for dual antiplatelet inhibition decreases, particularly for contemporary thin walled platforms, with rapid drug elution where dual antiplatelet therapy can be discontinued earlier than previously.[45] Cytostatic drugs in drug eluting stents reduce smooth muscle growth thereby reducing intimal hyperplasia and restenosis, but may also inhibit endothelialisation as well as causing inflammatory and hypersensitivity reactions that all contribute to a pro-thrombotic environment.[46] Clinical factors associated with stent

thrombosis includes procedure and lesion related parameters (e.g. coronary dissection, slow flow, stent mal-apposition, under-expansion of stent), patient characteristics (e.g. diabetes, advanced age, high platelet reactivity) and antiplatelet therapy (inadequate intensity of therapy, non-compliance, clopidogrel resistance and premature cessation of antiplatelet therapy).[38] As a result optimisation of stent results and optimal antiplatelet therapy is of crucial importance in preventing stent thrombosis, although some patients have impaired response to antiplatelet therapy[47] and cessation of dual antiplatelet therapy is linked to stent thrombosis.[48]

Our review includes nationwide or multicentre cohorts, which can account for the variation and provide a balanced overall risk profile. However, these studies have not considered the readmission rates at the hospital-level and there may be patterns in hospitals that increase the likelihood of readmissions, such as those with low volume of procedures and the proportion of procedures undertaken by trainees. There were a few single hospital studies that are more likely to provide uniformity of delivered care with a cohort that has a more consistent risk profile. The cause of readmission is just as important as being aware that patients are being readmitted, as some readmissions may be predictable and avoidable, while others may not; our review of the literature suggests that the majority of readmissions are for cardiac problems. In centres where most cases are elective day case procedures the cardiac problem may be addressed but any other existing illnesses are less likely to be managed unlike inpatient settings where a more holistic approach is taken. The majority of studies are from the United States which has a different healthcare system than that in Europe. Some of the studies are from insurance database registries that may only represent certain more affluent patients and not reflect the overall population. At the same time, patients from a system where there is both private and insurance-based healthcare is very different from one providing universal health care, such as in as the United Kingdom or France. Data derived

from centres from outside North America is limited, with only two studies reporting outcomes and the applicability of these two centre studies to practice outside of the United States is limited.

There are limited studies that evaluate measures to reduce post-PCI readmissions. First, it is clear that compliance to drug eluting stent therapy is paramount and patients should be well educated about the risks associated with discontinuation of antiplatelet therapy. Adherence to recommended guidelines regarding other secondary prevention drugs such as beta-blockers, angiotensin converting enzymes inhibitors/angiotensin II receptor blockers and statin therapy unless there is contraindication should be promoted. There is no evidence that early outpatient follow up can reduce readmissions however it makes clinical sense that high risk patients, especially those who have coronary disease which is left untreated after PCI procedure, should be followed up early. Use of cardiac monitoring post procedure may be of benefit to identify life threatening arrhythmias and echocardiographic evaluation cardiac function after PCI may be useful to identify high risk patients prior to discharge who may warrant device implantation or early follow up.

Conclusions

Readmission after PCI is common and its rate is highly influenced by the type of cohort studied. Most of the literature is based on studies derived from the United States that has a unique healthcare delivery model. It is unclear if these results are generalisable to other countries. There is clear evidence that majority of readmissions within 30 days are cardiac related. While there are many predictors of readmission following PCI, it is not known whether targeting patients with modifiable predictors could prevent or reduce the rates of readmission.

Author statement

All authors take responsibility for all aspects of the reliability and freedom from bias of the data presented and their discussed interpretation.

Contributors

Kwok CS and Mamas MA were responsible for the study design, concept and text of the manuscript. Hulme W, Olier I, Holroyd E did critical revision for important intellectual content.

Funding Sources

None.

Table 1: Description of studies

Study ID	Study design;Year;Country	No. of participants	Participant selection criteria	Rate of readmission	Top 10 causes of readmission
Curtis 2009	Retrospective cohort study; 2005; USA.	315,241	Medicare patients who underwent PCI.	30-day readmission rate: 45,964/315,241 (14.6%).	Chronic ischemic heart disease 29.2% Heart failure 9.6% Chest pain 6.7% Myocardial infarction 4.7% Arrhythmia 4.5% Pneumonia 4.5% Atherosclerosis 1.8% Procedural complication 1.7% General symptoms 1.5% Renal failure 1.4%
Hannan 2011	Retrospective cohort study; 2007; USA.	40,093	Patients in New York State PCI registry.	30-day readmission rate: 6,524/40,093 (15.6%).	Chronic ischemic heart disease 22.46% Chest pain 10.79% Heart failure 8.17% Complication as a result of previous procedure/medical care 6.98% Other noncardiac disease 6.08% Digestive system 6.08% Target vessel PCI 5.03% Respiratory system 4.69% Arrhythmias 4.33% Myocardial infarction 3.44%
Harjai 2012	Prospective cohort study; 2001-2009; USA.	4,262	Patients in the Guthrie Off-label Stent Registry.	30-day readmission rate: 486/4262 (11.4%).	Cardiac readmission 366/486 (75.3%). Noncardiac readmission 120/486 (24.7%).
Khawaja 2012	Prospective cohort study; 1998-2008; USA.	15,498	Patients who underwent PCI at St. Marys	30-day readmission rate: 1,459/15,498 (9.4%).	Cardiac readmission 1,003/1,498 (67.0%). Noncardiac readmission 495/1,498 (33.0%).

			Hospital in Rochester.		
Meadows 2012	Retrospective cohort study; 2006; USA.	6,687	Patients with ACS and PCI in a administrative claims database.	30-day readmission rate: 744/6687 (11.1%).	Non-cardiovascular readmission 41.4%. Revascularization procedure 35.5%. Other cardiovascular 14.2%. Chest pain 6.1%. Heart failure 1.7%. Stroke 1.0%.
Moretti 2015	Prospective cohort study; 2009-2011; Italy.	1,192	Patients who underwent PCI in a single center Italy.	30-day readmission rate: 53/1,192 (4.7%).	Unstable angina 11/53 (20.8%) Chest pain 7/53 (13.2%) Staged PCI 7/53 (13.2%) Heart failure 7/53 (13.2%) Myocardial infarction 4/53 (7.5%) Postinfarction angina 3/53 (5.7%) Staged cardiac surgery 3/53 (5.7%) Implantable cardioverter defibrillator implant 2/53 (3.8%) Atrioventricular block 2/53 (3.8%) Abdominal pain 2/53 (3.8%)
Przybysz-Zdunek 2012	Cohort study; 2008-2009; Poland.	2,039	Patients who underwent PCI in Poland.	30-day readmission rate: 277/2,039 (14.6%).	Cardiac problems 79.4% (44.4% stable coronary disease, 18.8% myocardial infarction and unstable angina, 9.0% congestive heart failure, 2.9% cardiac arrhythmia, 0.4% cardiac arrest, 4% other like structural heart disease and hypertension). Gastrointestinal 5.1% Cerebrovascular disease 2.2% Cancer 2.2% Diabetes and its complications 1.8% Respiratory disease 1.4% Renal insufficiency 1.1% Other 6.9%
Wasfy	Retrospective cohort	9,288	Patients who	30-day readmission	Chest pain or other symptoms concerning for angina

2014	study; 2007-2011; USA.		underwent PCI in the Partners Healthcare Hospitals in USA.	rate: 893/9,288.	<p>341 (38.1%)</p> <p>Staged PCI without new symptoms 59 (6.6%)</p> <p>Congestive heart failure 53 (5.9%)</p> <p>Vascular/bleeding complications of PCI 39 (4.4%)</p> <p>Gastrointestinal hemorrhage 28 (3.1%)</p> <p>Stent thrombosis 22 (2.5%)</p> <p>Syncope or presyncope: 22 (2.5%)</p> <p>Elective peripheral procedure or surgery not related to PCI 20 (2.2%)</p> <p>Elective CABG 19 (2.1%)</p> <p>Cholecystitis, colitis/enteritis, pancreatitis, cholangitis or abdominal pain 18 (2.0%)</p>
Yost 2013	Prospective cohort study; 2007-2010; USA.	3,255	Patients who underwent PCI in the American College of Cardiology National Cardiovascular Data Registry.	30-day readmission rate: 262/3,255.	<p>Cardiac reason for readmission related to index admission 93 (35.6%)</p> <ul style="list-style-type: none"> • Unstable angina 28 (10.7%) • Congestive heart failure 22 (8.4%) • Staged PCI 13 (5.0%) <p>PCI complication 31 (11.9%)</p> <ul style="list-style-type: none"> • In-stent thrombosis 12 (4.6%) <p>Noncardiac reason related to index admission 32 (12.2%)</p> <ul style="list-style-type: none"> • Infection/sepsis (2.3%) <p>Unrelated to index admission 105 (40.2%)</p> <ul style="list-style-type: none"> • Non-cardiac chest pain 27 (10.3%) • Gastrointestinal cause 20 (7.7%) • Infection/sepsis (3.4%) • Neurological cause 8 (3.1%)

Table 2: Causes of unplanned readmission*

Cardiac causes	Noncardiac causes
Chronic ischemic heart disease Chest pain Heart failure Arrhythmias Myocardial infarction Atherosclerosis Target vessel percutaneous coronary intervention	Complication as a result of previous procedure/medical care Digestive system Noncardiac circulatory system Respiratory system Endocrine, nutritional, and metabolic system Kidney and urinary tract Infectious and parasitic diseases Musculoskeletal system and connective tissue Cancer Injuries, poison and toxic effect of drugs Skin, subcutaneous tissue and breast Blood and blood-forming organs and immunologic disorders Other noncardiac disease

*Adapted from **Hannan EL**, Zhong Y, Krumholz H, Walford G, Holmes DR, Stamato NJ, Jacobs AK, Venditti FJ, Sharma S, King III, SB. 30-day readmission for patients undergoing percutaneous coronary interventions in New York State. *JACC Cardiovasc Interv* 2011;**4**:1335-1342.

Table 3: Predictors of readmission

Study ID	Predictors of readmission
Curtis 2009	Volume of PCI: ≤200: 14.7%, 201-400: 14.3%, >400: 14.8%. Profit status: not-for-profit: 14.7%, for profit 14.3%, governmental 14.2%. Teaching status: Council of Teaching Hospitals 15.0%, non-Council of Teaching Hospital 14.1%, nonteaching 14.6%. Speciality hospital: heart hospital 13.1%, nonspeciality hospital 14.6%.
Hannan 2011	Age >65 OR 1.02 (1.01-1.02), female OR 1.32 (1.25-1.40), ejection fraction <20% OR 2.08 (1.62-2.66), 20%-29% OR 1.31 (1.13-1.53), 30-39% OR 1.20 (1.07-1.35), ≥3 number of diseased vessels OR 1.12 (1.01-1.23), pre-procedural MI 1-14 days OR 1.16 (1.05-1.27), peripheral vascular disease OR 1.43 (1.29-1.59), malignant ventricular arrhythmia OR 1.50 (1.03-2.18), COPD OR 1.60 (1.44-1.77), diabetes OR 1.21 (1.13-1.30), renal failure creatinine 1.6-3.0 mg/dl OR 1.24 (1.12-1.37), creatinine >3.0 mg/dl OR 1.95 (1.33-2.86), dialysis OR 1.83 (1.54-2.18).
Harjai 2012	Female OR 1.44 (1.15-1.80), non-elective PCI OR 1.60 (1.26-2.04), peripheral artery disease OR 1.64 (1.22-2.20), prior myocardial infarction OR 1.31 (1.01-1.70), PCI of LAD OR 0.78 (0.62-0.98), lesion length >28mm OR 1.55 (1.16-2.07), Aspirin dose <325 mg/day OR 1.35 (1.01-1.80), PPI use OR 1.41 (1.12-1.77).
Khawaja 2012	Female OR 1.32 (1.17-1.48), medicare insurance OR 1.20 (1.01-1.43), less than high school education OR 1.35 (1.17-1.55), distance travelled (per 100 miles) OR 0.96 (0.92-0.99), MI 1-7 days OR 0.81 (0.69-0.94), CHF at presentation OR 1.36 (1.15-1.60), CVA/TIA OR 1.22 (1.04-1.44), moderate to severe renal disease OR 1.46 (1.12-1.89), COPD OR 1.31 (1.12-1.54), peptic ulcer disease OR 1.29 (1.05-1.59), metastatic cancer OR 1.92 (1.19-3.09), elective PCI OR 0.80 (0.70-0.91), procedural success OR 0.68 (0.55-0.84), length of stay OR 1.59 (1.37-1.85), PCI date (per year) OR 0.96 (0.94-0.99).
Moretti 2015	Periprocedural myocardial infarction OR 4.5 (1.1-16.8).
Przybysz-Zdunek 2012	Age OR 1.01 (1.00-1.03), congestive heart failure OR 1.52 (1.10-2.09) and chronic renal insufficiency OR 1.70 (1.04-2.79).
Yost 2013	Prior valve surgery OR 3.72 (2.16-6.40), peripheral artery disease OR 1.60 (1.16-2.21), diabetes mellitus OR 1.51 (1.16-1.97), pre-PCI left ventricular ejection fraction OR 0.94 (0.90-0.99), STEMI diagnosis OR 1.67 (1.06-2.65), NSTEMI diagnosis OR 1.80 (1.15-2.81), unstable angina diagnosis OR 1.99 (1.33-3.00) and worse lesion pre-stenosis OR 0.85 (0.76-0.98).

Table 3b: Pooled results for independent predictors of readmission

Independent predictor	No. of studies	Pooled odds ratios (95% CI)
Female sex	3	1.33 (1.26-1.39)
Pre- or peri-procedural MI	3	1.08 (0.74-1.56)
Peripheral vascular disease	3	1.46 (1.33-1.61)
Diabetes mellitus	2	1.30 (1.06-1.59)
Renal failure	3	1.54 (1.28-1.86)
Non-elective PCI	2	1.38 (1.09-1.76)

Table 4: Mortality rate for patients with early readmission vs no readmission

Study ID	Mortality rate for those readmission vs no readmission
Curtis 2009	30-day mortality for readmitted vs non-readmitted: 1,438/43,566 (3.3%) vs 1,529/254,829 (0.6%).
Harjai 2012	1 year mortality for early readmission vs no readmission: 34/428 (7.9%) vs 117/3694 (3.2%), aHR 2.12 (1.44-3.34).
Khawaja 2012	30-day readmission and 1 year mortality aHR 1.38 (1.08-1.75).
Moretti 2015	All-cause mortality for ACS/heart failure readmission vs no readmission: OR 3.3 (1.1-8.8).
Przybysz-Zdunek 2012	30-day mortality for readmitted vs non-readmitted: 10/277 (3.6%) vs 5/1,620 (0.3%).

References

1. A.J. Weiss, A. Elixhauser, R.M. Andrews, Characteristics of Operating Room Procedures in U.S. Hospitals, 2011. Health Cost and Utilization Project Statistical Brief #170, Rockville, MD: Agency for Healthcare Research and Quality. Available at: <https://www.hcup-us.ahrq.gov/reports/statbriefs/sb170-Operating-Room-Procedures-United-States-2011.jsp>
2. A.J. Epstein, D. Polsky, F. Yang, L. Yang, P.W. Groeneveld, Coronary Revascularization in the United States: 2001-2008, *JAMA*. 305 (2011) 1769-1776.
3. P.F. Ludman. BCIS Audit Returns Adult Interventional Procedures Jan 2014 to Dec 2014. Available at: http://www.bcis.org.uk/documents/BCIS_Audit_2014_07102015_for_web.pdf
4. S. Cook, M. Togni, N. Walpoth, W. Maier, V. Muehberger, V. Legrand, et al., Percutaneous coronary interventions in Europe 1992-2003, *Eurointerv*. 1 (2006) 374-379.
5. S. Ramakrishnan, S. Mishra, R. Chakraborty, K.S. Chandra, H.M. Mardikar, The report on the Indian coronary intervention data for the year 2011 – National Interventional Council, *Indian Heart J*. 65 (2013) 518-521.
6. R. Gao. Current status of percutaneous coronary intervention in China, *Heart*. 96 (2010) 415-418.
7. S. Ui, M. Chino, T. Isshiki. Rates of primary percutaneous coronary intervention worldwide, *Circ J*. 69 (2005) 95-100.
8. J.H. Wasfy, J.B. Strom, C. O'Brien, A.H. Zai, J. Luttrell, K.F. Kennedy, et al., Causes of short-term readmissions after percutaneous coronary intervention, *Circ Cardiovasc Interv*. 7 (2014) 97-103.
9. C. Fischer, H.F. Lingsma, P.J. Marang-van de Mheen, D.S. Kringos, N.S. Klazinga, E.W. Steyerberg, Is the readmission rate a valid quality indicator? A review of the evidence, *PLoS One*. 9 (2014) e112282.
10. N.I. Goldfield, E. McCullough, J.S. Hughes, et al., Identifying potentially preventable readmissions, *Health Care Financ Rev*. 30 (2008) 75-91.
11. P. Halfon, Y. Eggli, I. Pretre-Rohrbach, D. Meylan, A. Marazzi, B. Burnand, Validation of the Potentially Avoidable Hospital Readmission Rate as a Routine Indicator of the Quality of Hospital Care, *Med Care* 44 (2006) 972-981.
12. S. Kripalani, F. LeFevre, C.O. Phillips, M.V. Williams, P. Basaviah, D.W. Baker, Deficits in Communication and Information Transfer Between Hospital-Based and Primary Care Physicians, *JAMA*. 297 (2007) 831-841.
13. C.S. Kwok, S.V. Rao, P.K. Myint, B. Keavney, J. Nolan, P.F. Ludman, et al., Major bleeding after percutaneous coronary intervention and risk of subsequent mortality: a systematic review and meta-analysis, *Open Heart* 1 (2014) e00021.
14. G.N. Levine, M.J. Kern, P.B. Berger, D.L. Brown, L.W. Klein, D.J. Kereiakes, et al., Management of patients undergoing percutaneous coronary revascularization, *Ann Intern Med* 139 (2003) 123-136.
15. C.S. Kwok, E. Kontopantelis, P.K. Myint, A. Zaman, C. Berry, B. Keavney, et al., Stroke following percutaneous coronary intervention: type-specific incidence, outcomes and determinants seen by the British Cardiovascular Intervention Society 2007-12, *Eur Heart J*. 36 (2015) 1618-28.
16. C.S. Kwok, M.A. Khan, S.V. Rao, T. Kinnaird, M. Sperrin, I. Buchan, et al., Access and non-access site bleeding after percutaneous coronary intervention and risk of

- subsequent mortality and major adverse cardiovascular events: systematic review and meta-analysis, *Circ Cardiovasc Interv* 8 (2015) pii:e001645.
17. Public Law 111-148 - Patient Protection and Affordable Care Act (2010).
 18. S.F. Jencks, M.V. Williams, E.A. Coleman, Rehospitalizations among patients in the Medicare fee-for-service program, *N Engl J Med* 360 (2009) 1418-28.
 19. P. Robinson. Hospital readmissions and the 30 day threshold. A CHKS Market Intelligence Report (2010). Available at: <http://www.chks.co.uk/userfiles/files/CHKS%20Report%20Hospital%20readmissions.pdf>
 20. J.P. Curtis, G. Schreiner, Y. Wang, J. Chen, J.A. Spertus, J.S. Rumsfeld, et al., All-cause readmission and repeat revascularization after percutaneous coronary intervention in a cohort of medicare patients, *J Am Coll Cardiol* 54. (2009) 903-7.
 21. M. Rashid, M. Sperrin, P.F. Ludman, D. O'Neill, O. Nicholas, M.A. de Belder, et al., Impact of operator volume for percutaneous coronary intervention on clinical outcomes: what do the numbers say? *EHJ Qual Care Clin Outcomes*. 2 (2016) 16-22.
 22. E.L. Hannan, Y. Zhong, H. Krumholz, G. Walford, D.R. Holmes Jr, N.J. Stamato, et al., 30-day readmission for patients undergoing percutaneous coronary interventions in New York State, *JACC Cardiovasc Interv* 4 (2011) 1335-42.
 23. F.J. Khawaja, N.D. Shah, R.J. Lennon, J.P. Slusser, A.A. Alkatib, C.S. Rihal, et al., Factors associated with 30-day readmission rates after percutaneous coronary intervention, *Arch Intern Med* 117 (2012) 112-117.
 24. K.J. Harjai, M. Singh, J. Boura, Early readmissions after percutaneous coronary interventions in a rural tertiary center (from the Guthrie Health Off-Label Stent [GHOST] registry), *Am J Cardiol* 110 (2012) 491-497.
 25. E.S. Meadows, J.P. Bae, A. Zagar, T. Sugihara, K. Ramaswamy, R. McCracken, et al., Rehospitalization following percutaneous coronary intervention for commercially insured patients with acute coronary syndrome: a retrospective analysis. *BMC Res Notes*. 5 (2012) 342.
 26. C. Moretti, F. D'Ascenzo, P. Omede, F. Sciuto, D.G. Presutti, M. Di Cuia, et al., Thirty-day readmission rates after PCI in a metropolitan center in Europe: incidence and impact on prognosis, *J Cardiovasc Med*. 16 (2015) 238-245.
 27. G.W. Yost, S.L. Puher, J. Graham, T.D. Scott, K.A. Skelding, P.B. Berger, et al., Readmission in the 30 days after percutaneous coronary intervention. *J Am Coll Cardiol Interv*. 6 (2013) 237-244.
 28. B. Przybysz-Zdunek, M. Ploch, W. Pluta, M. Dada, G. Opolski, All-cause readmissions and repeat revascularization after percutaneous coronary intervention, *Cardiol J*. 19 (2014) 174-179.
 29. E.R. Marcantonio, S. McKean, M. Goldfinger, S. Kleefield, M. Yukofsky, T.A. Brennan, Factors associated with unplanned readmission among patients 65 years of age or older in a Medicare managed care plan. *Am J Med*. 107 (1999) 13-17.
 30. S. Aggarwal, V. Gupta, Demographic factors for 30 day readmission following percutaneous coronary intervention procedure: analysis of nationwide inpatient sample data, *Circulation*. 130 (2014) A15722.
 31. E.I. Williams, F. Fitton, Factors affecting early unplanned readmission of elderly patients to hospital, *BMJ*. 297 (1988) 784-787.
 32. D. Eccleston, T. Rafter, P. Sage, A. Whelan, C. Reid, M. Hug, et al., Predictors of readmission after coronary angioplasty in Australia. Results from a national multi-centre registry. *Heart Lung Circulation*. 22 (2013) S126-266.

33. T.W. Hegeman, T.J. Glorioso, A.E. Baron, P.M. Schneider, R.E. Burke, P.M. Ho, et al., 30-day readmission following PCI predicts worse long-term patient outcomes: insights for the VA CART program, *Circ Cardiovasc Qual Outcomes*. 7 (2014) A310.
34. E.J. Elliot, P. Kolm, W. Weinstraub. Predicting readmission risk following coronary revascularization at the time of admission, *Circ Cardiovasc Qual Outcomes*. 7 (2014) A231.
35. S.Y. Au, K.M. Chan, Y.H. Chan, W.S. Pang, Early unplanned readmission of elderly in Singapore: a retrospective study, *Ann Acad Med Singapore* 31 (2002) 738-44.
36. G.G. Biondi-Zoccai, P. Agostoni, G.M. Sangiorgi, F. Airoldi, J. Cosgrave, A. Chieffo, et al., Incidence, predictors, and outcomes of coronary dissection left untreated after drug-eluting stent implantation, *Eur Heart J*. 27 (2006) 540-546.
37. T. Kinnaird, C.S. Kwok, E. Kontopantelis, P. Ludman, M. de Belder, Anderson R, et al., Coronary perforation during PCI between 2006 and 2013: an analysis of 527,121 cases from the BCIS database, *Heart* 102 (2016) A8-A9.
38. S.D. Kristensen, E.C.L. Grove. Stent thrombosis: definition, mechanisms and prevention. *E-Journal Cardiol Pract*. 5(32) (2007).
39. M. Rashid, C.S. Kwok, S. Pancholy, S. Chugh, S.A. Kedev, I. Bernat, et al., Radial artery occlusion after transradial interventions: a systematic review and meta-analysis, *J Am Heart Assoc*. 5 (2016) e002686.
40. S. Shoukat, S.A. Gowani, A. Jafferani, S.H. Dhakam, Contrast-induced nephropathy in patients undergoing percutaneous coronary intervention, *Cardiol Res Pract*. 2010 (2010) 649164.
41. R.L. Reed, R.A. Pearlman, D.M. Buchner, Risk factors for early unplanned hospital readmission in the elderly, *J Gen Inter Med* 6 (1991) 223-8.
42. P.B. Berger, D.L. Bhatt, V. Fuster, P.G. Steg, K.A. Fox, M. Shao, et al., Bleeding complications with dual antiplatelet therapy among patients with stable vascular disease or risk factors for vascular disease: results from the Clopidogrel for High Atherothrombotic Risk and Ischemic Stabilization, Management, and Avoidance (CHARISMA) trial, *Circulation*. 121 (2010) 2575-2583.
43. A. Zia, S.B. Kamaruzzaman, M.P. Tan, Blood pressure lowering therapy in older people: Does it really cause postural hypotension or falls, *Postgrad Med*. 127 (2015) 186-93.
44. I. Iakovou, T. Schmidt, E. Bonizzoni, L. Ge, G.M. Sangiorgi, G. Stankovic, et al., Incidence, predictors, and outcome of thrombosis after successful implantation of drug-eluting stents. *JAMA*. 293 (2005) 2126-2130.
45. P. Urban, I.T. Meredith, A. Abizaid, S.J. Pocock, D. Carrie, C. Naber, et al., Polymer-free drug-coated coronary stents in patients at high bleeding risk. *N Engl J Med* 373 (2015) 2038-2047.
46. T.F. Luscher, J. Steffel, F.R. Eberli, M. Joner, G. Nakazawa, F.C. Tanner, et al., Drug-eluting stent and coronary thrombosis: biological mechanisms and clinical implications, *Circulation* 115 (2007) 1051-1058.
47. P. Wenaweser, J. Dorffler-Melly, K. Imboden, S. Windecker, M. Togni, B. Meier, et al., Stent thrombosis is associated with an impaired response to antiplatelet therapy, *J Am Coll Cardiol* 45 (2005) 1748-1752.
48. M. Pfister, H.P. Brunner-La Rocca, P.T. Buser, P. Rickenbacher, P. Hunziker, C. Mueller, et al., Late clinical events after clopidogrel discontinuation may limit the benefit of drug-eluting stents, *J Am Coll Cardiol*. 48 (2006) 2584-2591.