Percutaneous coronary intervention and 30-day unplanned readmission with chest pain in the United States (Nationwide Readmissions Database)

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Abstract
Percutaneous coronary intervention (PCI) improves anginal chest pain in most, but not all, treated patients. PCI is associated with unplanned readmission for angina and non-specific chest pain within 30-days of index PCI. Patients with an index hospitalization for PCI between January–November in each of the years 2010–2014 were included from the United States Nationwide Readmissions Database. Of 2,723,455 included patients, the 30-day unplanned readmission rate was 7.2% (n = 196,581, 42.3% female). This included 9.8% (n = 19,183) with angina and 11.1% (n = 21,714) with non-specific chest pain. The unplanned readmission group were younger (62.2 vs 65.1 years; P < 0.001), more likely to be females (41.0% vs 34.2%; P < 0.001), from the lowest quartile of household income (32.9% vs 31.2%; P < 0.001), have higher prevalence of cardiovascular risk factors or have index PCI performed for non-acute coronary syndromes (ACS) (OR: 3.46, 95% CI 3.39–3.54). Factors associated with angina readmissions included female sex (OR: 1.28, 95% CI 1.25–1.32), history of ischemic heart disease (IHD) (OR: 3.28, 95% CI 2.95–3.66), coronary artery bypass grafts (OR: 1.79, 95% CI 1.72–2.86), anaemia (OR: 1.16, 95% CI 1.11–1.21), hypertension (OR: 1.13, 95% CI 1.09, 1.17), and dyslipidemia (OR: 1.10, 95% CI 1.06–1.14). Non-specific chest pain compared with angina readmissions were younger (mean difference 1.25 years, 95% CI 0.99, 1.50), more likely to be females (RR: 1.13, 95% CI 1.10, 1.15) and have undergone PCI for non-ACS (RR: 2.17, 95% CI 2.13, 2.21). Indications for PCI other than ACS have a greater likelihood of readmission with angina or non-specific chest pain at 30-days. Readmissions are more common in patients with modifiable risk factors, previous history of IHD and anaemia.

KEYWORDS
acute coronary syndromes, angina, chest pain, chronic coronary syndromes, ischemic, percutaneous coronary intervention, readmissions, heart disease, outcomes
1 | INTRODUCTION

Percutaneous coronary intervention (PCI) is indicated for acute coronary syndromes (ACS) or the relief of anginal symptoms secondary to myocardial ischemia, in patients with obstructive coronary artery disease (CAD). Around 3 million procedures are performed worldwide every year. The results of recent randomized, controlled trials of clinical strategies involving invasive management of CAD have not provided evidence of clear benefits for coronary revascularization over medical therapy in patients with chronic coronary syndromes (CCS).1,2

In the ABSORB-4 trial, which compared clinical outcomes in patients treated with either a bioresorbable scaffold or a 3rd generation drug eluting stent, the occurrence and time-course of angina post-PCI was similar in both groups, occurring in 11% of subjects by 30 days and 22% of patients by 1-year.3 The clinical characteristics associated with anginal chest pain at these time-points and experience in less-selected, real-world populations are uncertain. Readmission within 30 days following PCI is not uncommon, with a broad spectrum of etiologies and degrees of severity.4 Readmissions are commonly secondary to cardiac-related disorders or PCI complications and it is reported that readmission is associated with a greater risk of mortality.5-8

In this study, we accessed a large, national readmissions database to investigate the proportion of patients re-admitted to hospital with chest pain attributed to angina or non-specific chest pain within 30 days after PCI for ACS or CCS and the associated clinical characteristics. In addition, we evaluated the cost burden of chest pain readmissions compared with readmissions due to other causes.

2 | METHODS

In the United States, the Healthcare Cost and Utilization Project (HCUP) Nationwide Readmissions Database (NRD) records, hospitalization and readmission data for all hospitalized patients within 21 States and is produced by the Agency for Healthcare Research and Quality. This study utilized deidentified data collected and distributed by HCUP and does not require consent from individual patients or an institutional board review (IRB) approval. The distribution of included municipalities is geographically diverse and represents 49.1% of all hospital inpatients, including patients with and without insurance. Admissions are linked by an individual identification number, which enables linkage between admissions independent of readmission location.

Patients were included if they are 18 years or older and underwent PCI at index admission (ICD-9 Procedure code: 00.66, 36.06, 36.07) with discharge data from 2010 to 2014. Only the first admission with PCI within a calendar year was considered. Cases were excluded if they died during index admission, had duplicate data, were missing demographic or readmission data, or readmitted electively. Additionally, patients admitted in December are excluded as they lack 30 days of follow-up. Patients who were readmitted with a primary chest pain diagnosis are defined by ICD-9 codes (Angina – ICD-9: 413.0, 413.1, 413.9; non-specific chest pain [NSCP] – ICD-9: 786.5, 786.51) and clinic classification software codes (stable coronary artery disease including angina – CCS: 101; Non-specific chest pain – CCS: 102; see Table A1).

Demographic, comorbidity at index admission and outcome data as well as detail of inpatient stay was captured through a combination of NRD coding, ICD-9 and Elixhauser comorbidity codes. Cost-to-charge ratios were applied to total charges as recommended by HCUP in order to provide an estimate of inpatient cost.

FIGURE 1 Flow diagram
The primary outcome of this analysis is 30-day readmission with a primary diagnosis of chest pain post-PCI, and variables associated with readmission. A sub-group analysis of the characteristics of patients with a primary diagnosis of angina and non-specific chest pain is also performed.

Statistical analysis was performed using IBM Statistics SPSS (version 24.0). Weighting is performed using sample discharge weights. Dichotomization of patients based on the presence or absence of readmission within 30 days and subsequent descriptive statistics are presented. Chi-square or Independent Student-T testing with 95% two-tailed significance was utilized for comparing patient demographics. Multiple logistic regression analyses were performed to evaluate the association between these variables and readmission within 30-days with angina, non-specific chest pain and the combined population readmitted with angina or non-specific chest pain. Furthermore, the relative risk (RR) of association with variables and readmission within 30-days of angina versus non-specific chest pain is also evaluated.

### RESULTS

Of 3,700,737 identified as undergoing PCI in the United States in the years 2010–2014, 2,723,455 were included in the analysis. The

| TABLE 1 | Patient demographics and characteristics including co-morbidities at index admission |
|---------|----------------------------------------------------------------------------------|
| Variable | All patients (n = 2,773,455) | Control group No readmission (n = 2,682,557) | All chest pain Unplanned readmission (n = 40,897) | NSCP Unplanned readmission (n = 21,714) | Angina Unplanned readmission (n = 19,183) |
| Age in years (SE) | 65.1 (0.01) | 65.1 (0.01) | 62.2 (0.07) | 61.6 (0.09) | 62.8 (0.10) |
| Female | 934,574 | 34.3% | 917,814 | 34.2% | 16,760 | 41.0% | 9448 | 43.5% | 7312 | 38.1% |
| Length of stay in days (SE) | 3.85 (0.00) | 3.87 (0.00) | 2.39 (0.00) | 1.84 (0.01) | 3.02 (0.03) |
| Cost of inpatient stay (SE) | $19,937 (10.6) | $20,133 (10.7) | $7,083 (48.7) | $5,064 (24.7) | $9,368 (97.3) |
| Quartile of median household income | | | | | |
| 0-25th | 850,333 | 31.2% | 836,868 | 31.2% | 13,465 | 32.9% | 7,030 | 32.4% | 6,435 | 33.5% |
| 26th-50th | 721,854 | 26.5% | 711,178 | 26.5% | 10,677 | 26.1% | 5,700 | 26.3% | 4,977 | 25.9% |
| 51st-75th | 632,303 | 23.2% | 622,988 | 23.2% | 9,315 | 22.8% | 5,098 | 23.5% | 4,217 | 22.0% |
| 76th-100th | 518,964 | 19.1% | 511,523 | 19.1% | 7,441 | 18.2% | 3,886 | 17.9% | 3,555 | 18.5% |
| Smoker | 1,106,460 | 40.6% | 1,091,323 | 40.7% | 15,138 | 37.0% | 7,875 | 36.3% | 7,263 | 37.9% |
| Obesity | 421,971 | 15.5% | 416,402 | 15.5% | 5,569 | 13.6% | 2,917 | 13.4% | 2,652 | 13.8% |
| Chronic renal failure | 407,294 | 15.0% | 401,715 | 15.0% | 5,579 | 13.6% | 2,738 | 12.6% | 2,841 | 14.8% |
| Family history of IHD | 296,638 | 10.9% | 293,374 | 10.9% | 3,264 | 8.0% | 1,619 | 7.5% | 1,645 | 8.6% |
| Personal history of IHD | 2,565,060 | 94.2% | 2,526,131 | 94.2% | 38,930 | 95.2% | 20,086 | 92.5% | 18,844 | 98.2% |
| Previous MI | 457,335 | 16.8% | 447,478 | 16.7% | 9,856 | 24.1% | 5,233 | 24.1% | 4,623 | 24.1% |
| Dyslipidemia | 1,915,626 | 70.3% | 1,886,214 | 70.3% | 29,412 | 71.9% | 15,301 | 70.5% | 14,111 | 73.6% |
| Hypertension | 2,032,126 | 74.6% | 2,000,647 | 74.6% | 31,479 | 77.0% | 16,586 | 76.4% | 14,893 | 77.6% |
| Diabetes mellitus | 1,027,612 | 37.7% | 1,011,495 | 37.7% | 16,118 | 39.4% | 8,490 | 39.1% | 7,628 | 39.8% |
| Heart failure | 101,593 | 3.7% | 101,241 | 3.8% | 353 | 0.9% | 76 | 0.4% | 277 | 1.4% |
| Valvular heart disease | 30,923 | 1.1% | 30,815 | 1.1% | 108 | 0.3% | 18 | 0.1% | 90 | 0.5% |
| History of stroke/TIA | 161,953 | 5.9% | 159,305 | 5.9% | 26,48 | 6.5% | 14,51 | 6.7% | 11,97 | 6.2% |
| Peripheral vascular disease | 316,558 | 11.6% | 312,850 | 11.7% | 37,08 | 9.1% | 17,02 | 7.8% | 2,006 | 10.5% |
| Anaemia | 345,133 | 12.7% | 340,076 | 12.7% | 5,058 | 12.4% | 2,424 | 11.2% | 2,634 | 13.7% |
| Atrial fibrillation | 349,320 | 12.8% | 345,303 | 12.9% | 4,017 | 9.8% | 1,799 | 8.3% | 2,218 | 11.6% |
| Previous CABG | 251,465 | 9.2% | 245,327 | 9.1% | 6,138 | 15.0% | 3,113 | 14.3% | 3,025 | 15.8% |
| Non-ACS index PCI | 913,026 | 33.5% | 887,497 | 33.1% | 25,529 | 62.4% | 17,208 | 79.2% | 8,321 | 43.4% |
| ACS index PCI | 1,810,429 | 66.5% | 1,795,059 | 66.9% | 15,369 | 37.6% | 4,506 | 20.8% | 10,863 | 56.6% |
| STEMI | 565,264 | 20.8% | 561,394 | 20.9% | 3,869 | 9.5% | 1,733 | 8.0% | 2,136 | 11.1% |
| NSTEMI/Unstable angina | 1,261,856 | 46.3% | 1,249,663 | 46.6% | 12,193 | 29.8% | 2,791 | 12.9% | 9,402 | 49.0% |

Abbreviations: ACS, acute coronary syndromes; CABG, coronary artery bypass grafts; IHD, ischemic heart disease; NSCP, non-specific chest pain; PCI, percutaneous coronary intervention.
reasons for exclusion are described in Figure 1. Of note, 326,759 were excluded due to a December discharge date. In total, 104,696 patients were excluded from analysis due to missing demographic, discharge or mortality data.

3.1 Characteristics of patients readmitted for chest pain or angina within 30-days post-PCI

Within this post-PCI cohort (n = 2,723,455), 196,581 (7.2%) had an unplanned hospital readmission for any cause within 30-days. Of these, 40,897 (20.8%) patients (1.5% of the whole post-PCI cohort) were readmitted with a primary diagnosis of chest pain at 30 days, including 19,183 patients with angina and 21,714 with non-specific chest pain. The demographics and medical history of the patients who were or were not readmitted during a 30-day period are provided within Table 1. Peak readmissions for chest pain, angina and non-specific chest pain are observed within the first 48 h following discharge post-PCI (Figure 2).

Multiple logistic regression models were created to examine the associations between clinical characteristics and co-morbidities and the likelihood of readmission with a primary diagnosis of angina or non-specific chest pain at 30 days after PCI. We found several characteristics that were strongly associated with readmission with chest

FIGURE 2 Distribution of readmissions with angina (A), non-specific chest pain (B), all chest pain (C), all-causes of readmission (D) within 30-days (X axis: days to readmission; Y axis: frequency)
pain at 30-days (Table 2). The unplanned readmission group were younger (62.2 vs 65.1 years; \( P < 0.001 \)), more likely to be females (41.0% vs 34.2%; \( P = 0.001 \)) and within the lowest quartile of household income (32.9% vs 31.2%; \( P < 0.001 \)). The readmission group also had a higher prevalence of previous ischemic heart disease (IHD), coronary artery bypass grafts (CABG), hypertension and dyslipidemia. Furthermore, they were more likely to have index PCI performed for non-ACS (odds ratio [OR]: 3.46, 95% CI 3.39, 3.54) (Supplementary Figure 1).

### 3.2 | Characteristics of patients readmitted for angina within 30-days post-PCI

Patients readmitted with angina within 30-days were more likely to be female (OR: 1.28, 95% CI 1.25, 1.32), younger (OR: 0.98, 95% CI 0.97, 0.99), associate with the 0–25% of median household income (OR: 1.06, 95% CI 1.02, 1.11), have history of IHD including previous myocardial infarction (OR: 1.44, 95% CI 1.39, 1.49) or coronary artery bypass grafting (OR: 1.79 95% CI 1.72, 1.86, dyslipidemia (OR: 1.10, 95% CI 1.02, 1.14), hypertension (OR: 1.13, 95% CI 1.09, 1.17) and anaemia (OR: 1.16, 95% CI 1.11, 1.21). These patients were also more likely to have undergone index PCI for indications other than ACS (OR: 1.49, 95% CI 1.45, 1.54). Smoking status at index admission, obesity, association with 76–100% of median household income, history of heart failure, valvular heart disease, peripheral vascular disease, and acute coronary syndrome on index PCI (OR = 0.67, 95% CI 0.65, 0.69) were less likely to be observed compared with those who were not readmitted within 30-days (Figure 3).

### 3.3 | Characteristics of patients readmitted for non-specific chest pain within 30-days post-PCI

Of those readmitted with non-specific chest pain within 30-days, female gender (OR: 1.57, 95% CI 1.53, 1.62), younger age (OR: 0.97, 95% CI 0.97, 0.97), association with 51–75% of household income (OR: 1.05, 95% CI 1.01, 1.10), previous history of coronary artery disease (OR: 1.36, 95% CI 1.32, 1.40), hypertension (OR: 1.12, 95% CI 1.09, 1.15), diabetes mellitus (OR: 0.97, 95% CI 0.95, 0.99), dyslipidemia (OR: 0.97, 95% CI 0.95, 0.99), and previous MI (OR: 1.20, 95% CI 1.15, 1.25) were more likely to be observed compared with those who were not readmitted within 30-days (Figure 3).

### TABLE 2  Demographic and clinical characteristics associated with the likelihood of readmission at 30-days with chest pain following PCI

| Variable                        | All chest pain (n = 40 897) | NSCP (n = 21 714) | Angina (n = 19 183) |
|---------------------------------|-----------------------------|-------------------|---------------------|
|                                  | Odds Ratio (95% C.I.)       | P value           | Odds Ratio (95% C.I.) | P value |
| Female                          | 1.44 (1.41, 1.47)           | <0.0005           | 1.57 (1.53, 1.62)    | <0.0005 |
| Age                             | 0.97 (0.97, 0.97)           | <0.0005           | 0.97 (0.97, 0.97)    | <0.0005 |
| Smoker                          | 0.87 (0.85, 0.89)           | <0.0005           | 0.91 (0.89, 0.94)    | <0.0005 |
| Obesity                         | 0.78 (0.76, 0.80)           | <0.0005           | 0.79 (0.76, 0.82)    | <0.0005 |
| Q1 (0–25th %)                   | 1.04 (1.01, 1.07)           | 0.02              | 1.01 (0.97, 1.05)    | 0.57    |
| Q2 (26–50th %)                  | 1.00 (0.97, 1.04)           | 0.787             | 1.02 (0.98, 1.06)    | 0.41    |
| Q3 (51–75th %)                  | 1.01 (0.98, 1.04)           | 0.746             | 1.05 (1.01, 1.10)    | 0.024   |
| Q4 (76–100th %)                 | 0.97 (0.94, 0.99)           | 0.02              | 0.99 (0.95, 1.03)    | 0.572   |
| Chronic kidney disease          | 0.94 (0.91, 0.97)           | <0.0005           | 0.88 (0.84, 0.92)    | <0.0005 |
| Family history of IHD           | 0.74 (0.71, 0.76)           | <0.0005           | 0.74 (0.70, 0.78)    | <0.0005 |
| Personal history of IHD         | 1.20 (1.15, 1.26)           | <0.0005           | 0.76 (0.70, 0.78)    | <0.0005 |
| Previous MI                     | 1.36 (1.33, 1.39)           | <0.0005           | 1.28 (1.24, 1.32)    | <0.0005 |
| Dyslipidemia                    | 1.08 (1.06, 1.11)           | <0.0005           | 1.07 (1.04, 1.10)    | <0.0005 |
| Hypertension                    | 1.12 (1.09, 1.15)           | <0.0005           | 1.11 (1.07, 1.14)    | <0.0005 |
| Diabetes Mellitus               | 0.97 (0.95, 0.99)           | 0.009             | 0.96 (0.93, 0.98)    | 0.002   |
| Heart Failure                   | 0.18 (0.17, 0.20)           | <0.0005           | 0.07 (0.05, 0.08)    | <0.0005 |
| Valvular Heart Disease          | 0.28 (0.23, 0.34)           | <0.0005           | 0.09 (0.06, 0.14)    | <0.0005 |
| History of Stroke/TIA           | 1.11 (1.07, 1.16)           | <0.0005           | 1.18 (1.11, 1.24)    | <0.0005 |
| Peripheral Vascular Disease     | 0.76 (0.73, 0.78)           | <0.0005           | 0.65 (0.62, 0.68)    | <0.0005 |
| Anaemia                         | 1.04 (1.01, 1.08)           | 0.009             | 0.94 (0.89, 0.98)    | 0.003   |
| Atrial Fibrillation             | 0.84 (0.82, 0.87)           | <0.0005           | 0.70 (0.66, 0.73)    | <0.0005 |
| Previous CABG                   | 1.67 (1.63, 1.72)           | <0.0005           | 1.54 (1.49, 1.61)    | <0.0005 |
| Non-ACS PCI on index adm.       | 3.46 (3.39, 3.54)           | <0.0005           | 8.26 (7.99, 8.54)    | <0.0005 |
| ACS PCI on index admission      | 0.29 (0.28, 0.30)           | <0.0005           | 0.12 (0.12, 0.13)    | <0.0005 |

Abbreviations: ACS, acute coronary syndromes; CABG, coronary artery bypass grafts; IHD, ischemic heart disease; NSCP, non-specific chest pain; PCI, percutaneous coronary intervention.
bypass grafting (OR: 1.54, 95% CI 1.49, 1.61), myocardial infarction (OR: 1.28, 95% CI 1.24, 1.32), hypertension (OR: 1.11, 95% CI 1.07, 1.14), dyslipidemia (OR: 1.07, 95% CI 1.04, 1.10), and history of cerebrovascular events (OR: 1.18, 95% CI 1.11, 1.24) are more likely characteristics compared with patients who were not readmitted. Patients who underwent PCI for indications other than ACS at index admission were observed to have a greater likelihood of readmission at 30-days (OR: 8.26, 95% CI 7.99, 8.54). Reduced likelihood is observed in those with a history of smoking, obesity, chronic kidney disease (stage 1–3), family or personal history of IHD, diabetes mellitus, atrial fibrillation, anaemia, peripheral vascular disease and valvular heart disease or history of heart failure prior to index PCI (Supplementary Figure 2).

### 3.4 | Comparisons of patients readmitted with angina versus non-specific chest pain

Compared with patients readmitted within 30 days for nonspecific chest pain, patients who were readmitted with a diagnosis of angina within 30 days were older, more likely to be male, to associate with the 0–25% of household income, have a smoking history, family or personal history of IHD, chronic kidney disease (stage 1–3), dyslipidemia, history of heart failure or valvular heart disease, peripheral vascular disease, anaemia, atrial fibrillation, previous CABG and acute coronary syndrome on admission for index PCI (Supplementary Table 3). Patients with angina readmissions within 30-days had a higher inpatient mortality rate (Supplementary Table 1). Total charges were greater in those readmitted with angina with longer average duration of admission compared with non-specific chest pain.

### 3.5 | Duration of admission and costs

Patients readmitted with angina or non-specific chest pain had a shorter duration of readmission hospital stay (mean: 2.3, 95% CI 2.37, 2.42) compared with those readmitted for other causes within a 30-day period (mean: 5.18 days, 95% CI 5.16, 1.21) (P < 0.005). Angina or non-specific chest pain readmissions were also associated with lower hospitalization costs ($7083) compared with other causes of readmission ($11 642) (P < 0.005) (Supplementary Table 2).

### 4 | DISCUSSION

We have assessed unplanned readmission with a primary diagnosis of angina or non-specific chest pain within 30-days of PCI in a large, national database. We have found that early readmission with angina or non-specific chest pain after PCI is uncommon. Only 1.5% of patients were readmitted within the first 30 days.
patients treated with PCI were readmitted with angina or non-specific chest pain and affected patients had more cardiovascular risk factors and history of previous IHD. Nonetheless, since many patients undergo PCI, a readmission rate of 1–2% within 30 days equates to a considerable number of patients. Readmission after PCI was associated with an appreciable cost. Mortality during readmission is low in keeping with the coded diagnoses.

4.1 Causes of angina post-PCI

PCI is indicated for patients with anginal symptoms despite guideline-directed medical therapy to relieve symptoms of angina and may improve prognosis.\(^9,10\) However, although PCI is routinely successful, angina may persist.\(^11\) The causes of persisting or recurrent angina include incomplete revascularization, complications of PCI for example, side-branch loss, or unusually, unsuccessful PCI. A further issue may be the underutilization of available secondary preventative therapy combinations, which may prevent the requirement to progress to invasive management in chronic coronary syndromes.\(^12\) An under-recognized problem is ischemia and no obstructive coronary artery disease (INOCA). This group of disorders includes microvascular angina, vasospastic angina or mixed microvascular/vasospastic angina, in the absence of obstructive (≥50% diameter stenosis) or flow-limiting (fractional flow reserve ≤0.80; non-hyperemic pressure ratio ≤ 0.89) CAD.\(^13\) Patients with INOCA have a burden of anginal symptoms and typically poorer quality of life compared to patients with obstructive CAD.\(^14\) Microvascular angina may be associated with obstructive CAD (Type 3 microvascular angina), or, alternatively, CAD may be falsely classified as obstructive when in fact the primary cause of angina is microvascular disease. Our analysis does not provide information on the etiology of the chest pain in this cohort out with diagnosis code however, it is observed that index acute coronary syndrome was significantly less common in angina and non-specific chest pain readmissions at 30-days compared with index population within this cohort. A limitation to this estimate is that readmissions from recurrent myocardial infarction are more likely to occur within an acute coronary syndrome subset rather than readmission with non-specific or angina pain. Furthermore, identification of culprit arteries may be less clear in patients undergoing PCI for non-ACS indications so as not, to provide symptomatic benefit for patients with angina, and therefore cause proportionately more readmissions. Further studies to investigate etiology within patients readmitted with chest pain including the success of revascularization, residual coronary disease burden and discharge medication are warranted.

Chest pain after PCI may be experienced in 36% to 42% of patients undergoing both elective and emergent PCI.\(^15-17\) It is most commonly described in the first 24 h following PCI but is described as occurring within the first 3 weeks.\(^16\) In addition to non-cardiac causes it is important to distinguish patients with benign chest pain from critical chest pain after PCI due to acute stent thrombosis, incomplete revascularization, or disease progression affecting alternative coronary regions. However, risk stratification in these patients is challenging and may be influenced by the presence of persistently elevated cardiac enzymes or electrocardiograph evolution in the absence of new myocardial injury.\(^18-20\) Benign chest pain and patients with stable angina post-PCI pain in the absence of ACS, pulmonary or upper gastrointestinal pathologies is therefore understandably recorded in up to one third of overall PCI re-admissions.\(^21,22\) No standard nomenclature for the clinical phenomenon of chest pain post-PCI currently exists due to differing opinions of etiology and there are no guidelines for a standardized approach to management.\(^23\)

A further entity may include the psychological burden associated with a diagnosis of non-specific chest pain and it is estimated that anxiety disorders are prevalent in 30–50% of these patients.\(^24\) Somatization disorders with chest pain symptoms may influence readmission, particularly in non-ACS PCI indications.

4.2 Healthcare implications of hospital readmission post-PCI

Readmissions are a significant source of burden both on the patient and the healthcare system, which is often used as a proxy-marker for quality of care and penalty systems are implemented for providers with greater proportions of readmission.\(^25\)

Patients with chest pain constitute between 0.6 to 2.4% of unplanned presentations to emergency departments and up to one in four admissions to medical and cardiology wards.\(^26-29\) In the United Kingdom, this represents a significant burden with non-ACS chest pain equating to an average of 15.8 and 16.8 bed days per 1000 population for angina and non-specific chest pain respectively with standalone 30-day mortalities of 1.5% and 0.7%.\(^28\) The incidence and demographical distribution of patients readmitted with chest pain syndromes has not previously been explored. Therefore, the burden on health services as well as mortality and major adverse cardiac event (MACE) rate for patients readmitted with chest pain post-PCI is not clearly defined.

Our study involved a large sample that is likely to be reasonably representative of the US population undergoing PCI. The NRD has been utilized previously in patients with chest pain, which provides precedent for selection in this study.\(^20\) Local audit and assessment of chest pain readmissions should be encouraged in order to establish local requirement for interventions, which may reduce readmissions with non-specific chest pain and angina following PCI. This would ensure appropriate utilization of available resources and financial investment dependent on the localized burden of readmissions.

4.3 Associations with cardiovascular risk factors: implications for risk stratification

Demographic factors associated with higher likelihood of unplanned readmission in this sample are in keeping with known cardiovascular risk factors. However, smoking in this sample was not associated with increased readmission at 30 days. This is based on index smoking
status and it is plausible that this may be subject to the smoking modification and cessation programmes, which are commonplace in the management of patients with coronary disease. Patients with heart failure, valvular heart disease and non-cardiac vascular disease were observed to be less likely to be re-admitted at 30-days. This is in part due to the proportion undergoing PCI for ACS in whom ventricular dysfunction if present will be identified following PCI rather than as a co-morbidity on index admission and may also be secondary to increased involvement of secondary care outpatient services in their management and treatment planning.

Optimization of modifiable risk factors prior to intervention is performed in surgical patients and the pre-operative assessment is commonplace in order to improve surgical morbidity and mortality. However, currently there are no similar formalized pathways for patients undergoing PCI which could be implemented in elective angiography patients to improve long-term outcomes. Median household income was significantly associated with increased likelihood of readmission at 30-days in patients with angina and those associating with the 76–100% had a lower likelihood of readmission with a primary diagnosis of angina. Chronic kidney disease in this population was not associated with increased likelihood of re-admission however, the majority of patients included are of mild impairment as would be expected to undergo PCI with contrast. Female gender was more likely for patients readmitted within 30-days with angina and non-specific chest pain and it is previously observed that microvascular and vasospastic angina with INOCA or obstructive CAD is more common in female patients. Male gender was observed in the majority of patients included of mild impairment as would be expected to undergo PCI with contrast. Female gender was more likely for patients readmitted within 30-days with angina and non-specific chest pain and it is previously observed that microvascular and vasospastic angina with INOCA or obstructive CAD is more common in female patients.

One evidence-based example of an intervention to reduce readmissions following PCI is a multimodal strategy as described by Tanguturi et al (2016). This involved a risk assessment of readmission with the production of patient videos regarding subsequent chest pain or symptoms of heart failure. In addition, a formal clinic review with a cardiology fellow and a computerized alert system for re-presentations facilitated early cardiologist review. This package of interventions reduced 30-day hospital readmission from 9.6% to 5.3% over the 4-year study period.

4.4 Limitations

Limitations included the composition of the database from separate yearly data, which prevents multi-year follow-up of these patients and excludes those admitted in December from 30-day follow-up. On the other hand, a longer follow-up period for example at 6 months would necessitate the exclusion of the inverse proportion for that year and would have reduced the external validity of the analysis. The database is comprised of inpatient admissions and does not include discharges from emergency care, community data or patients managed in observation areas following PCI. In the United States approximately 7.6 million patients present with chest pain per annum, four out of five will not require admission. A further limitation is the lack of information on completeness of revascularization for included patients or their prescribed medications at the time of discharge. This would be of value in this cohort, particularly where subsequent angina diagnoses are coded on readmission in patients who have undergone PCI for indications other than ACS.

5 CONCLUSIONS

Our study provides insights into the prevalence, risk factors and health burden of readmission with angina or non-specific chest pain following PCI. Secondary prevention measures to reduce cardiovascular risk such as correction of anaemia may help to optimize the clinical status of patients prior to undergoing PCI. PCI performed for an indication other than ACS is associated with a greater likelihood of readmission with angina or non-specific chest pain at 30-days within this cohort and further investigation of the etiology within these patients is required.

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CONFLICT OF INTEREST

Professor Colin Berry is employed by the University of Glasgow, which holds consultancy and research agreements for his work with companies that have commercial interests in the diagnosis and treatment of angina. The companies include Abbott Vascular, AstraZeneca, Boehringer Ingelheim, GSK, HeartFlow, Menarini, Novartis, and Siemens Healthcare. None of the other authors have any potential conflicts of interest.

DATA AVAILABILITY STATEMENT

The data underlying this article were provided by the Healthcare Cost and Utilization Project under licence. Data will be shared on request to the corresponding author with permission of the Healthcare Cost and Utilization Project

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## Table A1

Classification of clinic classification software codes for readmissions causes

| Causes of readmission | CCS code | Diagnosis |
|-----------------------|----------|-----------|
| **Respiratory**       |          |           |
| Respiration           | 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**         |          |           |
| Infection             | 1        | Tuberculosis |
|                       | 2        | Septicemia |
|                       | 3        | Bacterial infection |
|                       | 4        | Mycoses |
|                       | 5        | HIV infection |
|                       | 6        | Hepatitis |
|                       | 7        | Viral infection |
|                       | 8        | Other infection |
|                       | 9        | Sexually transmitted infection |
|                       | 76       | Meningitis |
|                       | 77       | Encephalitis |
|                       | 78       | Other CNS infection and poliomyelitis |
|                       | 90       | Inflammation or infection of eye |
|                       | 122      | Pneumonia |
|                       | 123      | Influenza |
|                       | 124      | Acute and chronic tonsilitis |
|                       | 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**          |          |           |
| Bleeding              | 60       | Acute posthaemorrhagic anaemia |
|                       | 153      | Gastrointestinal haemorrhage |
|                       | 182      | Haemorrhage during pregnancy; abruptio placenta; placenta previa |
| **Peripheral vascular disease** | | |
| 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**      |          |           |
| 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 |
| Causes of readmission | CCS code | Diagnosis                                           |
|-----------------------|----------|-----------------------------------------------------|
| Hyperplasia of prostate | 164      |                                                     |
| Inflammatory conditions of the male genital organs | 165      |                                                     |
| Other male genital disorders | 166      |                                                     |
| Prolapse of female genital organs | 170      |                                                     |
| Other female genital disorders | 175      |                                                     |
| Genitourinary congenital anomalies | 215      |                                                     |

### Renal disease

| CCS code | Diagnosis                                           |
|----------|-----------------------------------------------------|
| 156      | Nephritis; nephrosis; renal sclerosis               |
| 157      | Acute and unspecified renal failure                 |
| 158      | Chronic kidney disease                              |

### Gastrointestinal

| CCS code | Diagnosis                                           |
|----------|-----------------------------------------------------|
| 138      | Esophageal disorders                                |
| 139      | Gastroduodenal ulcer (except haemorrhage)          |
| 140      | Gastritis and duodenitis                            |
| 141      | Other disorders of stomach and duodenum             |
| 142      | Appendicitis and other appendiceal conditions       |
| 143      | Abdominal herna                                     |
| 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      | Haemolytic jaundice and perinatal jaundice          |
| 250      | Nausea and vomiting                                 |
| 251      | Abdominal pain                                      |

### TIA/stroke

| CCS code | Diagnosis                                           |
|----------|-----------------------------------------------------|
| 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

| CCS code | Diagnosis                                           |
|----------|-----------------------------------------------------|
| 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                   |

(Continues)
| Causes of readmission | CCS code | Diagnosis |
|-----------------------|----------|-----------|
| 235                   |          | Open wounds of head; neck; and trunk |
| 236                   |          | Open wounds of extremities |
| 239                   |          | Superficial injury; contusion |
| 244                   |          | Other injuries and conditions due to external causes |
| 260                   |          | All (external causes of injury and poisoning) |
| **Endocrine/metabolic** | 48       | Thyroid disorders |
|                       | 49       | Diabetes mellitus without complication |
|                       | 50       | Diabetes mellitus with complication |
|                       | 51       | Other endocrine disorders |
|                       | 53       | Disorders of lipid metabolism |
|                       | 58       | Other nutritional and endocrine/metabolic disorders |
|                       | 186      | Diabetes or abnormal glucose tolerance complicating pregnancy; childbirth; or the puerperium |
| **Neuropsychiatric**   | 650      | Adjustment disorders |
|                       | 651      | Anxiety disorders |
|                       | 652      | Attention-deficit, conduct, and disruptive behavior disorders |
|                       | 653      | Delirium, dementia, and amnestic and other cognitive disorders |
|                       | 654      | Developmental disorders |
|                       | 655      | Disorders usually diagnosed in infancy and childhood or adolescence |
|                       | 656      | Impulse control disorders, NEC |
|                       | 657      | Mood disorders |
|                       | 658      | Personality disorders |
|                       | 659      | Schizophrenia and other psychotic disorders |
|                       | 660      | Alcohol-related disorders |
|                       | 661      | Substance-related disorders |
|                       | 662      | Suicide and intentional self-inflicted injury |
|                       | 663      | Screening and history of mental health and substance abuse codes |
|                       | 670      | Miscellaneous mental health disorders |
|                       | 79       | Parkinson's disease |
|                       | 80       | Multiple sclerosis |
|                       | 81       | Other hereditary and degenerative nervous system conditions |
|                       | 82       | Paralysis |
|                       | 83       | Epilepsy, convulsions |
|                       | 84       | Headache including migraine |
|                       | 85       | Coma, stupor and brain damage |
|                       | 95       | Other nervous system disorders |
|                       | 216      | Nervous system congenital anomalies |
|                       | 650      | Adjustment disorders |
|                       | 651      | Anxiety disorders |
|                       | 652      | Attention-deficit, conduct, and disruptive behavior disorders |
|                       | 653      | Delirium, dementia, and amnestic and other cognitive disorders |
|                       | 654      | Developmental disorders |
|                       | 655      | Disorders usually diagnosed in infancy and childhood or adolescence |
|                       | 656      | Impulse control disorders |
|                       | 657      | Mood disorders |
|                       | 658      | Personality disorders |
| Causes of readmission | CCS code | Diagnosis                                                                 |
|-----------------------|----------|---------------------------------------------------------------------------|
|                       | 659      | Schizophrenia and other psychotic disorders                               |
|                       | 660      | Alcohol-related disorders                                                 |
|                       | 661      | Substance-related disorders                                               |
|                       | 662      | Suicide and intentional self-inflicted injury                             |
|                       | 663      | Screening and history of mental health and substance abuse codes          |
|                       | 670      | Miscellaneous mental health disorders                                    |
|                       |          | *Hematological/neoplastic*                                               |
|                       | 11       | Cancer of head and neck                                                   |
|                       | 12       | Cancer of esophagus                                                       |
|                       | 13       | Cancer of stomach                                                         |
|                       | 14       | Cancer of colon                                                           |
|                       | 15       | Cancer of rectum and anus                                                  |
|                       | 16       | Cancer of liver and intrahepatic bile ducts                              |
|                       | 17       | Cancer of pancreas                                                        |
|                       | 18       | Cancer of other gastrointestinal organs, peritoneum                       |
|                       | 19       | Cancer of bronchus, lung                                                   |
|                       | 20       | Cancer of other respiratory and intrathoracic                             |
|                       | 21       | Cancer of bone and connective tissue                                      |
|                       | 22       | Melanoma of skin                                                          |
|                       | 23       | Other non-epithelial cancer of skin                                       |
|                       | 24       | Cancer of breast                                                          |
|                       | 25       | Cancer of uterus                                                          |
|                       | 26       | Cancer of cervix                                                          |
|                       | 27       | Cancer of ovary                                                           |
|                       | 28       | Cancer of other female genital organs                                     |
|                       | 29       | Cancer of prostate                                                        |
|                       | 30       | Cancer of testis                                                          |
|                       | 31       | Cancer of other male genital organs                                       |
|                       | 32       | Cancer of bladder                                                         |
|                       | 33       | Cancer of kidney and renal pelvis                                         |
|                       | 34       | Cancer of other urinary organs                                            |
|                       | 35       | Cancer of brain and nervous system                                        |
|                       | 36       | Cancer of thyroid                                                         |
|                       | 37       | Hodgkin's disease                                                         |
|                       | 38       | Non-Hodgkin's lymphoma                                                    |
|                       | 39       | Leukemias                                                                 |
|                       | 40       | Multiple myeloma                                                          |
|                       | 41       | Cancer, other and unspecified primary                                     |
|                       | 42       | Secondary malignancies                                                    |
|                       | 43       | Malignant neoplasm without specification of site                          |
|                       | 44       | Neoplasm of unspecified nature or uncertain behavior                      |
|                       | 46       | Benign neoplasm of uterus                                                 |
|                       | 47       | Other and unspecified benign neoplasm                                     |
|                       | 59       | Deficiency and other anaemias                                              |
|                       | 61       | Sickle cell anaemia                                                       |
|                       | 62       | Coagulation and haemorrhagic disorders                                    |
|                       | 63       | Disease of white blood cells                                              |
### Table A1 (Continued)

| Causes of readmission | CCS code | Diagnosis |
|-----------------------|----------|-----------|
| 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 |
| Causes of readmission | CCS code | Diagnosis                                      |
|-----------------------|----------|------------------------------------------------|
| Maintenance chemotherapy, radiotherapy | 45       |                                                |
| Nutritional deficiencies | 52       |                                                |
| Fluid and electrolyte disorders | 55       |                                                |
| Cystic fibrosis       | 56       |                                                |
| Immunity disorder     | 57       |                                                |
| Hemorrhoids           | 120      |                                                |
| Other diseases of veins and lymphatics | 121      |                                                |
| Nonmalignant breast conditions | 167     |                                                |
| Inflammatory disease of female pelvic organs | 168      |                                                |
| Endometriosis         | 169      |                                                |
| Ovarian cyst          | 172      |                                                |
| Menopausal disorders  | 173      |                                                |
| Rheumatoid arthritis and related disease | 202     |                                                |
| Osteoarthritis        | 203      |                                                |
| Other non-traumatic joint disorders | 204      |                                                |
| Spondylolisthesis; intervertebral disc disorders; other back problems | 205      |                                                |
| Osteoporosis          | 206      |                                                |
| Acquired foot deformities | 208     |                                                |
| Other acquired deformities | 209    |                                                |
| Systemic lupus erythematosus and connective tissue disorders | 210   |                                                |
| Other connective tissue disease | 211    |                                                |
| Other bone disease and musculoskeletal deformities | 212  |                                                |
| Other congenital anomalies | 217    |                                                |
| Complication of device; implant or graft | 237   |                                                |
| Complications of surgical procedure or medical care | 238 |                                                |
| Burns                 | 240      |                                                |
| Fever of unknown origin | 246     |                                                |
| Lymphadenitis         | 247      |                                                |
| Gangrene              | 248      |                                                |
| Malaise and fatigue   | 252      |                                                |
| Allergic reactions    | 253      |                                                |
| Rehabilitation care; fitting of prostheses; and adjustment of devices | 254 |                                                |
| Administrative/social admission | 255 |                                                |
| Medical examination/evaluation | 256 |                                                |
| Other aftercare       | 257      |                                                |
| Other screening for suspected conditions (not mental disorders or infectious disease) | 258 |                                                |
| Residual codes; unclassified | 259 |                                                |

**Heart failure**
- Congestive heart failure non-hypertensive | 108

**Arrhythmia**
- Cardiac dysrhythmias | 106
- Cardiac arrest and ventricular fibrillation | 107

**Conduction disorder**
- Conduction disorders | 105

**Valve disorders**
- Heart valve disorder | 96

**Hyper/hypotension**
- Essential hypertension | 98
- Hypertension with complications and secondary hypertension | 99
- Hypertension complicating pregnancy; childbirth and the puerperium | 183

(Continues)
### Table A1 (Continued)

| Causes of readmission | CCS code | Diagnosis                                           |
|-----------------------|----------|-----------------------------------------------------|
| Pericarditis          | 97       | Peri-, endo- and myocarditis, cardiomyopathy       |
| Coronary artery disease including angina | 101 | Coronary atherosclerosis and other heart disease includes angina |
| Acute myocardial infarction | 100 | Acute myocardial infarction                         |
| Others (cardiac)      | 103      | Pulmonary heart disease                             |
|                       | 104      | Other and ill-defined heart disease                 |
|                       | 213      | Cardiac and circulatory congenital anomalies        |