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Differences in outcome of percutaneous coronary intervention between Indigenous and non-Indigenous people in Victoria, Australia: a multicentre, prospective, observational, cohort study

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Summary

Background Data on the patient characteristics and health outcomes of Indigenous Australians having revascularisation for treatment of coronary artery disease are scarce. The aim of this study was to assess differences in patient characteristics, presentations, and outcomes among Indigenous and non-Indigenous Australians having percutaneous coronary intervention (PCI) in urban and larger regional centres in Victoria, Australia.

Methods In this multicentre, prospective, observational cohort study, data were prospectively collected from six government-funded tertiary hospitals in the state of Victoria, Australia. The Melbourne Interventional Group PCI registry was used to identify patients having PCI at Victorian metropolitan and large regional hospitals between Jan 1, 2005, and Dec 31, 2018. The primary outcome was long-term mortality. Secondary outcomes were 30 day mortality and 30 day major adverse cardiovascular events (MACE), defined as a composite endpoint of death, myocardial infarction, and target-vessel revascularisation. Regression analyses, adjusted for clinically relevant covariates and geographical and socioeconomic indices, were used to establish the influence of Indigenous status on these study outcomes.

Findings 41 146 patient procedures were entered into the registry, of whom 179 (0·4%) were recorded as identifying as Indigenous Australian, 39 855 (96·9%) were not Indigenous Australian, and 1112 (2·7%) had incomplete data regarding ethnicity and were excluded. Compared with their non-Indigenous counterparts, Indigenous patients were younger, more often women, and more likely to have comorbidities. Indigenous Australians were also more likely to live in a regional community and areas of socioeconomic disadvantage. Procedural success and complication rates were similar for Indigenous and non-Indigenous patients having PCI. At 30 day follow-up, Indigenous Australians were more likely to be taking optimal medical therapy, although overall follow-up rates were lower and prevalence of persistent smoking was higher. Multivariable analysis showed that Indigenous status was independently associated with increased risk of long-term mortality (hazard ratio 2·49, 95% CI 1·79–3·48; p<0·0001), 30 day mortality (odds ratio 2·78, 95% CI 1·09–7·12; p=0·033), and 30-day MACE (odds ratio 1·87, 95% CI 1·03–3·39; p=0·039).

Interpretation Indigenous Australians having PCI in urban and larger regional centres are at increased risk of mortality and adverse cardiac events. Clinically effective and culturally safe care pathways are urgently needed to improve health outcomes among Indigenous Australians who are having PCI.

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Introduction

The past three decades have seen marked advances in treatments for cardiovascular disease, resulting in improved outcomes globally. Yet these improvements in care and outcomes have not necessarily been distributed equally, and health disparities for some population groups remain. In Australia, a substantial gap in life expectancy remains between Indigenous Australians and non-Indigenous Australians, a large portion of which is related to cardiovascular disease.[1–3] The difference in incidence of acute coronary syndromes and ischaemic heart disease is particularly notable, and has a major role in premature mortality among Indigenous Australian populations.[3–5]

Encouragingly, there have been substantial improvements in health outcomes for Indigenous Australians over the past 15–20 years.[6] Mortality caused by cardiac conditions among Indigenous Australians has almost halved since 1998, and access to timely diagnosis and guideline-based therapies for cardiac disease have improved.[6] However, challenges remain, including disparities in access to angiography and revascularisation among Indigenous Australians, and a widening of the gap has been observed among some parameters, such as rates of cardiovascular hospital admissions.[6–8] Further, data on patient characteristics and outcomes among Indigenous Australians who proceed to percutaneous

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See Online for appendix

Research in context

Evidence before this study

We searched Ovid MEDLINE on Feb 3, 2021, for papers published from inception until Feb 3, 2021, using the search terms "Indigenous Australians.mp", "health services, Indigenous" or "Aboriginal and Torres Strait Islander.mp" combined with the AND function using the search terms "angioplasty, balloon, coronary", "percutaneous coronary intervention", "revascularisation.mp", "myocardial infarction", "coronary artery bypass", or "coronary artery bypass graft.mp", with no language restrictions. We also did a further search of references, grey literature, and relevant government reports. Several studies have assessed access to care and outcomes among Indigenous Australians presenting with myocardial infarction or in those who have had coronary-artery bypass surgery. However, few studies present long-term follow-up, and data regarding Indigenous Australians in the state of Victoria are especially scarce. No studies (outside of abstracts) were identified that specifically assessed outcomes of percutaneous coronary intervention (PCI).

Added value of this study

This study evaluates disparities in characteristics and outcomes between Indigenous and non-Indigenous Australians having PCI between 2005 and 2018 in Victoria, Australia—a state of approximately 6·4 million people in the southeastern part of the country. Compared with their non-Indigenous counterparts, Indigenous patients were younger, more often women, more likely to have comorbidities, and more likely to live in regional communities and areas of socioeconomic disadvantage. Procedural success was similar between groups, but Indigenous Australians were more likely to be taking optimal medical therapy at 30 days, although follow-up rates were lower and persistent smoking higher. Indigenous status was associated with more than twice the risk of long-term mortality during a median of 5 years of follow-up, independent of age, comorbidities, presentation, socioeconomic status, and geographical remoteness. Independently higher risk of mortality and major adverse cardiovascular events at 30 days was also observed.

Implications of all the available evidence

Despite improvements in access to cardiovascular care and health outcomes over the past two decades, Indigenous Australians having coronary intervention in larger urban and regional centres appear to be at higher risk of worse outcomes, independent of socioeconomic status and geographical remoteness. Clinically effective and culturally safe care pathways are urgently needed to improve health outcomes among Indigenous Australians who are having PCI.

coronary intervention (PCI), the most common form of revascularisation, are scarce. Given the inequalities related to cardiovascular disease outcomes, identification of any differences in PCI cohorts and potential explanations for these differences could highlight systems of care that can be improved.

This study sought to assess differences in patient characteristics, presentations, and outcomes between Indigenous and non-Indigenous Australians having PCI in urban and larger regional centres in Victoria, Australia, a state of approximately 6·4 million people in the southeastern part of the country, which accounts for 7·2% of Australia's Indigenous population.[9]

Methods

This was a multicentre, prospective, observational cohort study of consecutive adult patients having PCI procedures between Jan 1, 2005, and Dec 31, 2018, who were prospectively enrolled in the Melbourne Interventional Group (MIG) PCI registry. Differences in patient characteristics, treatments, and clinical outcomes were assessed by Indigenous status.

Data sources and setting

The MIG registry is a voluntary PCI registry, established in 2004, that prospectively collects PCI data from six government-funded tertiary hospitals in the state of Victoria, Australia (four in Melbourne, one in Geelong, one in Ballarat).[10] All participating centres provide 24 h catheterisation laboratory services, and four of the six centres have on-site cardiothoracic surgery. The MIG registry hospital network covers approximately 25–35% of all PCI procedures done in the state, and 40–50% of PCI procedures done for ST-elevation myocardial infarction (STEMI) with some yearly variation.[11] Demographic, clinical, and procedural characteristics are recorded on standardised case-report forms at the time of index PCI, with 30 day outcome data and medication data collected by site nurse coordinators via telephone follow-up or record review. Long-term mortality is derived through periodic linkage with the Australian National Death Index (median follow-up 5·0 years). Approval was gained from each individual hospital's ethics committee before commencement of the registry and opt-out informed consent was obtained in all patients. Ethics approval for this specific analysis was also gained from the Alfred Hospital Ethics Committee (approval number 156/20). In Victoria, a coordinated approach to Indigenous health research and Indigenous data governance is needed. In 2021, the Victorian Aboriginal Community Controlled Health Organisation (also known as VACCHO) commenced development of a Victorian Aboriginal Research Accord. In the absence of such an accord, two Indigenous researchers (LB and JO'B) and members of the Victorian Aboriginal community were engaged across all phases of the research project. Knowledge arising from

the Victorian Aboriginal Research Accord Project will be used to guide the research team on how to best create value from Indigenous data in ways that are grounded in Victorian Aboriginal worldviews.

Study definitions

Indigenous status was established from the standardised MIG case-report form, which was based on hospital records or patient reports according to Australian national best-practice guidelines.[12] The standard question, "Are you of Aboriginal or Torres Strait Islander origin?", is mandatory for health services at first registration of all patients.[12] Although this question is government mandated, adherence to this protocol is not uniform across health services and under-identification of Indigenous status in health cohorts is well described.[13]

Geographical remoteness was established through each patient's residential area postcode using the Accessibility and Remoteness Index of Australia (ARIA), a geographical accessibility index that divides Australia into five classes of remoteness (major city, inner regional, outer regional, remote, and very remote) to reflect relative access to services in non-metropolitan Australia.[14] Because of low numbers of patients in the registries from remote or very-remote regions, these groups were combined with the outer regional group for the purposes of this study.

Socioeconomic status was determined using the Index of Relative Socioeconomic Disadvantage (IRSD) score, a well validated system that uses national census data that ranks each residential postcode into deciles on the basis of household income, unemployment rate, home ownership and motor-vehicle ownership, educational level, and non-English speaking background.[15] For the purposes of this study, we divided the IRSD score into quintiles, with the first quintile including patients living in the lowest two IRSD-score deciles (most disadvantaged) and the fifth quintile including patients living in the highest two IRSD-score deciles (least disadvantaged).

Indication for PCI was classified as STEMI, non-ST elevation acute coronary syndrome (NSTEACS), and non-acute coronary syndrome (non-ACS) presentations according to standard definitions.[16,17] Transferred patients were defined as patients who initially presented to a non-PCI-capable centre and were transferred to a PCI centre. PCI for STEMI was classified into four categories as follows: primary PCI (within 24 h); late-presentation PCI (>24 h without previous thrombolysis); rescue PCI (PCI following failed thrombolysis as evidenced by ongoing ischaemic chest pain, haemodynamic instability, or residual ST elevation of ≥50%); and post-successful thrombolysis PCI (PCI following successful thrombolysis as evidence by resolution of ischaemic chest pain and a reduction in ST elevation of ≥50%).

Outcomes

The primary outcome of the study was long-term mortality. Secondary outcomes were 30 day mortality and 30 day

	Indigenous	Non-Indigenous	p value
Demographics			
Ethnicity	179 (<1%)	39 855 (>99%)	..
Age	53 (11)	65 (12)	<0·0001
<50 years	68 (38%)	4373 (11%)	<0·0001
50–59 years	69 (39%)	9032 (23%)	..
60–69 years	30 (17%)	11 759 (30%)	..
70–79 years	10 (6%)	9955 (25%)	..
≥80 years	2 (1%)	4736 (12%)	..
Gender			
Female	62 (35%)	9290 (23%)	<0·0001
Male	117 (65%)	30 565 (77%)	..
BMI (kg/m²)	29 (6)	29 (5)	0·37
ARIA			
Major city	46 (26%)	27 167 (69%)	<0·0001
Inner regional	56 (32%)	9953 (25%)	..
Outer-regional remote or very remote	74 (42%)	2483 (6%)	..
IRSD quintile			
1 (most disadvantaged)	86 (49%)	6481 (16%)	<0·0001
2	40 (23%)	5742 (15%)	..
3	20 (11%)	6149 (16%)	..
4	16 (9%)	8824 (22%)	..
5 (least disadvantaged)	14 (8%)	12 399 (31%)	..
Smoking status			
Ever smoker	147 (85%)	26 018 (67%)	<0·0001
Current smoker	105 (60%)	9801 (25%)	<0·0001
Comorbidities			
Hypertension	128 (72%)	26 422 (66%)	0·14
Dyslipidaemia	121 (68%)	26 363 (66%)	0·70
Diabetes	77 (43%)	10 096 (25%)	<0·0001
Insulin-requiring diabetes	40 (22%)	2775 (7%)	<0·0001
Prior stroke	6 (3%)	2335 (6%)	0·15
PVD	12 (7%)	2376 (6%)	0·68
OSA	7 (4%)	1811 (5%)	0·68
Heart failure	10 (6%)	1597 (4%)	0·28
eGFR			<0·0001
>60 mL/min per 1·73 m²	140 (80%)	29 020 (76%)	..
30–59 mL/min per 1·73 m²	18 (10%)	8009 (21%)	..
<30 mL/min per 1·73 m²	17 (10%)	1272 (3%)	..
Dialysis	12 (7%)	546 (1%)	<0·0001
Coronary artery disease			
Previous MI	2 (1%)	497 (1%)	0·87
Previous PCI	52 (29%)	10 286 (26%)	0·32
Previous CABG	10 (6%)	3254 (8%)	0·21

Data are presented as number (%) or mean (SD). ARIA=Accessibility and Remoteness Index of Australia. BMI=body-mass index. CABG=coronary-artery bypass grafts. eGFR=estimated glomerular filtration rate. MI=myocardial infarction. OSA=obstructive sleep apnoea. PCI=percutaneous coronary intervention. PVD=peripheral vascular disease. IRSD=Index of Relative Socioeconomic Disadvantage.

Table 1: **Baseline characteristics**

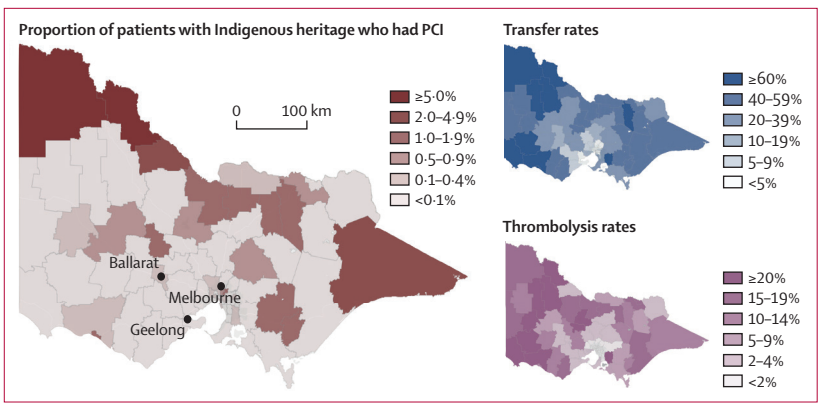

Figure: **Proportion of Indigenous Australians in the MIG registry who had PCI, who were transferred from another centre before receiving PCI, and who underwent thrombolysis before PCI**
Locations of hospitals included in the study are marked: Melbourne (four hospitals), Geelong (one hospital), and Ballarat (one hospital). MIG=Melbourne Interventional Group. PCI=percutaneous coronary intervention.

major adverse cardiovascular events (MACE), defined as a composite endpoint of death, myocardial infarction, and target-vessel revascularisation. Other clinical outcomes presented included the following outcomes: in-hospital length of stay, MACE, myocardial infarction, and major bleeding; 30 day loss to follow-up, all-cause mortality, cardiac death, MACE, stroke, myocardial infarction, target vessel revascularisation, readmission, and persistent smoking; and 12 month all-cause mortality. Optimal medical therapy at 30 days was defined as being on medications from all five guideline-recommended classes (aspirin, a second antiplatelet, β blockers, angiotensin-converting enzyme inhibitors or angiotensin receptor blockers, and statins). Partially optimised medical therapy was defined as being on four guideline-recommended medications as previously outlined, while non-optimised medical therapy was defined as being on up to three guideline-recommended medications.

Statistical analysis

Continuous data are expressed as mean (SD) for parametric data or median (IQR) for non-parametric data and are compared using Student's *t* tests or Mann-Whitney *U* tests as appropriate. Categorical variables are presented as number (%) and are compared using Pearson's χ^2 test. Associations between Indigenous status and outcomes were assessed using multilevel mixed-effects regression models adjusted for clinically relevant covariates and with inclusion of ARIA and IRSD as random effects, to account for geographical and socioeconomic clustering. Clinically relevant covariates selected for inclusion in the model were age, sex, current smoking, hypertension, dyslipidaemia, diabetes, previous stroke, chronic obstructive pulmonary disease, peripheral vascular disease, heart failure, previous myocardial infarction, previous PCI, previous coronary artery bypass grafts, STEMI, out-of-hospital cardiac arrest, cardiogenic shock, thrombolysis, and lesion severity. For the primary endpoint, we used a parametric survival model based on the Weibull distribution reporting hazard ratios (HRs) and 95% CIs. For secondary endpoints, we used a multilevel logistic-regression model reporting odds ratios (ORs) and 95% CIs. Left ventricular-ejection fraction (LVEF) and estimated glomerular filtration rate (eGFR) were not included as covariates in the primary analysis because of missing data (12·2% of missing data for LVEF and 5·5% for eGFR). We did a sensitivity analysis using the same multilevel-regression models for both the primary and secondary endpoints including LVEF and eGFR in the models (n=32 185). We also did subgroup analyses to assess the presence of effect modification using interaction terms in the same regression models among relevant subgroups of patients including by age, sex, region, socioeconomic status, diabetic status, indication for PCI, requirement for transfer for PCI, and by year of PCI. Statistical analysis was done using Stata version 14.2 for Windows. Mapping was done using ArcGIS (ESRI, Redlands, CA, USA) to graphically display the proportion of Indigenous Australians having PCI by local government area across the state of Victoria in the MIG cohort, with comparison to thrombolysis and transfer rates before PCI. All calculated p values were two sided, and a p value lower than 0·05 was considered statistically significant.

Role of the funding source

The funder of the study had no role in the study design, data collection, data analysis, data interpretation, or writing of the report.

Results

41 146 patient procedures were entered into the MIG registry between Jan 1, 2005 and Dec 31, 2018. Of these, 179 (0·4%) patients were recorded as identifying as Indigenous Australian, 39 855 (96·9%) patients were not Indigenous Australian, and 1112 (2·7%) patients had incomplete field data regarding ethnicity and were excluded.

Indigenous Australians having PCI were on average younger than non-Indigenous Australians, and were more frequently female (table 1). Indigenous Australians were more likely to reside in inner-regional communities, outer-regional communities, or remote communities (figure), with some variation in remoteness by indication groups (appendix). The proportion of Indigenous Australians living in an area of socioeconomic disadvantage was also higher than in non-Indigenous Australians, as were proportions of both current and previous cigarette smoking.

Prevalence of diabetes, insulin-requiring diabetes, severe renal impairment, and dialysis were higher in Indigenous Australians than in other populations. Other comorbidities were similar between groups, including hypertension, dyslipidaemia, previous stroke, peripheral vascular disease, sleep apnoea, previous heart failure, and previous myocardial infarction, PCI, or coronary-artery bypass surgery.

Among Indigenous Australians, the indication for PCI was more likely to be NSTEACS and less likely to be non-ACS (table 2). When limited to patients presenting with STEMI, Indigenous Australians had higher prevalence of thrombolysis and rescue PCI than non-Indigenous Australians, although prevalence of primary PCI was lower. Left-ventricular function was more frequently impaired at initial assessment. Prevalence of cardiogenic shock and out-of-hospital cardiac arrest was similar between both populations.

Patients with Indigenous heritage were more likely to initially present to a non-PCI-capable centre and require subsequent interhospital transfer (table 2, figure), a finding consistent across all indication groups except for post-thrombolysis. People who identified as Indigenous were less likely to achieve a door-to-balloon time of up to 90 min than non-Indigenous patients. However, this finding was no longer significant after exclusion of patients that required interhospital transfers (table 2).

Prevalence of procedural success, procedural complications, femoral access, and use of drug-eluting stents were similar between groups.

Clinical outcomes were similar between groups, including long-term mortality, 30 day mortality, 30 day MACE, and in-hospital outcomes (table 3). Duration of long-term mortality follow-up was shorter for Indigenous Australians than non-Indigenous Australians. Length of stay from admission to discharge was longer for Indigenous Australians. However, length of stay was similar after transferred patients were excluded.

Prevalence of persistent smoking at 30 day follow-up was higher among Indigenous Australians. Medication follow-up was less frequently able to be established among Indigenous Australians. However, among patients that completed 30 day medication follow-up, a higher proportion of Indigenous Australians were on optimal medical therapy, although a lower proportion were on partially optimised medical therapy or non-optimised medical therapy than non-Indigenous populations.

For the primary endpoint, multivariable regression models showed a significant association between Indigenous Australian status and long-term mortality after PCI, independent of confounders including socioeconomic status and remoteness, with a median follow-up of 5·2 years (table 4). Similarly, for secondary endpoints, multilevel multivariable logistic regression showed that Indigenous Australian status was independently associated with 30 day MACE and 30 day mortality (table 4).

In sensitivity analyses, including LVEF and eGFR in the model, an independent association was still observed for the primary endpoint (HR 2·18, 95% CI 1·49–3·18; p<0·0001), but not for secondary endpoints (30 day MACE OR 1·27, 95% CI 0·62–2·62; 30 day mortality OR 1·11, 95% CI 0·32–3·84; appendix).

In subgroup analyses for the primary endpoint, two significant interactions were observed showing a stronger association between Indigenous status and the primary endpoint among men and patients with NSTEMI (men $p_{interaction}$=0·0050 and NSTEMI $p_{interaction}$=0·030; appendix). No significant interactions were observed when stratified by age, geographical remoteness, socioeconomic status, diabetic status, transfer before PCI, or by year of PCI procedure. For secondary endpoints, no significant interactions were observed for any subgroups (appendix).

	Indigenous	Non-Indigenous	p value
Presentation			
Non-ACS	41 (23%)	13 439 (34%)	0·0020
NSTEACS	79 (44%)	14 132 (36%)	0·016
STEMI	58 (33%)	12 263 (31%)	0·64
Primary PCI	21 (36%)	7947 (65%)	<0·0001
Rescue PCI	11 (19%)	565 (4·6%)	<0·0001
Late presentation (PCI >24 h)	17 (29%)	2827 (23%)	0·26
Post successful thrombolysis	9 (16%)	924 (7·6%)	0·015
OHCA	8 (4·5%)	1261 (3·2%)	0·32
Cardiogenic shock	10 (5·6%)	1497 (3·8%)	0·20
LVEF ≤45%	62 (39%)	8250 (24%)	<0·0001
Transfers and timing			
Initially presented to non-PCI centre requiring transfer	90 (50%)	7752 (20%)	<0·0001
Transfer rates by indication			
Non-ACS	9 (22%)	563 (4·2%)	<0·0001
NSTEACS	47 (60%)	4269 (30%)	<0·0001
STEMI (primary PCI)	4 (19%)	956 (12%)	0·32
STEMI (rescue)	8 (73%)	427 (76%)	0·83
STEMI (PCI >24 h)	14 (82%)	772 (27%)	<0·001
STEMI (after successful thrombolysis)	8 (89%)	759 (82%)	0·60
Primary PCI timing (STEMI)			
Symptom-to-door time	104 (70–242)	107 (70–177)	0·61
Door-to-balloon time	100 (46–127)	69 (45–97)	0·14
DTBT ≤90 min	9 (45%)	5318 (69%)	0·021
DTBT ≤90 min (transfers excluded)	8 (50%)	4550 (67%)	0·15
Procedural characteristics			
Procedural success	171 (96%)	37 641 (94%)	0·53
Multivessel disease	27 (36%)	6332 (39%)	0·57
ACC/AHA type B2–C	98 (55%)	22 657 (57%)	0·57
Femoral access	121 (68%)	20 604 (72%)	0·22
Drug-eluting stent	117 (65%)	24 085 (60%)	0·18
Complications			
Transient or persistent no reflow	6 (3·4%)	1252 (3·3%)	0·94
Coronary perforation	0	99 (0·3%)	0·50
Vascular complication	1 (0·6%)	270 (0·7%)	0·85

Data are presented as number (%). ACC/AHA=American College of Cardiology/American Heart Association. ACS=acute coronary syndrome. DTBT=door-to-balloon time. LVEF=left-ventricular ejection fraction. NSTEACS=non-ST-elevation acute coronary syndrome. OHCA=out-of-hospital cardiac arrest. PCI=percutaneous coronary intervention. STEMI=ST-elevation myocardial infarction.

Table 2: **Presentation and procedural characteristics**

Discussion

In this multicentre study, we assessed the characteristics and outcomes of Indigenous Australians having PCI in

	Indigenous	Non-Indigenous	p value
In-hospital outcomes			
Length of stay (days)			
From admission	4 (2–6)	3 (1–5)	0·0066
From PCI	2 (1–4)	1 (1–4)	0·066
Excluding transferred patients	3 (1–5)	3 (1–4)	0·82
MACE	13 (7%)	1824 (5%)	0·087
Myocardial infarction	1 (1%)	214 (1%)	0·81
Major bleeding	2 (1%)	879 (2%)	0·32
30 day outcomes			
Loss to follow-up	7 (4%)	182 (<1%)	<0·0001
Death	9 (5%)	1278 (3%)	0·17
Cardiac	5 (3%)	1025 (3%)	0·85
MACE	17 (9%)	2474 (6%)	0·069
Stroke	0	197 (<1%)	0·35
Myocardial infarction	6 (3%)	754 (2%)	0·15
TVR	4 (2%)	881 (2%)	0·98
Readmission	17 (11%)	4486 (12%)	0·81
Persistent smoking	69 (43%)	4308 (12%)	<0·0001
Medication follow-up completed	142 (79%)	36 648 (92%)	<0·0001
DAPT	138 (97%)	34 279 (94%)	0·077
Optimal medical therapy	102 (72%)	21 224 (58%)	0·0010
Partially optimised medical therapy	33 (23%)	11 283 (31%)	0·011
Non-optimised medical therapy	7 (5%)	4141 (11%)	0·0050
Longer-term outcomes			
12 month mortality	14 (8%)	2275 (6%)	0·23
Long-term mortality	39 (22%)	8195 (21%)	0·69
Follow-up, years	3·8 (1·7–8·8)	5·2 (2·2–9·0)	0·0066

Data are presented as number (%) or median (IQR). Optimal medical therapy was defined as being on five guideline-directed medications (dual antiplatelets, ACE inhibitor, β blocker, and statin); suboptimal medical therapy was defined as being on up to three guideline-directed medications. Major bleeding after PCI was defined as bleeding requiring transfusion, prolonging hospital stay, or leading to a fall in haemoglobin higher than 30 g/L. Myocardial infarction after PCI was defined as symptoms of ischaemia with an increase in creatine kinase or creatine-kinase myocardial band up to three times the upper limit of normal, or a substantial ST segment change, development of new Q waves in up to two contiguous electrocardiographic leads, or new left-bundle branch block pattern. DAPT=dual antiplatelet treatment. MACE=major adverse cardiac events. NDI=national death index. PCI=percutaneous coronary intervention. TVR=target-vessel revascularisation.

Table 3: **Clinical outcomes**

	Indigenous *vs* non-Indigenous	p value
Primary endpoint		
Long-term mortality, aHR (95% CI)	2·49 (1·79–3·48)	<0·0001
Secondary endpoints		
30 day mortality, aOR (95% CI)	2·78 (1·09–7·12)	0·033
30 day major adverse cardiac events, aOR (95% CI)	1·87 (1·03–3·39)	0·039

Comparisons between Indigenous and non-Indigenous groups were adjusted for age, sex, smoking status, hypertension, dyslipidaemia, diabetes, previous occurrence of stroke, chronic obstructive pulmonary disease, peripheral vascular disease, heart failure, previous myocardial infarction, previous percutaneous coronary intervention, previous coronary artery-bypass surgery, ST-elevation myocardial infarction, out-of-hospital cardiac arrest, cardiogenic shock, thrombolysis, and lesion complexity. aHRs represent time-to-death analysis using a multilevel regression model based on a Weibull distribution, with geographic remoteness and socioeconomic status included as random effects to account for clustering. aORs represent a multilevel logistic-regression model with geographic remoteness and socioeconomic status included as random effects to account for clustering. aHR=adjusted hazard ratio. aOR=adjusted odds ratio.

Table 4: **Multivariable analysis of the primary and secondary endpoints**

larger urban and regional centres in Victoria, Australia. The major findings can be summarised as follows: Indigenous Australians made up 0·4% of the PCI cohort, were younger, more commonly from regional communities of lower socioeconomic status, and had higher prevalence of renal impairment, diabetes, and smoking than non-Indigenous Australians. In the setting of increased remoteness, prevalence of thrombolysis and interhospital transfers were higher, resulting in longer door-to-balloon times for STEMI and overall length of stay. Procedural success and complications were similar; however, in the multivariable analysis, 30 day and long-term outcomes were worse, particularly among male patients and patients with NSTEMI. Indigenous Australians were more likely to be taking optimal medical therapy at 30 days, although overall follow-up rates were lower and persistent smoking higher than among non-Indigenous Australians.

In Australia, there is approximately an 8 year life-expectancy gap between Indigenous Australians and non-Indigenous Australians.[1] An estimated 14% of the health gap is attributable to ischaemic heart disease,[2] and the mortality related to ischaemic heart disease is twice as high among Indigenous Australians than among non-Indigenous Australians (117 deaths *vs* 59 deaths per 100 000 per year).[3] These higher rates of cardiovascular disease and mortality are compounded by disparities in cardiovascular care. Although both life expectancy and disparities in care have seen substantial improvements over the past 15 years,[1,6] differences in access to specialist review,[6] angiography,[18,19] and revascularisation treatments[6,7,20] remain between Indigenous Australians and non-Indigenous Australians. Our data suggest that these inequalities extend to short-term and long-term outcomes following PCI in Victoria, with higher risk of MACE and mortality independent of comorbidities, clinical presentation, socioeconomic status, and geographical remoteness.

The reasons for these disparities are complex, including social determinants of health, communication difficulties, poor access to care, and cultural safety.[21] Our data show that geographical factors have a major role for PCI, whereby higher rates of regional and remote living result in higher rates of thrombolysis and interhospital transfers for patients with acute coronary syndrome, in turn leading to delays in time to PCI. These delays could potentially explain

the lower left ventricular function at initial assessment in Indigenous Australians. An important observation in the present study is the absence of variation in symptom-to-door time between the Indigenous and non-Indigenous cohorts, which refutes possible misconceptions in the health-care provider community that disparities might relate to inaction or delayed action by Indigenous Australians with ACS. Comorbidities associated with incident coronary disease, disease progression, and mortality, such as diabetes, renal impairment, and smoking were higher in Indigenous Australians than other populations, consistent with previous studies, which have attributed this disparity to lower socioeconomic status and social determinants of health.[21,22] A lower proportion of Indigenous Australians had PCI for non-ACS indications, which could relate to reduced access and difficulties travelling to have the non-invasive testing required to diagnose stable coronary syndromes. Care after PCI has similar challenges, with lower overall follow-up rates consistent with previous studies.[23] Of note, rates of optimal medical therapy were higher among Indigenous Australians who were followed up than among non-Indigenous Australians. Although more complete use of optimal medical therapy in patients with ACS is required, there was a greater difference in optimal medication use than could be explained by the difference in rates of ACS alone, making this finding encouraging. Previous Australian data have shown associations between education level, employment status, household income, and remoteness category and cardiovascular disease among both Indigenous and non-Indigenous cohorts.[24] However, Indigenous Australians have been reported to have higher rates of cardiovascular disease than non-Indigenous Australians of the same age and socioeconomic group, with suggested reasons for this disparity including discrimination and racism, stress, dispossession, and grief.[24] Ethnic differences in genetic susceptibility and inherited traits have been shown in some populations.[25] Although this is an alternative explanation, it would likely only partially mediate risk given the social context.

There is an urgent need to increase the amount and quality of information about the cardiovascular health needs of Indigenous people living in both urban and rural settings. In this study we highlighted the existence of important differences in Indigenous health outcomes following PCI. Improving Indigenous health status has been a longstanding goal in Australia, and the gap in health outcomes remains intolerably wide. Previous studies have contributed to a deficit discourse in Indigenous health research by focusing on disparities in access to diagnosis, angiography, and revascularisation.[26] Few studies have investigated Indigenous health outcomes following revascularisation. Taking a solutions-focused approach, our study highlights improvement in follow-up after PCI as a focus for all health-care services, communities, and policy makers with a shared commitment to improving health outcomes for Indigenous Australians. Improving access to primary care, non-invasive cardiac investigations, and specialist follow-up, such as through telemedicine,[27,28] in addition to streamlining care pathways for regional and remote ACS patients to reduce delays in treatment could have significant benefits. The findings are particularly important for Victoria's Aboriginal community that has been in Australia for millennia and who are losing their next generation of Elders to premature-onset coronary artery disease and its complications. As such, improvements in care pathways are not only important for improving health outcomes but also for preserving Indigenous cultural knowledge and traditions.

The need to involve Indigenous Australian communities and leaders in Indigenous health research and interpretation is self-evident. However, achieving this goal to a satisfactory level is not straightforward. Data regarding Indigenous Australians are generally held by non-Indigenous government or private institutions, raising questions regarding appropriate data use that respects Indigenous data sovereignty.[29,30] Several institutions have established Indigenous Data Governance committees, but these committees are by no means widespread, nor is funding readily available to establish such committees. Widespread deficit framing in Indigenous health-care research[26] has fostered distrust between Indigenous communities and these institutions, increasing the difficulty of establishing such committees. This research has prompted continuing engagement with Victorian Aboriginal community members and leaders in health care and health research. Efforts are ongoing in the establishment of an Indigenous Data Sovereignty framework for the MIG registry.

Underidentification of Indigenous Australians in health datasets warrants some discussion. The percentage of Indigenous Australians having PCI in the MIG registry was 0·4%, significantly lower than the 0·9% of Indigenous Australians in Victoria.[9] Moreover, the MIG registry includes only public hospitals, and this percentage could feasibly be lower if private hospitals were also included in the analysis. Part of this discrepancy might relate to reduced access to angiography and PCI.[7] However, in Victoria, age-standardised hospitalisation rates for circulatory diseases are 1·3 times higher for Indigenous Australians than for non-Indigenous Australians suggesting the true percentage should be higher. Underidentification of Indigenous Australian status has been observed in other cohorts,[13] and is likely to be an issue in this cohort, both among the 2·7% of patients that were excluded without race recorded and among patients recorded as non-Indigenous. Urban residents, older people, and socially more advantaged Indigenous Australians are at greater risk of underidentification in hospitalised cohorts.[13]

This study has several limitations. First, as discussed, the prevalence of Indigenous Australians in this PCI

registry is lower than estimates in the general population in Victoria, which could affect the results. Second, this study reports outcomes following PCI at six public hospitals in Victoria, and the generalisability of these results to other populations needs to be carefully considered. Although Victoria is the second most populous state in Australia, it is the smallest of the mainland states by area. Therefore, the geographical challenges identified in this study are mostly reflective of challenges unique to inner-regional and outer-regional communities. These challenges are likely to be similar to inner-regional and outer-regional communities in many areas of the country, but are less generalisable to remote areas (such as Western Australia, Northern Territory, South Australia, and parts of eastern Queensland) where difficulties in access to diagnostic testing and follow-up could be magnified. Outcomes beyond 30 days are limited to all-cause mortality, with longer-term cardiac-specific outcomes not available in the dataset. Finally, we included a long period of observation (2005 to 2018) to increase the sample size and maximise follow-up, but practices and outcomes could have changed across the study period. We attempted to address this problem with the subgroup analysis assessing outcomes across time-period tertiles, but readers should be aware of this limitation when interpreting the results.

Indigenous Australians having coronary interventions in larger urban and regional centres appear to be at higher risk of worse outcomes, and the challenges of timely PCI treatment with adequate follow-up in regional settings are highlighted by this study. Improvements in PCI outcomes in Indigenous Australians should be a focus for health policy, and programmes targeting timely access to PCI for regional patients and close clinical follow-up, including telemedicine and access to specialists, could be of great value.

Contributors

LPD and AEA developed the study concept, protocol, ethics application, and drafted the initial manuscript. LPD, DD, SJD, DS, AB, DC, EO, CH, MF, CMR, and AEA contributed to data curation and had access to, and have verified, the underlying data. CMR, AEA, DC, DS, and AEA contributed to funding acquisition. LD did the formal analysis in conjunction with DD. All authors including LB and JO'B critically reviewed the manuscript, were involved with interpretation of the data, and gave final approval for publication.

Declaration of interests

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Data sharing

Deidentified data can be made available in accordance with the Monash University data-sharing policies upon reasonable request to the MIG registry data custodian (CMR).

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