



Trends and predictors of recurrent acute coronary syndrome hospitalizations and unplanned revascularization after index acute myocardial infarction treated with percutaneous coronary intervention

Matias B. Yudi, MBBS,^{a,b} David J. Clark, MBBS, DMedSci,^{a,b} Omar Farouque, MBBS, PhD,^{a,b} Nick Andrianopoulos, MBBS, MBIostat,^c Andrew E. Ajani, MBBS, MD,^{b,c} Angela Brennan, RN,^c Jeffrey Lefkovits, MBBS,^{c,d} Melanie Freeman, MBBS,^e Chin Hiew, MBBS,^f Laura A. Selkrig, MBBS,^g Jessica O'Brien, MBBS,^g Anthony M. Dart, MBChB, PhD,^g Christopher M. Reid, BA, MSc, PhD,^{c,h} and Stephen J. Duffy, MBBS, PhD^{c,g}, on behalf of the Melbourne Interventional Group

ABSTRACT Background Repeat hospitalizations for recurrent acute coronary syndrome (ACS) or unplanned revascularization after acute myocardial infarction (MI) are common, costly and potentially preventable. We aim to describe 10-year trends and identify independent risk factors of these repeat hospitalizations.

Methods We analyzed data from 9615 patients from the Melbourne Interventional Group registry (2005–2014) who underwent percutaneous coronary intervention (PCI) for their index MI and survived to discharge. Patients with ≥ 1 hospitalization for recurrent ACS events and/or unplanned revascularization in the year after discharge were included in the recurrent coronary hospitalization group. We assessed yearly trends of recurrent coronary events and identified independent predictors using multivariate analysis.

Results Recurrent coronary hospitalization occurred in 1175 (12.2%) patients. There was a significant decrease in the rate of recurrent ACS hospitalization (15.3%–7.6%, P for trend $<.001$) and unplanned revascularization (4.2%–2.1%, P for trend = .01), but not in all-cause re-hospitalizations (P for trend = .28). On multivariate analysis, female gender, diabetes mellitus, previous coronary bypass surgery, previous PCI, reduced ejection fraction, heart failure, multi-vessel coronary disease and obstructive sleep apnea were independent predictors of recurrent coronary hospitalizations (all $P < .05$).

Conclusions Recurrent hospitalization for ACS or unplanned revascularization has decreased significantly over the past decade. Risk factors for such events are numerous and largely non-modifiable, however they identify a cohort of patients in whom non-culprit vessel PCI in multi-vessel disease, optimization of left ventricular dysfunction and diabetes management may improve outcomes. (Am Heart J 2019;212:134-43.)

From the ^aDepartment of Cardiology, Austin Health, Melbourne, Australia, ^bDepartment of Medicine, University of Melbourne, Melbourne, Australia, ^cCentre of Cardiovascular Research and Education in Therapeutics (CCRE), Monash University, Melbourne, Australia, ^dDepartment of Cardiology, Royal Melbourne Hospital, Melbourne, Australia, ^eDepartment of Cardiology, Box Hill Hospital, Melbourne, Australia, ^fDepartment of Cardiology, Geelong Hospital, Geelong, Australia, ^gDepartment of Cardiovascular Medicine, Alfred Hospital, Melbourne, Australia, and ^hSchool of Public Health, Curtin University, Perth, Australia.

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Reprint requests: Department of Cardiovascular Medicine, Alfred Hospital, Commercial Road, Melbourne 3004, Australia. Tel.: +613 9076 2732; Fax: +613 9076 2461.

E-mail: s.duffy@alfred.org.au

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Background

Coronary heart disease (CHD) remains the leading cause of mortality and morbidity throughout the world.¹ The significant decrease in short-term morbidity and mortality from acute myocardial infarction (MI) coupled with the high risk of recurrent events in those with known CHD has increased the emphasis on post-discharge care and secondary prevention of CHD.²⁻⁴ In particular, there has been significant attention paid to reducing hospital readmissions as they are common, costly and potentially preventable.^{5,6} Consequently, payers and policymakers have begun viewing hospital readmissions as an indicator of quality of care.⁷

Numerous studies have reported 30-day readmission rates after MI and percutaneous coronary intervention (PCI) while attempting to identify risk factors for such events.⁸⁻¹⁹ However, a systematic review failed to identify variables consistently associated with repeat rehospitalisations.²⁰ Although a predictive model has been proposed, its use is limited by the numerous variables needed to retain sufficient predictive ability, reducing its clinical utility.²¹ Furthermore, a significant proportion of readmissions are not cardiac in nature.¹⁸ Thus it may be more appropriate to focus on repeat hospitalizations due to recurrent ACS or unplanned revascularizations. To our knowledge only one study has focused on risk factors for coronary-related re-hospitalizations while long-term trends of this remain largely unexplored.²²

Thus the aims of our study were to describe the decade-long (2005–2014) trends in the frequency of 12-month recurrent hospitalizations for ACS and unplanned revascularization post MI treated with PCI, and to determine independent predictors of these events.

Methods

The study cohort included consecutive patients enrolled in the Melbourne Interventional Group (MIG) registry who underwent percutaneous coronary intervention for management of their index acute myocardial infarction between January 2005 and November 2014. The MIG registry is a multi-center PCI registry and has been previously described in detail.²³ Briefly, demographic, clinical, procedural and in-hospital outcome data are prospectively recorded on case-report forms using standardized definitions for all fields with follow up performed at 30 days and 12 months.²⁴ Readmissions were confirmed by chart review.

The registry is coordinated by the Centre of Cardiovascular Research and Education in Therapeutics; an independent research body within the School of Public Health and Preventive Medicine at Monash University (Melbourne, Australia). An audit of a number of verifiable fields from 5% of randomly selected procedures at each institution is undertaken periodically.²⁵ In the most recent audit, 27 fields were assessed with data accuracy of 98%. This compares favorably to audits from other large registries.²⁶ The ethics committee in each participating hospital has approved the MIG registry, including the use of “opt-out” consent. To “opt-out” means consent is presumed unless the patient declines participation. All participating sites give each patient a “Patient Information Sheet”. If a patient informs a staff member that they do not wish to participate, the patient's data are not collected.

Patients who underwent PCI as part of their management of acute myocardial infarction (MI; includes ST-elevation myocardial infarction [STEMI] and non-ST-elevation myocardial infarction [NSTEMI]) and survived to hospital discharge were included. STEMI was defined as ECG changes (new ST-segment elevation at the J-point or

development of Q-waves in two or more contiguous leads) with confirmed myocardial necrosis (elevation in troponin T or I or CK-MB on at least one occasion within 24 hours from the index event). NSTEMI was defined as biomarker elevation consistent with myocardial necrosis and one of: either ST-segment depression or T-wave abnormality on ECG; or ischemic symptoms. Exclusion criteria included patients with clinical unstable angina but normal cardiac biomarkers and those with out-of-hospital cardiac arrest.

Patients were divided into two groups: patients with ≥ 1 hospitalization for recurrent ACS events and/or unplanned revascularization were included in the recurrent coronary hospitalization group and those free of such hospitalizations were in the no recurrent coronary hospitalization group. The follow up was 12 months. Patients who underwent planned or “staged” PCI/CABG were included in the no coronary event group unless they had other unplanned coronary readmissions or revascularization. Staged PCI was defined as a planned procedure performed as part of a multi-vessel revascularization strategy. Patients who died in the 12-month follow up during or post a recurrent coronary readmission were included in the recurrent coronary event group. Patients who died during a non-coronary admission, or they never had a coronary readmission were included in the no coronary event group.

Re-hospitalization was defined as an admission to an acute-care hospital after successful discharge from their index admission. We counted no more than one re-hospitalization for each discharge. ACS events included STEMI, NSTEMI and unstable angina. Unstable angina was defined by clinical history suggestive of progressive or unstable ischemic symptoms without cardiac biomarker elevation.

Acute management of all patients including interventional strategy, stent selection and antithrombotic therapy were left at the discretion of the operator in all procedures. Optimal secondary prevention pharmacotherapy was encouraged according to guidelines. No records were made of contraindications to medications or decisions regarding use/omission of particular guideline-directed therapies.

The primary outcome was 12-month hospitalization for recurrent ACS or unplanned revascularization. We then determined independent predictors of these repeat hospitalizations. Continuous variables are expressed as mean \pm standard deviation (SD), and categorical data are expressed as numbers/percentages. Continuous variables were compared using Student's *t*-test. Categorical variables were compared using Fisher's exact or Pearson's chi-square tests as appropriate. Variables were tested for linear trends across the years 2005–2014 using Stata's *nptrend* command. This is a nonparametric test for trend across ordered groups, which is an extension of the Wilcoxon rank-sum test. Multivariate logistic regression was used to estimate the adjusted odds ratio and 95% confidence intervals (CI) for predictors of recurrent coronary events. Variables with $P < .10$ in the univariate logistic regression were entered into stepwise backward

selection multivariate logistic regression to obtain adjusted odds ratio estimates. All statistical analyses were performed using Stata 13.1, StataCorp LP, College Station, TX. $P < .05$ was considered to be statistically significant.

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Results

Trends in hospitalization

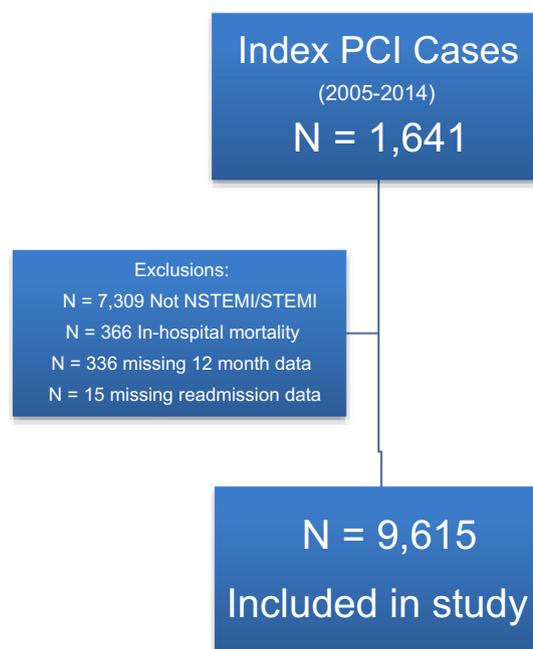
Out of the 9981 consecutive patients with their index acute myocardial infarction, 9615 (96.3%) survived to discharge and were included in our study (Figure 1). Of the survivors, 1175 (12.2%) had a recurrent hospitalization for an ACS or an unplanned revascularization in the 12 months following their index PCI. There was a significant decrease in the 12-month rate of these unplanned coronary hospitalizations over the 10-year period from 15.3% in 2005 to 7.6% in 2014 (p-value for trend < 0.001). There was also a significant decrease in the 12-month rate of unplanned revascularization from 4.2% to 2.1% (p-value for trend = 0.01). In contrast, the rate of 12-month all-cause re-hospitalization was 33.5% through the 10-year period with no significant change (p-value for trend = 0.28) (see Figure 2).

Clinical characteristics

Baseline demographic, clinical presentation and angiographic characteristics are shown in Tables 1 and 2. Patients with recurrent coronary hospitalizations were likely to be older and of female gender. Furthermore, they had more co-morbidities, with higher rates of hypertension, hypercholesterolemia, diabetes mellitus, previous myocardial infarction/percutaneous coronary intervention/coronary artery bypass grafting, peripheral vascular disease, obstructive sleep apnea, rheumatoid arthritis and chronic renal failure (all $P < .01$). Paradoxically, current smokers were less likely to have recurrent coronary hospitalizations (26.8% vs 32.2%, $P < .01$).

Patients with recurrent coronary hospitalizations were more likely to have initially presented with NSTEMI (66.4% vs 59.9%, $P < .01$), and have recent heart failure (6.6% vs 4.4%, $P < .01$). Furthermore, these patients had more advanced atherosclerosis as evidenced by higher rates of multivessel CAD (63.7% vs 53.3%, $P < .01$), left main disease (10.7% vs 5.7%, $P < .01$) and PCI to a bypass graft (4.7% vs 1.9%, $P < .01$). In STEMI, patients with

Figure 1



Study Design.

recurrent coronary hospitalizations had longer door-to-balloon times and worse left ventricular ejection fraction.

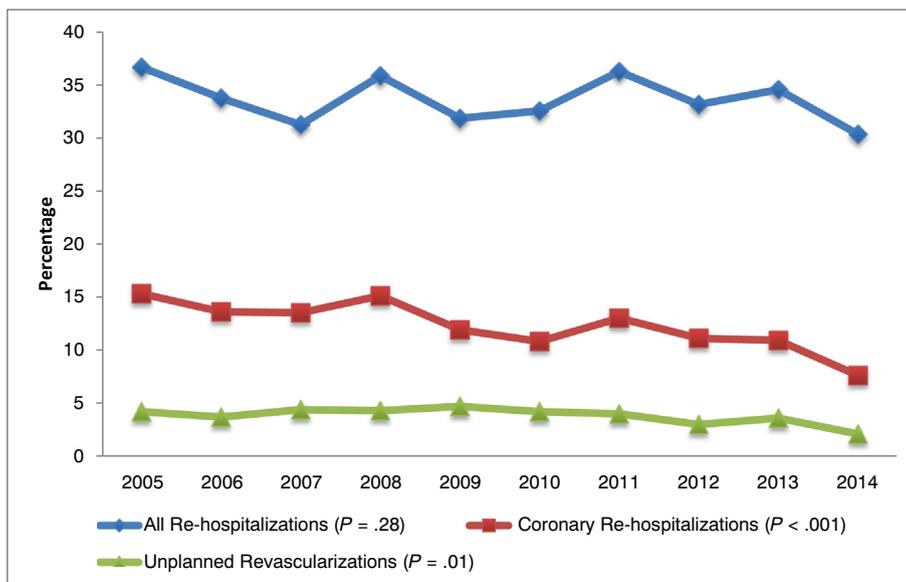
Although initial PCI success rates were equivalent between the groups, those with recurrent coronary hospitalizations were more likely to require repeat emergency PCI during the index admission (1.5% vs 0.7%, $P < .01$) but less likely to have unplanned CABG (0.3% vs 1.1%, $P = .02$). There was no difference in in-hospital bleeding between the two cohorts (2.9% vs 2.7%, $P = .73$).

Secondary prevention pharmacotherapy at 30-days and 12-months is shown on Table 3. Those with recurrent coronary hospitalizations had higher rate of aspirin (98.8% vs 97.8%, $P = .03$) and thienopyridine use (88.2% vs 81.9%, $P < .01$) but a lower rate of statin use (93.5% vs 96.3%, $P < .01$) at 30-days. At 12-months, only the higher use of thienopyridines (68.8% vs 61.2%, $P < .01$) persisted while the initial difference in aspirin and statin use was no longer statistically significant. In patients with recurrent coronary hospitalizations there was higher use of ezetimibe, long-acting nitrate therapy and calcium channel blockers at 30 -days and 12-months possibly suggesting more difficult to treat hypercholesterolemia and recurrent angina.

Clinical Outcomes

Of the 1175 patients with recurrent coronary hospitalizations, 797 (67.9%) had unstable angina, 283 (24.1%) had a NSTEMI and 95 (8.1%) had a STEMI (Table 4). In this

Figure 2



Yearly trends in all-cause re-hospitalizations, coronary re-hospitalizations and unplanned revascularizations.

Table 1. Baseline clinical characteristics

	Recurrent coronary hospitalization N = 1175	No recurrent coronary hospitalization N = 8440	P
Age, years± SD	64.7 ± 13.2	63.8 ± 12.5	.01
Age >75 years	314 (26.7)	1907 (22.6)	<.01
Caucasian	1123 (95.7)	7960 (94.3)	.06
Male	836 (71.2)	6441 (76.3)	<.01
BMI, kg/m ²	28.1 ± 5.5	28.1 ± 5.2	.80
Current smoker	311 (26.8)	2696 (32.2)	<.01
Hypertension	756 (64.3)	4967 (58.9)	<.01
Hypercholesterolemia	776 (66.0)	5175 (61.5)	<.01
Diabetes mellitus	311 (26.5)	1659 (19.7)	<.01
Family history of CAD	502 (43.8)	3302 (40.0)	.01
Previous MI	304 (25.9)	1462 (17.3)	<.01
Previous PCI	252 (21.5)	1231(14.6)	<.01
Previous CABG	120 (10.2)	350 (4.2)	<.01
Heart Failure	61 (5.2)	215 (2.6)	<.01
Peripheral vascular disease	95 (8.1)	401 (4.8)	<.01
Stroke	73 (6.2)	426 (5.1)	.10
Chronic lung disease	137 (11.7)	794 (9.4)	.02
Obstructive sleep apnea	60 (5.1)	282 (3.4)	<.01
Rheumatoid arthritis	33 (3.0)	147 (1.8)	<.01
eGFR ≥60 ml/min/1.73 m ²	860 (74.1)	6566 (79.4)	<.01
eGFR 30–60 ml/min/1.73 m ²	259 (22.3)	1506 (18.2)	<.01
eGFR <30 ml/min/1.73 m ²	42 (3.6)	196 (2.4)	<.01

Data are number (%), unless otherwise specified. Abbreviations: BMI, body mass index; CAD, coronary artery disease; MI, myocardial infarction; CABG, coronary artery bypass graft surgery; eGFR, estimated glomerular filtration rate.

cohort, 366 (31.1%) patients had an unplanned revascularization. Angiography without PCI was undertaken in 457 (38.9%) patients with recurrent acute coronary syndromes. Planned, same-day angiography without PCI

was undertaken in 186 (2.2%) patients without recurrent coronary hospitalizations. Staged (planned) revascularization was undertaken in 135 (11.5%) patients who subsequently had recurrent coronary hospitalizations in

Table 2. Clinical presentation and angiographic characteristics.

	Recurrent coronary hospitalization N = 1175	No recurrent coronary hospitalization N = 8440	P
Heart failure (<2 weeks prior to PCI)	77 (6.6)	372 (4.4)	<.01
Atrial fibrillation	42 (4.9)	333 (5.1)	.03
Killip class ≥ 2	115 (11.0)	853 (11.1)	.94
Cardiogenic shock	34 (2.9)	252 (3.0)	.86
STEMI	395 (33.6)	3384 (40.1)	<.01
NSTEMI	780 (66.4)	5056 (59.9)	<.01
DTBT <90 minutes (STEMI only)	219 (55.4)	2051 (60.6)	.05
Radial approach	166 (14.1)	1454 (17.2)	.03
Femoral approach	1005 (85.5)	6964 (82.5)	.03
Ejection fraction >45%	706 (66.5)	5622 (72.9)	<.01
Single vessel CAD	426 (36.3)	3932 (46.8)	<.01
Multi-vessel CAD	747 (63.7)	4478 (53.3)	<.01
Left main disease	39 (10.7)	139 (5.7)	<.01
Lesion PCI – LAD	515 (36.5)	3438 (34.9)	.26
Lesion PCI – LCx	165 (11.7)	1244 (12.6)	.31
Lesion PCI – RCA	433 (30.7)	3476 (35.3)	<.01
Lesion PCI – LM	13 (0.9)	51 (0.5)	.06
Lesion PCI – Graft	66 (4.7)	191 (1.9)	<.01
ACC/AHA lesion classification B2/C	832 (58.9)	5744 (58.4)	.69
Estimated lesion length	19.6 \pm 9.4	19.6 \pm 8.6	.12
Bare-metal stent	604 (51.4)	4165 (49.4)	.39
Drug-eluting stent	506 (43.1)	3811 (45.2)	.39
POBA	65 (5.5)	464 (5.5)	.39
Number of stents inserted	1.25 \pm 0.67	1.19 \pm 0.6	<.01
Successful PCI	1173 (99.8)	8419 (99.8)	.76
Cardiac Rehabilitation Referral	54 (91.5)	686 (91.2)	.94

Data are number (%), unless otherwise stated. Abbreviations: *STEMI*, ST-elevation myocardial infarction; *NSTEMI*, non-ST-elevation myocardial infarction; *DTBT*, door-to-balloon-time; *CAD*, coronary artery disease; *PCI*, percutaneous coronary intervention; *LAD*, left anterior descending artery; *LCx*, left circumflex artery; *RCA*, right coronary artery; *LM*, left main coronary artery; *POBA*, plain old balloon angioplasty.

Table 3. Secondary prevention pharmacotherapy.

	Recurrent coronary hospitalization N = 1175	No recurrent coronary hospitalization N = 8440	P
Medications at 30 Days			
Aspirin	1125 (98.8)	7865 (97.8)	.03
Thienopyridine	1003 (88.2)	6574 (81.9)	<.01
Statin	1057 (93.5)	7700 (96.3)	<.01
Beta-blocker	928 (82.1)	6684 (83.8)	.16
ACE-I/ARB	955 (84.6)	6807 (85.3)	.54
Warfarin/NOAC	75 (6.6)	540 (6.8)	.86
Spirolactone	28 (3.00)	140 (2.0)	.06
Eplerenone	31 (3.3)	157 (2.3)	.05
Ezetimibe	56 (6.0)	226 (3.3)	<.01
Fibrate	13 (1.4)	94 (1.3)	.96
Nitrate	111 (11.9)	486 (7.1)	<.01
Calcium channel blocker	153 (16.4)	696 (10.2)	<.01
Medications at 12 Months			
Aspirin	1010 (96.2)	7268 (95.1)	.11
Thienopyridine	719 (68.8)	4652 (61.2)	<.01
Statin	969 (92.9)	7111 (93.8)	.28
Beta-blocker	822 (79.3)	5738 (76.0)	.02
ACE-I/ARB	826 (79.6)	6221 (82.3)	.03
Warfarin/NOAC	67 (6.4)	361 (4.8)	.02
Spirolactone	55 (5.6)	160 (2.2)	<.01
Eplerenone	20 (2.0)	133 (1.8)	.70
Ezetimibe	78 (7.9)	351 (4.9)	<.01
Fibrate	20 (2.0)	107 (1.5)	.20
Nitrate	172 (17.4)	573 (8.0)	<.01
Calcium channel blocker	175 (17.8)	882 (12.3)	<.01

Data are number (%), unless otherwise stated. Abbreviations: *ACE-I*, angiotensin converting enzyme inhibitor; *ARB*, angiotensin receptor blocker; *NOAC*, novel oral anti-coagulant.

Table 4. Clinical outcomes.

	Recurrent coronary hospitalization N = 1175	No recurrent coronary hospitalization N = 8440	P
Planned revascularization	135 (11.5)	626 (7.4)	<.01
Unplanned revascularization	366(31.1)	-	
Any ACS readmission	909(77.4)	-	
NSTEMI readmission	283 (24.1)	-	
STEMI readmission	95 (8.1)	-	
Angiography without PCI	457 (38.9)	186 (2.2)	<.01
Heart failure admission	79 (6.7)	176 (2.1)	<.01
Arrhythmia admission	48 (4.1)	131 (1.6)	<.01
Stroke admission	14 (1.2)	50 (0.6)	.02
Other admission	305 (26.0)	1323 (15.7)	<.01
12-month mortality	61 (5.2)	186 (2.2)	<.01
12-month cardiac death	43 (3.7)	53 (0.6)	<.01

Data are number (%), unless otherwise stated. Abbreviations: ACS, Acute coronary syndrome; STEMI, ST-elevation myocardial infarction; NSTEMI, non-ST-elevation myocardial infarction. Arrhythmia admission is defined as admission due to sustained ventricular tachycardia or ventricular fibrillation, heart block, atrial fibrillation or atrial flutter.

Table 5. Independent predictors of recurrent hospitalizations for acute coronary syndromes and unplanned revascularizations.

	Odds Ratio	95% CI	P
Previous CABG	2.07	1.60–2.66	<.01
Heart failure	1.52	1.10–2.11	.01
Obstructive sleep apnea	1.43	1.04–1.97	.03
Female	1.37	1.19–1.59	<.01
Multi-vessel CAD	1.35	1.17–1.55	<.01
Left ventricular ejection fraction 30–45%	1.27	1.10–1.46	<.01
Previous PCI	1.26	1.06–1.50	<.01
Diabetes	1.22	1.05–1.43	.01

Abbreviations: CABG, coronary artery bypass graft; CAD, coronary artery disease; PCI, percutaneous coronary intervention.

addition and in 626 (7.4%) of patients with no unplanned recurrent coronary hospitalizations ($P < .01$).

Patients with recurrent coronary hospitalization also had higher rates of admission with heart failure (6.7% vs 2.1%, $P < .01$), arrhythmia (4.1% vs 1.6%, $P < .01$), stroke (1.2% vs 0.6%, $P = .02$) and non-cardiovascular admissions (26.0% vs 15.7%, $P < .01$).

There were 61 (5.2%) deaths in the patients with recurrent coronary events and 186 (2.2%) in patients without recurrent coronary events ($P < .01$). Most (43 [70.5%]) of the deaths in the recurrent coronary events group were cardiac in nature, while only 53 (28.5%) were cardiac deaths in those without recurrent coronary events.

Multivariate predictors of recurrent coronary events were: advanced atherosclerosis as evidenced by multi-vessel CAD, previous PCI or CABG; female gender; diabetes mellitus; left ventricular (LV) dysfunction, obstructive sleep apnea and a history of heart failure (Table 5).

A sub-analysis of patients with recurrent coronary hospitalizations due to unstable angina only revealed the difference in baseline clinical characteristics and multivariate predictors of recurrent coronary events were driven by patients presenting with NSTEMI and STEMI.

There was no difference in 12-month mortality in patients with unstable angina irrespective of whether or not they had recurrent coronary hospitalization (1.4% vs 2.2%, $P = .12$). However, this sub-group analysis is associated with reduced power.

Discussion

In our study comprising a contemporary cohort of patients with MI treated with PCI, 1 in 8 patients (12.2%) required hospitalization for recurrent ACS or an unplanned revascularization in the following year. Of these patients however, only 1 in 3 had a biomarker positive ACS. Encouragingly, during the 10-year period from 2005 to 2014, we observed a significant decrease in coronary-related hospitalizations and unplanned revascularization, though no improvement was seen in all-cause re-hospitalizations. Lastly, we identified independent predictors of hospitalization for recurrent ACS or unplanned revascularization, namely known CAD (previous CABG or PCI), multi-vessel CAD, female gender, diabetes mellitus, heart failure, LV dysfunction and sleep apnea. Although these risk factors are largely non-modifiable they identify a cohort of patients in whom non-culprit vessel PCI in multi-vessel disease, optimization of LV dysfunction and diabetes management, and close follow-up after discharge may improve outcomes.

Given the decline in mortality rates from MI over the past decade,² it is crucial to optimize secondary prevention measures in order to reduce the morbidity burden of CHD. As repeat hospitalizations are common, costly and potentially avoidable, they have become a marker of quality care.⁷ The major emphasis has been on all-cause hospitalizations at 30-days after MI. However, this is potentially flawed as only 10–43% of readmissions are related to the index MI or to symptoms of CHD.^{8–19} Furthermore 12-month follow up maybe more appropriate to assess the efficacy of secondary prevention measures.

Our study is the largest assessing 12-month re-hospitalizations for recurrent ACS or unplanned revascularization. Previously, Arnold et al reported a rate 6.8% for recurrent ACS and 4.1% for unplanned revascularizations in 3283 patients with MI.²² This is slightly lower than our combined rate of 12.2%. Interestingly, both studies reported a high rate of readmissions for biomarker negative ACS; 58% of our readmissions were due to unstable angina compared to 74% in Arnold's study.²² In another study of 9081 patients who had undergone PCI for ACS and stable angina with 30-day follow-up, 341 (4%) represented with chest pain syndromes but only 21 of these patients (6%) had an MI and 9 (3%) required target-vessel revascularization.¹² Furthermore 288 (84%) had at least one diagnostic investigation, most commonly coronary angiography. This highlights both the low risk of biomarker positive ACS in patients following PCI and the high rates of investigations in patients with biomarker negative chest pain. In the era of high-sensitivity troponin assays, patients with biomarker-negative ACS and known coronary anatomy may not necessarily, or at least routinely, require re-hospitalization.²⁷ This could significantly decrease health care spending, not only of readmission, but also on consequent investigations particularly repeat angiograms.

To our knowledge, our study is the first to describe long-term temporal trends of recurrent ACS, unplanned revascularization as well as all-cause re-hospitalization at 12 months following MI. Previous studies have focused on 30-day,¹⁵ 90-day¹⁶ or 6-month¹⁴ re-hospitalization rates. It was encouraging to observe a downward trend in the rates of recurrent ACS events and unplanned revascularizations. Most importantly this has occurred despite a decade-long trend towards older patients with a greater burden of comorbidities undergoing PCI in our registry.²⁸ We have also previously reported a significant temporal improvement in secondary prevention pharmacotherapy in our cohort, and this could partly explain the improvement trend.²⁹ Overall, our patients with recurrent coronary events actually had higher thienopyridine and β -blocker use at 12 months, with equivalent rates of aspirin and statin therapy. This suggests they were not under-treated despite being older and having more co-morbidities. However, it is also plausible the decrease in ACS re-hospitalization could be due to increasing accuracy of diagnosing biomarker negative ACS as non-ischemic chest pain, especially in the era of high-sensitivity troponin assays. Our registry does not capture details of non-cardiac diagnoses, including non-cardiac chest pain. Nonetheless reducing any chest pain admissions after MI, even if there is no biomarker elevation, and accurately ruling out ACS with high-sensitivity troponin should be a priority as these presentations are common, costly and can affect a patient's quality of life.

Although coronary-related re-hospitalizations have decreased over time, all-cause hospital readmissions have been steady in our study. This supports the notion that all-cause readmissions may not necessarily be a good measure of quality of care in patients initially presenting with MI or requiring PCI.¹⁸ This contention however is not universal as financial incentives have led to a reduction in all-cause readmissions in the United States.³⁰ In that study, from 2007 to 2015, 30-day re-hospitalization rates decreased from 21.5% to 17.8% in patients with MI, heart failure and pneumonia. The sharpest decline corresponded to the introduction of the Affordable Care Act in 2010, which applies financial penalties to hospitals with higher than expected readmission rates. Although observational unit stay numbers increased over this time period, this did not account for the overall decrease in readmission. In Australia, like in most of the developed world, there are no financial incentives to prevent recurrent hospitalization after MI. Whether financial penalties for readmissions would work in health care systems outside the United States is still unknown.

Identifying independent predictors of readmissions after MI is important to be able to understand potential deficiencies in quality of care and to implement target strategies to decrease readmission rates. However this has been particularly difficult as studies have varied patient populations, data derived from both clinical and administrative databases and differing outcomes at varying follow-up periods. A systematic review analyzed 35 studies and found few patient characteristics were consistently associated with readmissions.²⁰ Consequently, a prediction model has been developed and validated in a PCI population.²¹ Wasfy et al identified age, female gender, heart failure, chronic kidney disease, chronic lung disease, peripheral vascular disease, cardiogenic shock, presentation with MI and known CAD as pre-PCI predictors of readmission. Post-PCI predictors identified were β -blocker use at discharge, PCI complications, diabetes, drug-eluting stents and length of stay (with β -blocker use and drug-eluting stents being protective). It is apparent by the number of variables identified that readmission risk is multifactorial. Indeed, the model proposed requires multiple variables to retain sufficient predictive ability (C-statistic = 0.69), reducing its clinical utility. Other studies have also identified predictors of readmission post MI or PCI, with most but not all variables included in Wasfy's model.^{8-11,13-19,22} Six of the 8 risk factors for readmission identified in our study are present in the model proposed along with ejection fraction and multivessel CAD in our model. Given we only included patients with MI undergoing PCI, we have described a more homogenous patient population and this may explain the smaller number of independent predictors identified. It is apparent the risk factors identified for readmissions are either largely non-

modifiable or chronic disease states, thus potentially the best strategy to reduce readmission is early post-discharge follow-up and optimization of co-morbidities. However, three of the identified risk factors in our study might potentially be modified to reduce the risk of ACS re-hospitalizations. Firstly, an admission for MI requiring PCI is an opportunity to introduce or optimize therapy for LV dysfunction, which may reduce recurrent admissions. Secondly, recent data from several, small randomized studies have suggested that revascularization of non-culprit lesions in patients with STEMI reduces recurrent coronary events.³¹⁻³³ Many of our patients had multi-vessel CAD, and treatment of all lesions may have reduced readmission rates further. Lastly, secondary prevention guidelines suggest aiming for a HbA1c level < 7% in diabetic patients.³⁴ As we do not collect HbA1c levels in our registry we cannot comment on the diabetic control of the patients in our study. However, the index ACS admission is an opportunity to optimize diabetic management and this may consequently reduce recurrent ACS hospitalizations.

Our study has several limitations that warrant discussion. Firstly, as it is a PCI registry we have not included patients with MI who were treated either medically or with coronary artery bypass surgery. Although our findings are therefore only applicable to those MI patients treated with PCI, our patient population is more uniform, and is reflective of current guideline-indicated practice.³⁴ As a large number of variables are consistently associated with readmissions, perhaps specific predictive models should be used in MI patients treated with PCI, surgery or with medical therapy alone. Secondly, it is likely unaccounted variables may also be associated with readmissions. For example, we do not capture baseline quality of life and depression levels but they have been independent predictors of unplanned hospitalizations after MI.¹¹ Thirdly, we capture cardiac rehabilitation referral but not participation, which has been associated with reduced readmissions post MI.³⁵ Finally, readmission relied on patient reporting the event and medical record confirmation of details. Patient underreporting would lead to underestimation of the hospitalization rates.

Conclusion

In patients with MI treated with PCI, recurrent hospitalizations for ACS or unplanned revascularizations have decreased over the past decade. Risk factors for such events are numerous and largely non-modifiable however they identify a cohort of patients in who close follow-up after discharge may be warranted. Optimization of therapy for LV dysfunction, diabetes and non-culprit vessel PCI in patients with multi-vessel CAD may reduce readmission rates further.

Melbourne Interventional Group Investigators

MIG Data Management Centre, CCRE, Monash University
Professor Chris Reid, Dr. Nick Andrianopoulos, Ms. Angela Brennan, Ms. Vibhasha Chand, Dr. Diem Dinh.

MIG Steering Committee

Professor Chris Reid, A/Professor Andrew Ajani, Dr. Stephen Duffy, Dr. David Clark, Professor Gishel New, Dr. Melanie Freeman, Dr. Chin Hiew, Dr. Nick Andrianopoulos, Dr. Ernesto Oqueli, Ms. Angela Brennan.

The following Investigators, Data Managers and Institutions participated in the MIG Database:

Alfred Hospital: SJ Duffy, JA Shaw, A Walton, A Dart, A Broughton, J Federman, C Keighley, C Hengel, KH Peter, D Stub, W Chan, J O'Brien, L Selkrig, K Rankin, R Vandernet, R Huntington, S Pally;

Austin Hospital: DJ Clark, O Farouque, M Horrigan, J Johns, L Oliver, J Brennan, R Chan, G Proimos, T Dortimer, B Chan, V Nadurata, R Huq, D Fernando, A Al-Fiadh, M Yudi, H Sugumar, J Ramchand, H Han. S Picardo, L Brown;

Ballarat Base Hospital: E Oqueli, C Hengel, A Sharma, B Zhu, N Ryan, T Harrison;

Box Hill Hospital: G New, L Roberts, M Freeman, M Rowe, G Proimos, Y Cheong, C Goods, D Fernando, A Teh, S Parfrey, J Ramzy, A Koshy, P Venkataraman, D Flannery;

Geelong Hospital: C Hiew, M Sebastian, T Yip, Michael Mok, C Jaworski, A Hutchinson, C Cimenkaya, P Ngu, B Khialani, H Salehi, M Turner, J Dyson, B McDonald, D Van Den Nouwelant, K Halliburton;

Monash University: H Krum, C Reid, N Andrianopoulos, AL Brennan, V Chand, D Dinh, BP Yan;

Royal Melbourne Hospital: AE Ajani, R Warren, D Eccleston, J Lefkovits, R Iyer, R Gurvitch, W Wilson, M Brooks, S Biswas, J Yeoh.

Disclosures

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