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ORIGINAL ARTICLE

Temporal Changes in Characteristics, Treatment and Outcomes of Heart Failure Patients Undergoing Percutaneous Coronary Intervention Findings From Melbourne Interventional Group Registry

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Background Limited data exist on whether outcomes of patients with heart failure (HF) undergoing percutaneous coronary intervention (PCI) have improved over time. The purpose of this study was to assess temporal trends in patient characteristics, treatment and outcomes of patients with HF undergoing PCI.

Methods Using data from the Melbourne Interventional Group (MIG), we evaluated temporal trends of procedure volume, major adverse cardiac events (MACE; a composite of all-cause mortality, myocardial infarction and target vessel revascularisation) and rates of cardiovascular readmission, all-cause death and cardiovascular death in consecutive patients with HF undergoing PCI. Change over time was assessed by Box-Jenkins autoregressive integrated moving average (ARIMA) models.

Results Data from 1,604 patients were analysed. In our cohort, there were no significant changes in the number of procedures performed annually and patient characteristics between January 2005 and December 2014. Optimal use of HF therapy has improved over the study period. Planned clopidogrel therapy of more than 12 months increased in tandem with increasing use of drug-eluting stents (DES). Procedural success was high (≥90%). However, the rates of MACE, cardiovascular readmission, all-cause death and cardiovascular death remained unchanged throughout the study period.

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Conclusions Clinical outcomes in HF patients undergoing PCI have remained unchanged despite improvement in medical technology and contemporary therapeutic measures.

Keywords Heart failure • Percutaneous coronary intervention • Trends • Forecasting

Introduction

Coronary artery disease is the most common cause of heart failure (HF) in the developed world, associated with over 60% of cases [1,2]. The presence and extent of coronary artery disease may augment the progression of HF, leading to higher mortality among ischaemic compared with non-ischaemic HF patients [3].

Revascularisation is advocated to improve ventricular function and prognosis for patients with ischaemic cardiomyopathy [4], and there is an increasing number of patients with left ventricular dysfunction referred for revascularisation [5]. Both pre-existing HF and the development of *de novo* HF as a complication of acute myocardial infarction (AMI) are associated with poorer outcomes [6,7].

To date, limited data exist on temporal trends of HF patients undergoing percutaneous coronary intervention (PCI). Importantly, the impact of changing medical technology and contemporary therapeutic measures on this high risk subset of patients has not been described. To appropriately align efforts towards reducing long-term mortality and morbidity of HF patients who undergo PCI, it is crucial to understand temporal changes in this population.

The Melbourne Interventional Group (MIG) is a clinical registry that captures data pertaining to PCI at six major public hospitals in Victoria, Australia. It provided an opportunity to explore the prevalence and outcomes in the subset of patients with HF. In this study we sought to examine temporal trends in patient characteristics, treatment and outcomes among HF patients undergoing PCI over a period of 10 years.

Methods

Study Design and Patient Population

Data were drawn from the MIG registry, which has previously been described in detail [8]. In brief, MIG collects data pertaining to PCI and outcomes at six major public hospitals in Melbourne, Australia. The registry, which currently has enrolled over 25,000 patients, documents demographic, clinical and procedural characteristics of all patients undergoing PCI and captures information about medications and outcomes at 30 days and 12 months. These include rehospitalisation and its causes, death and its causes, MI and target vessel revascularisation. All adverse events are confirmed by reviewing the patients' medical records at the relevant hospitals. Cause of death outside hospital is determined by the primary physician, but not independently adjudicated.

The presence of HF in MIG is clinician-determined, and classified as either existing (present more than 2 weeks prior to the index PCI) or newly diagnosed (within 2 weeks prior to the index PCI). Clinicians determine the presence of HF on the basis of objective diagnostic criteria and/or clinical features.

Baseline patient demographics, clinical, procedural characteristics and outcomes at 1 year in each study year were analysed. Thereafter, each year of the study period was divided into quarters (January to March, April to June, July to September, and October to December). Cases were assigned to these intervals based on the date of the procedure. The primary analysis examined temporal trends of the total number of procedures and major adverse cardiac events (MACE; a composite of all-cause mortality, myocardial infarction and target vessel revascularisation). Secondary analysis evaluated trends of all-cause death, cardiovascular death and readmissions for cardiovascular causes, namely HF, AMI, recurrent angina, arrhythmia, coronary revascularisation and stroke.

Statistical Analysis

Changes in procedure volume and clinical outcomes over time were assessed by Box-Jenkins autoregressive integrated moving average (ARIMA) models, which characterise temporal changes in trend, cycles and seasons, and also allow for dynamic time series forecasting [9]. Raw data were converted to their natural logarithm values to stabilise the variance of the time series and improve the estimation. The shift in trends of procedure volume and event rates were assessed by the augmented Dickey Fuller test, which tests for 'stationarity' in the data series. We also assessed autocorrelation and partial autocorrelation functions to assess the models' stationarity and the Portmanteau (Q) test to assess 'white noise' [10]. Goodness-of-fit was assessed using minimal Akaike and Bayesian Information Criteria (AIC and BIC, respectively). The predictive accuracy of the models were validated with actual observations in 40 quarters (1 January 2005 to 31 December 2014) and assessed by mean absolute percentage error (MAPE). MAPE of less than or equal to 10% indicates highly accurate forecasts; $10\% < \text{MAPE} < 20\%$ indicates good forecasts; $20\% < \text{MAPE} < 50\%$ indicates reasonable forecasts and MAPE indicates inaccurate forecasts [11]. We explored various formulations of the ARIMA model, and selected the best performing model with the lowest overall values of AIC, BIC and MAPE.

For the present study, we included all patients who were documented as having HF and underwent PCI between January 2005 and December 2014 in the analyses of patient and procedural characteristics. For the time series analyses, we excluded data from year 2004 (when the registry was established) and also cases from two of the six hospitals (one joined the registry in 2012 while the other had approximately

25% incomplete 12-month follow-up data). These data were excluded (i) to avoid 'ramp-up' in the series (sudden increase in the capacity as sites were introduced to the registry), hence affecting the assessment of the stationarity of the models, and (ii) to reduce bias that results from incomplete follow-up. All statistical analyses were performed using Stata 14 (StataCorp, College Station, TX, USA).

Results

Tables 1 and 2 summarise patient and procedural characteristics for the cohort. A total of 1,604 HF patients (7.1% of the overall cohort) were included in the MIG registry between 2005 and 2014. Overall, patients had a weighted mean age of 70.2 years, 71% were male, 68% had a history of smoking and 64.4% had no or mild HF symptoms (i.e. New York Heart Association [NYHA] functional class I and II). In addition, 78.5% were hypertensive, 74.6% were dyslipidaemic and 71.7% were overweight/obese (BMI $\geq$ 25 kg). There was a gradual increase in the uptake of guideline-directed medical therapies for HF. Overall, more than 80% of the patients were treated with guideline-directed medical therapies, namely ACE inhibitors/ARB, beta blockers, statins, aspirin and clopidogrel. The demographic and clinical characteristics of these patients remained similar throughout the study period.

A total of 1,957 lesions were treated in the study period, with a weighted mean of 1.2 lesions per patient. A total of 68% of the procedures were documented as urgent and procedural success rate was 93.9%. A total of 76.3% of patients had multi-vessel disease, 29.9% had ST-elevation MI (STEMI) and 16.2% had cardiogenic shock at presentation. Of note, we observed that there was a shift towards the use of drug eluting stents from bare metal stents, and also a transition to longer planned duration of clopidogrel ($\geq$12 months) from shorter planned duration ($\leq$3 months) after coronary stenting. At 1-year post-PCI, 28.8% of patients experienced MACE, 23.7% were readmitted for cardiovascular causes, 7.3% died from any cause and 3.7% died from cardiovascular causes.

The characteristics of the selected models are summarised in Table 3. The predictive accuracy of the selected models was high, with MAPE less than 10%. Despite fluctuations from quarter-to-quarter and short-run increases and decreases in the observed trends, the procedure volume and event rates over the 10-year period in patients with HF were found to be stationary, as confirmed by the Dickey-Fuller test. This means that the differences observed between time points were not statistically significant, with the data series meeting the criterion for 'stationarity' over the duration of the assessment period. With the assumption that there are no major changes in procedural practices within the hospitals under study over the short to medium term, these trends are expected to continue. Figures 1 and 2 illustrate the observed and forecasted values for all outcomes of interest and the total number of procedures performed in each quarter, in the log-transformed formats.

Discussion

We described temporal changes in patient characteristics, treatment and outcomes of HF patients undergoing PCI over a time period of 10 years in the Australian public hospital setting. Our group has previously reported trends in baseline characteristics and outcomes among overall patients enrolled in the MIG registry [12]. As anticipated, patients with HF in the registry were elderly, with multiple diseased coronary vessels and co-morbidities. There was greater use of drug eluting stents and prolonged use of dual antiplatelet therapy over the time period of the study. The overall rates of MACE, all-cause mortality, cardiovascular death and cardiovascular readmissions were relatively high but remained stable throughout the study period. These observations occurred on a background of optimal pharmacological treatment for both HF and coronary heart disease. These trends are expected to continue.

Direct comparison with data from other studies is difficult in view of inherent differences in their study designs, definitions and changing diagnostic criteria over time. Nevertheless, observational data suggest that prognosis of HF patients with significant coronary artery disease has remained poor over the last few decades. A meta-analysis of 19 observational studies suggested that long-term ($\geq$1 year) mortality rate of patients with left ventricular systolic dysfunction undergoing PCI was 15.6% [13]. Najafi et al. reported that the 1-year mortality among patients with early onset HF post-MI was 4% (95% CI: 2.9 to 5.5). In the same study, 10-year survival did not improve after adjusting for potential confounders between 1984 and 1993 [14]. Spencer et al. reported that the 1-year post-discharge mortality rate in patients with HF complicating AMI was about 21%, and remained unchanged over the 20-year period between 1975 and 1995, even after controlling for potential confounders [15]. A large observational study in Canada reported that, among those who survived the index AMI hospitalisation, the 5-year mortality rate was 39.1% for those with HF compared to 26.7% among those without HF ($p < 0.0001$) [16]. It is worth noting that these data were obtained from an era where procedural and medical therapies were less sophisticated than current practice.

A recent analysis by Spoon et al. examining trends in cause-specific long-term mortality after index PCI at a single centre suggests a switch from predominantly cardiac to non-cardiac causes of death among patients undergoing PCI over the past two decades [17]. We did not observe such a change in our analysis, but compared to our study population, patients in Spoon's study were younger (mean age 66 years) and had less multivessel disease (64%) and HF (12%). The two study populations, however, did have similar prescribing rates of aspirin, statins, beta blockers and anti-platelets.

In Australia, various initiatives to improve performance of care at a national level have led to improved door-to-balloon time in patients with STEMI, time to acquire and interpret 12-lead electrocardiogram before and after arrival at the hospital, along with timeliness to get catheterisation laboratory ready after mobilisation [18]. Whether we are observing a 'plateau' in outcomes among patients with HF undergoing

Table 1 Patient characteristics by year.

Patient characteristics	Year										Total population[#]
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	
Number of patients	116	187	164	147	167	117	151	188	211	156	1,604
Age, yr (median)	72.0	73.0	72.0	72.0	71.0	71.0	72.0	71.0	71.0	73.0	71.8
Men, %	68.1	73.3	71.3	68.0	73.7	71.8	66.9	67.0	76.8	70.5	71.0
Race, %											
Caucasian	97.4	93.6	95.1	98.0	97.0	93.1	97.4	96.3	93.8	89.1	95.0
Asian	2.6	1.6	1.2	0.7	1.2	3.4	–	1.1	1.4	5.1	1.9
Aboriginal/Torres Strait Islander	–	0.5	1.2	0.7	0.6	–	–	–	1.0	–	0.8
Indian/Sri Lankan/Pakistan/Bangladesh	–	1.6	2.5	0.6	–	2.6	–	1.0	2.4	1.9	1.8
Others	–	2.7	–	–	1.2	0.9	2.6	1.6	1.4	1.9	1.8
Smoking history, %	59.3	66.1	77.0	70.8	74.6	65.5	61.7	62.0	69.5	70.8	68.0
Systolic blood pressure, mmHg	–	–	–	–	126.6	124.1	122.9	121.0	122.2	124.2	123.4
Heart rate, beats/min	–	–	–	–	76.8	76.9	79.8	74.3	77.6	71.7	76.2
Serum creatinine, mg/dL	1.5	1.7	1.5	1.6	1.5	1.4	1.6	1.4	1.4	1.5	1.5
eGFR, ml/min/1.73 m^2											
<30	8.7	12.7	8.6	13.8	10.9	10.4	16.3	11.6	12.9	15.2	12.2
30–59	43.5	43.6	45.4	40.0	35.5	34.8	35.4	35.9	38.6	40.0	39.3
≥60	47.8	43.7	46.0	46.2	53.6	54.8	48.3	52.5	48.5	44.8	48.5
Body mass index, kg/m^3 (mean)	28.3	28.5	28.1	28.5	29.6	27.9	27.9	29.1	29.2	28.0	28.6
<20	6.0	4.4	6.9	4.8	3.5	5.4	5.6	2.8	3.8	5.6	4.8
20–24.9	23.9	31.9	23.8	20.0	21.5	22.3	28.2	20.6	20.8	22.9	23.6
25–29.9	38.8	30.8	38.6	34.3	35.4	44.6	38.0	36.6	37.7	38.2	37.0
≥30	31.3	32.9	30.7	40.9	39.6	27.7	28.2	40.0	37.7	33.3	34.7
NYHA, %											
I & II	67.3	52.2	61.0	62.4	67.1	64.5	60.7	69.9	72.0	66.4	64.4
III & IV	32.7	47.8	39.0	37.6	32.9	35.5	39.3	30.1	28.0	33.6	35.6
Mean EF, %	42.5	44.5	40.3	39.8	41.6	41.9	40.5	43.7	39.9	43.5	41.8
Admission status, %											
Referral	2.6	4.3	1.8	0.7	0.6	1.7	6.0	1.1	1.9	5.8	2.6
Elective	42.3	29.4	36.0	24.5	26.3	32.5	15.9	25.5	22.3	23.7	27.2
Emergency department	43.1	49.2	48.8	46.3	50.3	44.4	55.0	47.9	52.1	46.1	48.7
Transfer from other facility	10.3	16.6	9.8	19.7	19.8	17.1	16.5	19.1	17.5	19.9	16.8
Others	1.7	0.5	3.6	8.8	3.0	4.3	6.6	6.4	6.2	4.5	4.6
Previous interventions, %											
Previous PCI	22.4	20.3	30.5	29.9	33.5	47.9	34.4	32.5	31.3	30.1	30.9
Previous CABG	15.5	22.5	30.5	17.7	19.8	17.1	18.5	21.8	19.4	16.7	20.3
Previous valvular surgery	1.7	2.1	1.8	2.7	2.4	1.7	2.7	2.7	2.4	5.1	2.6
Medical history, %											
Hypertension	72.4	78.1	78.7	78.2	78.4	78.6	80.8	80.2	79.2	81.4	78.8
Previous MI	36.0	47.9	56.7	53.1	46.7	58.1	43.7	48.1	45.2	42.3	47.8
Atrial fibrillation[‡]	–	–	16.3	14.9	16.8	15.4	14.6	17.7	17.1	10.3	15.5
Diabetes mellitus	28.7	41.2	43.3	46.3	40.1	43.6	37.1	43.9	42.7	44.9	41.5
Diet[!]	9.1	19.5	15.4	17.7	10.5	9.8	16.1	15.9	11.1	21.4	14.9
Oral hypoglycaemic agents[!]	54.6	62.3	56.3	47.1	53.7	64.7	55.4	52.4	57.8	55.7	56.0
Insulin[!]	39.4	28.6	31.0	33.8	43.3	35.3	37.5	41.5	43.3	31.4	36.7
Dyslipidaemia	71.6	76.6	78.5	79.9	77.3	72.4	75.5	66.8	71.6	76.3	74.6
Chronic kidney disease	9.5	11.2	7.3	11.6	9.6	10.3	14.6	9.0	11.4	11.5	10.6
Cerebrovascular disease	6.1	14.1	14.0	18.5	22.8	15.4	15.9	11.2	12.8	13.5	14.5
Obstructive sleep apnoea	4.4	5.4	6.7	5.4	6.6	6.0	9.9	5.9	7.1	9.6	6.7

Table 1. (continued).

Patient characteristics	Year										Total population[#]
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	
Peripheral vascular disease	12.3	13.5	22.4	24.5	15.0	17.1	15.2	13.9	15.7	10.3	15.9
Rheumatoid arthritis	8.3	1.6	2.4	2.7	1.2	2.6	5.3	3.7	2.8	1.9	3.1
COPD/Asthma	16.4	17.7	19.5	12.9	19.2	16.2	19.9	20.2	23.7	17.3	18.6
Medications at 30-days post-PCI, %											
ACE inhibitor/ARB	78.7	75.7	84.0	85.7	80.0	82.4	81.7	78.1	80.0	76.1	80.1
BB	72.3	69.8	68.8	81.6	86.9	80.4	86.7	88.7	84.4	86.2	80.8
MRA	–	19.6	14.4	16.3	12.4	22.6	23.1	20.8	24.3	23.3	19.7
Statins	85.1	81.4	88.0	89.1	93.1	93.0	89.2	92.5	90.8	88.8	89.1
Aspirin	93.6	91.5	92.8	97.1	98.5	97.1	96.7	98.1	88.6	96.6	94.8
Clopidogrel	87.2	92.9	94.4	92.2	93.2	89.3	93.5	81.8	66.9	70.9	85.5
Prasugrel	–	–	–	–	1.2	3.4	2.7	6.9	5.7	5.8	4.5
Ticagrelor	–	–	–	–	–	–	–	4.8	14.2	13.5	10.8
Outcomes at 12 months, %[¶]											
MACE	26.7	30.7	28.7	30.3	29.5	27.5	33.6	35.9	22.8	21.5	28.8
All-cause mortality	6.7	10.0	7.4	7.1	3.3	5.5	6.2	11.1	6.3	8.4	7.3
CV death	3.3	6.0	3.7	2.0	1.6	4.4	1.8	6.8	3.2	–	3.7
Non-CV death	3.3	4.0	2.8	4.0	1.6	–	4.4	2.6	3.2	5.6	2.9
Hospitalisation for CV causes	25.6	24.7	23.2	25.3	31.2	26.4	23.0	25.6	26.0	4.7	23.7

Abbreviations: eGFR, estimated glomerular filtration rate; NYHA, New York Heart Association functional classification; EF, ejection fraction at procedure; PCI, percutaneous coronary intervention; CABG, coronary artery bypass graft; ACEI, angiotensin-converting enzyme inhibitors; ARB, angiotensin receptor blockers; BB, beta blockers; MRA, mineralocorticoid receptor antagonists; MACE, major adverse cardiac events.

[‡]At the commencement of the procedure.

[#]Sample size-weighted mean.

[!]Denominator is total number of patients with diabetes.

[¶]Excluded two hospitals to avoid 'ramp-up' issues and bias (as discussed in methods section).

PCI remains unclear. These patients represent the most complicated and frail cohort, with poorer prognosis compared with the general population undergoing PCI.

To date, data that exist on revascularisation in patients with coronary artery disease and left ventricular systolic dysfunction are more robust for coronary artery bypass grafting (CABG) than for PCI [19]. A recent report from Surgical Treatment for Ischemic Heart Failure Extension Study (STICHES) showed that CABG, in addition to optimal medical therapy, conferred a significant clinical benefit over medical therapy alone for up to 10 years in HF patients [20]. A meta-analysis by Wolff et al. concluded that revascularisation strategies are superior to medical treatment in patients with reduced ejection fraction and CAD, in particular CABG had more favourable outcomes compared with PCI in this setting [21]. Interestingly, PCI using everolimus-eluting stent was found to be associated with a similar survival compared with CABG in patients with multivessel disease and severe left ventricular systolic dysfunction, although PCI was associated with increased risk of repeat revascularisation and MI (in those with incomplete revascularisation) whereas CABG was associated with higher risk of stroke [22].

Contemporary clinical practice guidelines generally favour CABG over PCI for revascularisation in patients with chronic HF and systolic left ventricular dysfunction. Specifically, the 2014 European Society of Cardiology (ESC) and the European Association of Cardio-Thoracic Surgery (EACTS) ascribed a class IIb recommendation for PCI in this subgroup [23]. In contrast, there was no recommendation from the 2012 American College of Cardiology Foundation (ACCF)/American Heart Association (AHA) regarding the use of PCI in the same population [24].

The importance of optimising medical therapy in HF patients with significant coronary artery disease cannot be understated. Adherence to guideline-recommended HF treatment is associated with improved outcomes [25,26]. On a broader scope, findings from both Clinical Outcomes Utilizing Revascularization and Aggressive Drug Evaluation (COURAGE) trial and Bypass Angioplasty Revascularization Investigation 2 Diabetes (BARI 2D) Study reaffirmed the need to optimise evidence-based medical therapy in patients with stable coronary artery disease undergoing revascularisation [27].

The knowledge of myocardial viability may aid decision-making in the catheterisation laboratory and subsequently improve outcomes in these high risk ischaemic HF patients. The frequency of dysfunctional but viable myocardium in this sub-population is estimated to be around 60% [28]. Several meta-analyses have consistently concluded that evidence of myocardial viability is associated with improved survival after

Table 2 Procedural characteristics by year.

Procedural characteristics	Year										Total population[#]
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	
Number of procedures	116	187	164	147	167	117	151	188	211	156	1,604
Number of lesions treated	135	222	198	189	208	143	188	228	246	200	1,957
Number of lesions treated (mean)	1.2	1.2	1.2	1.3	1.3	1.2	1.2	1.2	1.2	1.3	1.2
ST elevated myocardial infarction	23.3	28.9	29.3	28.6	32.9	25.6	33.1	34.0	33.7	25.0	29.9
Cardiogenic shock	11.2	14.4	17.1	17.0	14.4	12.8	20.5	19.7	19.0	12.2	16.2
HF at presentation	78.5	70.1	79.3	71.4	76.7	65.0	75.5	70.2	70.6	53.9	71.1
PCI status											
Elective, %	43.1	30.0	37.8	24.5	23.4	30.7	18.5	26.0	23.7	41.7	29.4
Urgent, %	52.6	66.3	61.0	74.8	75.4	68.4	80.8	71.3	74.4	57.7	68.8
Rescue, %	4.3	3.7	1.2	0.7	1.2	0.9	0.7	2.7	1.9	0.6	1.8
Disease extent											
Multivessel disease	70.8	80.7	76.2	80.3	73.0	75.2	72.2	80.8	76.3	74.4	76.3
Vessel treated											
Left main coronary artery	1.7	4.8	7.9	3.4	2.4	2.6	2.7	6.4	5.2	5.1	4.4
Left anterior descending artery	46.6	31.6	37.8	41.5	41.3	45.3	45.0	37.8	36.0	39.1	39.5
Left circumflex artery	16.4	18.7	17.1	17.7	17.4	12.8	19.9	17.0	18.5	14.7	17.2
Right coronary artery	23.3	25.1	21.3	25.9	29.9	29.9	25.8	24.5	28.0	30.1	26.4
Lesion characteristics											
B2 & C	55.6	59.0	57.1	61.2	62.3	62.4	57.6	68.6	64.5	71.2	62.3
Bifurcation	11.2	9.6	14.6	16.3	6.6	13.7	13.9	11.2	12.3	18.6	12.7
Ostial	0.9	7.5	13.4	9.5	13.8	12.0	15.9	9.6	10.4	18.0	11.3
TIMI flow grade pre-PCI											
0	19.7	21.7	21.8	25.5	23.1	18.2	23.4	28.0	27.2	16.0	22.8
1	3.8	2.3	2.0	4.3	4.3	7.7	5.9	3.1	5.3	6.0	4.4
2	6.8	12.4	10.2	11.2	12.5	8.4	5.9	15.8	10.6	6.5	10.3
3	69.7	63.6	66.0	59.0	60.1	65.7	64.8	53.1	56.9	71.5	62.5
TIMI flow grade post-PCI											
0	3.8	2.7	2.5	2.1	3.9	–	2.7	5.7	4.5	3.0	3.5
1	0.7	–	2.0	1.1	0.5	2.8	–	1.3	2.4	0.5	1.4
2	3.0	4.5	2.5	2.7	1.9	0.7	1.1	1.8	0.8	3.5	2.3
3	92.5	92.8	92.9	94.2	93.7	96.5	96.2	91.2	92.3	93.0	93.4
Lesion result, %											
Successful	100.0	96.0	94.4	95.8	93.3	94.4	94.7	90.8	91.1	92.0	93.9
Stent type											
Balloon only	9.6	5.9	9.6	11.1	13.5	9.8	11.2	13.6	12.2	11.0	10.8
Bare-metal stent (BMS)	41.5	43.2	57.1	60.3	52.4	44.8	53.2	43.0	37.4	21.5	45.2
Drug-eluting stent (DES)	48.9	50.9	33.3	28.6	34.1	45.4	35.6	43.4	50.4	67.5	43.9
Mean stent diameter (mm)	2.9	3.0	2.9	2.9	3.1	3.0	2.90	3.0	2.9	2.9	3.0
Mean stent length (mm)	17.4	16.7	17.1	17.8	17.8	16.9	16.8	18.4	17.9	18.3	17.5
Glycoprotein IIb/IIIa inhibitor	36.2	36.0	30.5	29.3	31.1	29.9	29.1	33.0	22.8	20.5	29.6
Planned duration of clopidogrel											
≤3 months	30.3	29.1	41.7	55.1	48.1	31.2	37.1	29.9	23.3	14.4	33.6
6months	22.9	17.1	3.2	1.4	2.5	0.9	1.4	2.3	1.0	1.4	5.1
≥12 months	46.8	53.7	55.1	43.5	49.4	67.9	61.4	67.8	75.7	84.2	61.2

Abbreviation: PCI, percutaneous coronary intervention; HF, heart failure.

[#]Sample size-weighted mean.

Table 3 Goodness-of-fit and predictive accuracy of the selected ARIMA models.

Variable*	ARIMA model	AIC#	BIC†	MAPE‡
Total number of procedure	2,0,1	−4.068	2.265	0.52%
MACE rate	0,0,2	35.985	42.319	1.22%
CV readmission rate	1,0,0	31.225	35.975	0.27%
All-cause death rate	2,0,2	68.063	75.970	5.27%
CV death rate	2,0,1	60.036	67.518	5.38%

Abbreviations: ARIMA, autoregressive integrated moving average; AIC, Akaike Information Criteria; BIC, Bayesian Information Criteria; MAPE, mean absolute percentage error; MACE, major adverse cardiac events; CV, cardiovascular.

*All variables were converted to their natural logarithm. The event rates were calculated per 100 procedures.

#Akaike's Information Criterion.

†Bayesian Information Criterion.

‡Mean absolute percentage error.

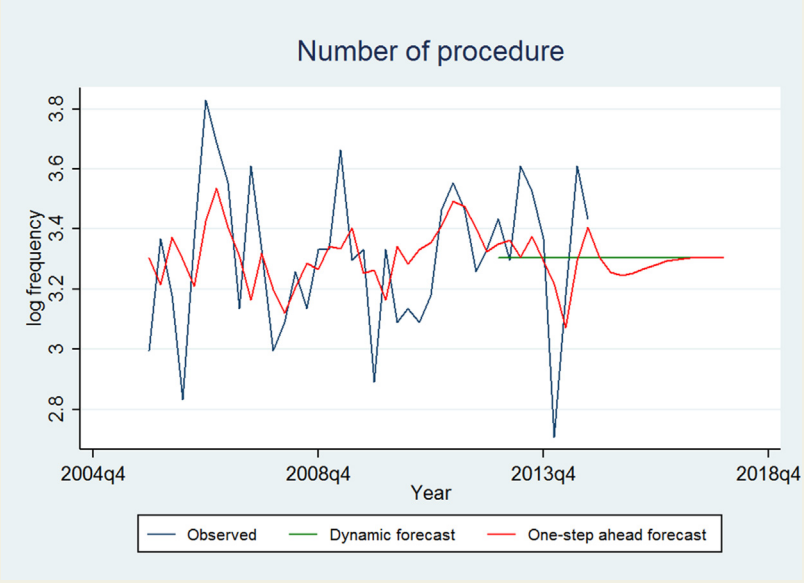

Figure 1 Trends and forecasts in procedure volume.
Trends and forecasts in procedure volume in the log-transformed format. The blue line represents the total number of procedures performed in each quarter. The green and red lines depict the predicted number of procedures using dynamic and one-step ahead forecasts, respectively. Despite fluctuations from quarter-to-quarter, there were no significant changes in the observed and predicted number of procedures performed over a period of 10 years. The trend is expected to continue.

revascularisation [29,30]. Data from recent trials have been inconclusive [31,32]. The potential benefits of myocardial viability testing and its feasibility to be implemented in 'real-world' clinical practice; with the aim to better identify ischaemic HF patients who are likely to have improved outcome and symptomatic benefit after PCI, deserves further exploration. Unfortunately, there was no systematic collection of myocardial viability in our PCI registry.

Limitations

Several limitations in our study warrant mention. Our analyses are descriptive and do not provide causal explanations for the observations. The ARIMA models may be limited by the operational characteristics of the four sites studied and may not be representative of other centres. However, all sites under consideration are large, tertiary referral institutions and perform high volumes of PCI. Separate subgroup analyses based on important clinical characteristics such as acute/chronic HF, ejection fraction and cardiogenic shock were not performed because of the relatively small sample size and event rates within each quarter after stratification. We did not further explore the association between the rates of stent type (DES vs BMS) use, planned duration of dual antiplatelet therapy ($\leq$3 months vs $\geq$12 months) and the temporal trends as full knowledge of the underlying explanatory factors (e.g. site capacity and/or system issues) over the

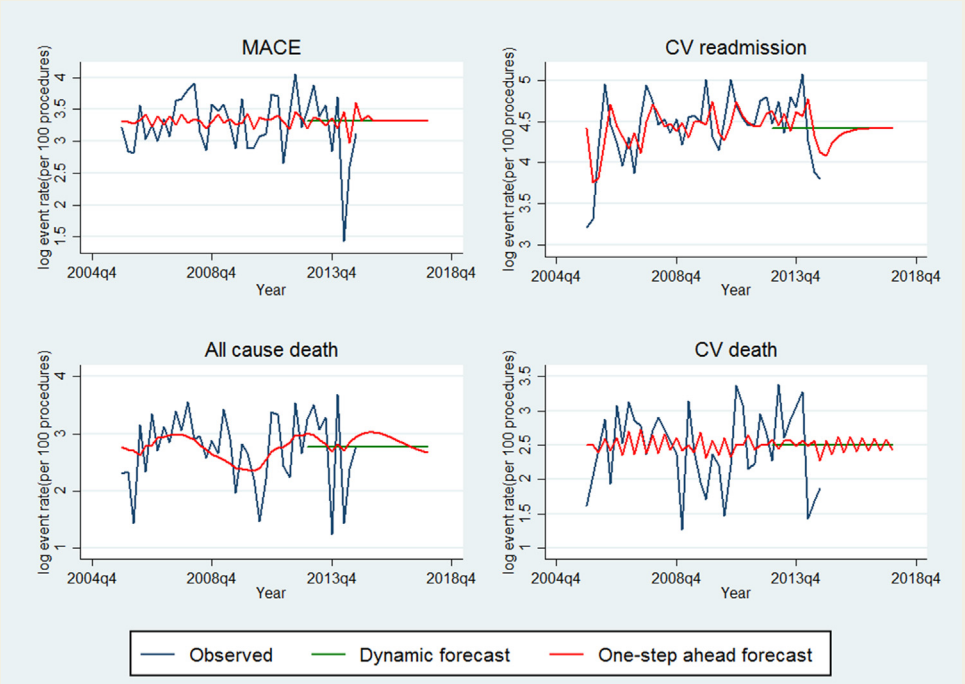

Figure 2 Trends and forecasts in outcomes of interest.
The blue line represents the observed outcomes in each quarter. The green and red lines depict the predicted outcomes using dynamic and one-step ahead forecasts, respectively. Despite fluctuations from quarter-to-quarter, there was no significant growth in the observed and predicted rates of outcomes over a period of 10 years. The trends are expected to continue.

observed period was not known or recorded. Data misclassification may have been present, as in any clinical registry dependent on data capture from clinical sites. However, to our knowledge, there was no differential data misclassification between subgroups, which would have led to information bias. Lastly, changes in the clinical practice guidelines, health policy and diagnostic technologies and strategies may have confounded our findings.

Conclusion

In conclusion, we found that the temporal changes in patient characteristics, treatment and outcomes of patients with HF undergoing PCI enrolled in the MIG registry remained relatively stable from 2005 to 2014. We predict that these trends would persist over the short-term.

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Conflict of Interest

The authors have no conflicts of interest to declare.

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