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Estimating the Cost-Effectiveness and Return on Investment of the Victorian Cardiac Outcomes Registry

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3 **Estimating the Cost-Effectiveness and Return on Investment of the Victorian Cardiac**
4 **Outcomes Registry**
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8 **Running title: An economic evaluation of VCOR**
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Abstract

Objectives: In this present study, we sought to evaluate the clinical and cost impacts attributed to the Victorian Cardiac Outcomes Registry (VCOR) in Victoria, Australia.

Design: A modelled cost-effectiveness study of VCOR was conducted from the Australian health care system and societal perspectives.

Setting: Observed deaths and costs attributed to coronary heart disease (CHD) over the five-year period from 2014 to 2018 were compared to deaths and costs arising from a hypothetical situation which assumed that VCOR did not exist. Comparisons were made using decision analytic life table models. Data from the Australian Bureau of Statistics and published sources simulated the follow-up of Victorians aged ≥ 25 years for five years, or until death. A conservative assumption that VCOR contributed to 0.5% of the proportional change in trends in patient mortality attributed to CHD observed over the study period. The marginal costs of VCOR operation and years of life saved (YoLs) were estimated.

Primary outcome measures: The return on investment (ROI) ratio and the incremental cost-effectiveness ratio (ICER).

Results Over a five year period, the ROI ratio estimated for VCOR was 17.2. That is, for every dollar invested in VCOR, a net return of \$17.20 Australian Dollars (AU\$) was estimated. The ICER estimated for VCOR was \$10,902 per YoLS. Scenario analyses supported the robustness of our findings.

Conclusions

Based on conservative assumptions, VCOR is cost-effective and represents a sound investment for the Victorian health care system. Our evaluation highlights the value of CQRs in Australia.

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3 **Key words:** Cost-effectiveness; acute coronary syndrome; cardiovascular disease; clinical
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5 quality registries; quality improvement.
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Strengths and limitations of this study

- Real-world registry data from VCOR captured temporal changes in the management of patients undergoing PCI in Victoria, Australia.
- Improvements in the uptake of radial access PCI and in timely reperfusion of STEMI patients were, in part, attributed to VCOR.
- There was uncertainty around the clinical benefit conferred by VCOR with respect to trends in mortality.
- It was not possible to assess the impact of VCOR on readmissions or patient morbidity or quality-of-life using ABS data.

Introduction

Coronary heart disease (CHD) is a significant cause of morbidity and mortality in Australia. In 2017-2018, the prevalence of CHD in Australia was estimated to be 3% (580,300) of the adult population ¹. Although mortality from CHD has declined significantly since the 1960s, it remains the leading cause of death (approximately 11%) in Australia ². With regard to disease burden, CHDs had contributed to 6.3% (10.4 disability adjusted life years (DALYs) per 10,000 population) of the total disease burden and 2% of hospitalisations in Australia in 2018 ^{1,3}.

Of the prevalent adult population with CHD in 2017-18, it is estimated that 40% had experienced angina and 74% had suffered acute coronary syndrome (ACS) ¹. Percutaneous coronary intervention (PCI) is the preferred means of revascularisation therapy for many patients presenting with ACS based on Australian and international guidelines ^{4,5}. Across Australia, 44,886 PCIs were performed between 2017-2018; in Victoria alone, 48% of all PCIs across Victoria in 2019 were performed for the management of ACS ⁶.

The cost burden attributed to the management of CHD, including costs of PCI, are correspondingly high. Based on estimates from the Australian Institute of Health and Welfare (AIHW), in 2018-2019, CHD accounted for \$2.35 billion in health expenditure in Australia, representing 2% of total health expenditure ⁷. Few studies have explored the cost burden of PCIs in Australia. However, the considerable volume of procedures performed annually, at an estimated average cost per procedure of \$13,293 ⁸, indicates that PCIs contribute to a significant proportion of costs in the management of CHD.

Clinical quality registries (CQRs) are increasingly utilised to inform projects for the improvement of health care processes, adherence to evidence-based guidelines and standards,

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3 and reducing the costs attributed to care delivery ⁹⁻¹². Through the collection of patient
4 outcomes data for cardiovascular procedures, it is possible to benchmark a hospitals'
5 performance to its peers and adherence to national standards of care and evidence-based
6 guidelines ⁹. Additionally, CQRs have significant utility in medical research ⁹⁻¹¹. Previous
7 studies have demonstrated that major improvements to patient outcomes may be attributed to
8 the existence of CQRs ⁹. However, although there are many studies utilising data from CQRs,
9 few have assessed the clinical and cost impacts attributed to a CQR ¹⁰. Therefore, in the
10 present study, we aimed to assess the cost-benefit of the Victorian Cardiac Outcomes
11 Registry (VCOR) from an Australian societal perspective, as well as evaluating the cost-
12 effectiveness of VCOR from the perspective of the Australian health system.
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30 **Methods**

31 *Model structure*

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33 Life table modelling and decision analysis were used to explore the clinical and cost impacts
34 of VCOR against a hypothetical scenario which assumed that VCOR did not exist (No
35 VCOR) ¹³. Life tables were constructed using age and sex-specific mortality rates for adults
36 aged ≥ 25 years, based on Victorian population data sourced from the Australian Bureau of
37 Statistics (ABS) ^{14 15}. Each cohort was followed until death, or up to five years in the base
38 case. Within each cohort (VCOR or No VCOR), separate life tables were created for 14 age
39 and sex subgroups. Age was stratified into seven 10-year age bands (25 – 34, 35 – 44, 45 –
40 54, 55 – 64, 65 – 74, 75 – 84, 85+), with the starting age in each subgroup being the weighted
41 average age in the age band.
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57 The clinical and cost outputs for each model were totalled to determine the overall cost-
58 effectiveness and return-on-investment (ROI) attributed to VCOR.
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Model population

Our base case modelled population was profiled on the total Victorian population aged ≥ 25 years in each year from 2014 to 2018 using ABS inputs. Data pertaining to the total Victorian population, and mortality in each year from 2010 to 2019, were sourced from the ABS (see Supplemental Table 1) ^{14 15}. Although ABS data were available for 2010 to 2019, our modelled population was profiled to reflect PCIs performed between January 2014 to December 2017 in VCOR. A separate, linked dataset of patient, clinical and procedural characteristics collected by VCOR was made available for the analysis of trends in clinical practice across Victorian hospitals. This dataset was used to inform the extent to which the registry had contributed to changes in CHD mortality over time in the economic model informed by ABS data (see '*Effectiveness of VCOR*' below).

Transition probabilities

Data for estimating the incidence of all-cause mortality, and mortality attributed to CHD (based on ICD-10 codes: 120 – I25), were sourced for each age and sex subgroup from the ABS ^{14 15} (Table 1).

Table 1: Trends in CHD mortality over time and costs used in the economic model

Parameter		Year					P-value*
CHD mortality							
Sex	Age group (years)	2014	2015	2016	2017	2018	
Males	25 - 34	0.00%	0.00%	0.00%	0.00%	0.00%	0.382
	35 - 44	0.01%	0.01%	0.01%	0.01%	0.01%	0.013
	45 - 54	0.04%	0.04%	0.04%	0.03%	0.03%	0.006
	55 - 64	0.10%	0.08%	0.08%	0.07%	0.08%	0.051
	65 - 74	0.21%	0.18%	0.17%	0.17%	0.17%	0.092
	75 - 84	0.61%	0.57%	0.59%	0.54%	0.47%	0.033
	85+	2.24%	2.38%	2.24%	2.06%	2.04%	0.106
	All	0.09%	0.09%	0.09%	0.08%	0.08%	0.001
Females	25 - 34	0.00%	0.00%	0.00%	0.00%	0.00%	0.357
	35 - 44	0.00%	0.00%	0.00%	0.00%	0.00%	0.071
	45 - 54	0.01%	0.01%	0.01%	0.00%	0.01%	0.283
	55 - 64	0.02%	0.02%	0.02%	0.02%	0.01%	0.073
	65 - 74	0.06%	0.06%	0.06%	0.06%	0.05%	0.121
	75 - 84	0.32%	0.30%	0.27%	0.28%	0.22%	0.023
	85+	1.90%	1.90%	1.71%	1.68%	1.42%	0.016
	All	0.07%	0.07%	0.06%	0.06%	0.05%	0.016
Costs							
Cost of mortality		\$5,609					
VCOR annual costs		\$600,000					
VoSLY		\$220,262					

CHD = coronary heart disease; VCOR = Victorian Cardiac Outcomes Registry; VoSLY =

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3 value of statistical life year
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6 * Based on simple linear regression analyses
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12 The likelihood of all-cause or CHD mortality was estimated by dividing the number of deaths
13 (all-cause or CHD-related) in each sex and age subgroup by the Victorian population for each
14 subgroup^{14 15}. The likelihood of non-CHD mortality was estimated by subtracting the
15 likelihood of CHD mortality from the likelihood of all-cause mortality^{14 15}.
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25 *Effectiveness of VCOR*

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28 VCOR is a state-wide, ongoing population based CQR. It was established in 2012 to monitor
29 the performance of cardiac services in hospitals across Victoria^{6 12}. The key focus of VCOR
30 currently is on patients undergoing PCI and cardiac implanted electronic devices^{6 12}. The
31 economic evaluation was based on estimating the downstream clinical and cost impacts of
32 VCOR relative to a hypothetical scenario in which VCOR did not exist (No VCOR). In the
33 absence of efficacy data, VCOR was assumed to contribute to 0.5% of the reduction in CHD
34 mortality over time observed in the economic model. That is, without VCOR contributing to
35 reductions in CHD mortality over time, the extent to which CHD mortality declined over
36 time had decreased by 0.5%. This represented a conservative estimate of the mortality
37 benefits attributed to benchmarking and feedback through VCOR. The assumed contribution
38 of VCOR was justified based on current literature demonstrating that the registry data
39 collection for the purposes of routine health systems benchmarking and feedback is, of itself,
40 likely to contribute to reductions in mortality over time^{9 11}. A similar approach whereby the
41 benefits of a cardiac CQR was assumed to contribute to temporal trends in patient mortality
42 has been published elsewhere¹¹.
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3 Based on data from the ABS, the risk of CHD mortality in Victoria has decreased steadily
4 over the period from 2014 to 2018 (Table 1). Notably, the clinical management of CHD has
5 also evolved over time. This may in part be attributed to ongoing benchmarking and feedback
6 through VCOR. First, in the period since VCOR was established, implementation of PCI via
7 radial access (instead of femoral access) had improved considerably ⁶. A Cochrane review of
8 PCI via radial versus femoral access concluded that radial access was associated with
9 reductions in major bleeding events, access site complications and mortality in the setting of
10 ACS ¹⁶. This is supported by data from cardiac registries in the US, UK and Australia ¹⁷⁻¹⁹.
11 Secondly, in addition to improved uptake of radial access PCI, hospital adherence to a door-
12 to-balloon/device time (DBDT) has improved, with all PCI-capable hospitals across Victoria
13 achieving a median DBDT time of ≤ 90 minutes ⁶. Such changes in clinical practice have
14 been attributed, in part, to ongoing benchmarking and feedback through VCOR ^{6 20 21}.

34 *Cost inputs*

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37 Table 1 summarises the cost inputs used in the economic model. All costs were updated to
38 2021 values using the Australian Health Price Index and were expressed as Australian
39 Dollars (AU\$) ²².

47 *Cost of VCOR*

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50 VCOR is funded through the Victorian Department of Health, Medibank Private and in-kind
51 funding through Monash University ⁶. Based on the VCOR annual report for 2018, the
52 average annual cost borne by the Victorian Department of Health was \$605,346 for the
53 period from 2014 to 2018 (see Supplemental Table 2) ²³. We therefore assumed the annual
54 cost of registry operation to be \$600,000; this was varied in scenario analyses (see below).
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Cost of mortality

There was an absence of relevant data pertaining to the costs of death. As per previous analyses^{11 24 25}, we assumed that deaths due to CHD incurred 50% of the costs of CHD hospitalisations. The cost of hospitalisations for CHD was estimated using data pertaining to diagnosis-related groups (DRGs) and their costs for publicly-funded casemix hospitalisations in 2017/18 (see Supplemental Table 3)²⁶. This method has been used in similar economic evaluations^{11 24 25}. The same cost was applied to deaths due to non-CHD causes.

Cost of a year of life

The value of a statistical life year (VoSLY) was assumed to be \$220,262. This was based on the VoSLY estimated by the Australian Government's Office of Best Practice Regulation of \$213,000 in 2019, adjusted to 2021 values²⁷.

Discounting

A discount rate of 5% per annum was applied to years of life lived and costs incurred beyond the first year²⁸.

Economic evaluation

The base case economic evaluation involved 14 separate life table models created using ABS data, stratified by sex and age band to represent five years of coverage (2014 – 2018 inclusive) of VCOR. The expected values across sex and age subgroups for the VCOR and

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3 No VCOR were aggregated to represent the clinical and cost impacts of VCOR over five
4 years for the total Victorian population at risk of mortality from CHD.
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8 The primary cost-benefit analysis estimated differences between the two groups with regard
9 to net societal costs. This was defined as the cost of VCOR operation, minus the cost savings
10 attributed to reduced CHD mortality, added to the costs saved by prolonging years of life
11 lived in the cohort. The primary outcome was the net cost attributed to VCOR operation. A
12 key secondary outcome for our study was the incremental cost-effectiveness ratio (ICER) for
13 VCOR compared with No VCOR in terms of cost per year of life saved (YoLS). The
14 commonly used willingness-to-pay threshold of \$50,000 per QALY gained in determining
15 cost-effectiveness²⁸ was used in lieu of an official willingness to pay threshold in Australia.
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30 *Statistical analyses*

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33 A linked dataset of 32,198 consecutive PCIs conducted in VCOR over a period of four years
34 (1 January 2014 to 31 December 2017) was made available for the analysis of changes in
35 clinical practice over time in Victoria. Pearson's chi-square tests for categorical variables,
36 and univariate linear regression modelling or generalized linear regression modelling (GLM)
37 for continuous variables, were used to explore differences in patient or procedural trends over
38 time.
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48 To explore changes in clinical practice over time, the population was stratified by sex and
49 indication for PCI: non-ACS reasons, unstable angina, non-ST elevation myocardial
50 infarction (NSTEMI) and ST elevation myocardial infarction (STEMI). Backward stepwise
51 logistic regression with a P-value threshold of 0.10 was used to identify the following
52 potential confounders of radial access, and DBDT ≤ 90 minutes: age (< 75 years and ≥ 75
53 years); in-hours hospital arrival (between 08:00 to 18:00 on a workday); cardiogenic shock or
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3 intubated out-of-hospital cardiac arrest (OHCA); left ventricular ejection fraction (LVEF);
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5 medicated diabetes mellitus; peripheral vascular disease; cerebrovascular disease; chronic
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7 oral anticoagulation therapy; prior coronary artery bypass grafting; previous PCI; use of
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9 glycoprotein IIb/IIIa inhibitors; use of thienopyridine or ticagrelor; estimated glomerular
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11 filtration rate (eGFR); required mechanical ventricular support; lesion complexity (American
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13 College of Cardiology/American Heart Association type A/B1 versus type B2/C lesions);
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15 unprotected left main PCI; chronic total occlusion PCI and in-stent restenosis PCI^{29 30}.

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17 Multivariable logistic regression models with adjustment for key predictors identified in
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19 stepwise regression were used to explore annual trends in radial access and DBDT metrics.
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22 The results of these analyses were used to inform the economic model drawn from ABS
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24 inputs.
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29 To explore trends in CHD mortality over time using mortality data from the ABS, simple
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31 linear regression modelling was performed with the year as the independent variable, and
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33 CHD mortality as the dependent variable. A P-value <0.05 was considered statistically
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35 significant.
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39 The economic evaluation was performed with Microsoft Excel[®]; STATA 14 (StataCorp LP,
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41 College Station, Texas) was used to explore changes in clinical practice over time.
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46 47 *Sensitivity analyses* 48

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50 A series of one-way sensitivity analyses were undertaken to determine the impact of
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52 uncertainty around key model parameters. Input parameters were varied individually in
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54 deterministic sensitivity analyses, while other variables were maintained at base case values
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56 to estimate the impact of parameters on cost-benefit/effectiveness. Key parameters assessed
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were the time horizon, the assumed contribution of VCOR to CHD mortality trends, costs assumed for CHD mortality, and the VoSLY.

Patient and public involvement

No patients or the public were involved in this study.

Results

VCOR population

Data from 32,198 consecutive PCIs in Victoria over a four-year period (1 January 2014 to 31 December 2017) was used to explore the impact of VCOR on clinical practice. Baseline and procedural characteristics of the VCOR population are presented in the Supplementary material (Supplemental Tables 4 and 5). The cohort was predominately male (77%), overweight or obese (76.2%) undergoing PCI for ACS (50.9%) in public hospitals (63.2%). Table 2 presents the results of multivariable modelling on changes in radial access and DBDT over time.

Table 2: Changes in radial access and DBDT over time

Parameter	OR (95% CI)*	P-value
Likelihood of Femoral Access		
STEMI		
Males	0.65 (0.62 0.69)	<0.001
Females	0.73 (0.66 0.82)	<0.001

Parameter	OR (95% CI)*	P-value
NSTEMI		
Males	0.70 (0.66 0.74)	<0.001
Females	0.74 (0.67 0.81)	<0.001
UA		
Males	0.72 (0.65 0.80)	<0.001
Females	0.73 (0.63 0.85)	<0.001
Non-ACS		
Males	0.72 (0.70 0.75)	<0.001
Females	0.74 (0.70 0.80)	<0.001
Likelihood of DBDT ≤90 minutes †		
Males	1.15 (1.07 1.24)	<0.001
Females	1.17 (1.01 1.36)	0.035

ACS = acute coronary syndrome; DBDT = door-to-balloon/device time; NSTEMI = non-ST-elevation myocardial infarction; STEMI = ST-elevation myocardial infarction; UA = unstable angina

* Adjusted for key confounding variables

† Primary PCI for STEMI presentations excluding all inter-hospital transfer arrivals and patients with STEMI onset while a current in-patient

The likelihood of patients managed through femoral access decreased annually across all non-ACS and ACS indications for PCI ($P < 0.001$) (see Table 2). For patients undergoing primary PCI for STEMI, the likelihood of timely reperfusion (DBDT \leq 90 minutes) increased annually by at least 15% across both sexes ($P < 0.05$) (Table 2).

Economic analysis of the total Victorian population

Table 3 presents the base-case analysis in terms of the overall clinical and cost impacts attributed to five years of full coverage of VCOR for the Victorian population aged ≥ 25 years from 2014 to 2018.

Table 3: Results of the base case economic model

Parameter	Overall (N = 4,017,397)		Difference
	VCOR	No VCOR	
Clinical outcomes, n (%N)			
CHD mortality	19,065 (0.47%)	19,159 (0.48%)	-93
Non-CHD mortality	140,455 (3.50%)	140,442 (3.50%)	12
Total	159,520 (3.97%)	159,601 (3.97%)	-81
Years lived *	17,887,125	17,886,913	211
Cost outcomes			
VCOR *	\$2,727,570	-	\$2,727,570
CHD mortality *	\$98,517,938	\$99,001,034	-\$483,096
Non-CHD mortality *	\$722,495,795	\$722,436,037	\$59,758
Total health cost *	\$823,741,304	\$821,437,071	\$2,304,233
VoSLY *	\$3,939,854,066,111	\$3,939,807,513,735	\$46,552,376
ICER (\$/YoLS) ^a			\$10,902
ROI ratio *			17.2

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3 CHD = coronary heart disease; ICER = incremental cost-effectiveness ratio; ROI = return-on-
4 investment; VCOR = Victorian cardiac outcomes registry; VoSLY = value of statistical life
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10 All costs are expressed in Australian dollars (AU\$)

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13 * Results discounted at an annual rate of 5%
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20 Over this period, a total of 19,065 CHD-related deaths occurred across Victoria. Based on the
21 assumption that VCOR contributed to 0.5% of the temporal change in CHD mortality over
22 time, the clinical benefit attributed to VCOR was the prevention of 93 CHD-related deaths
23 and 211 (discounted) years of life saved. A total of \$483,096 was saved over this period due
24 to the prevention of CHD mortality. This was balanced against a higher incidence of non-
25 CHD mortality in the VCOR cohort (because the risk of non-CHD death was not assumed to
26 have changed by VCOR), which incurred an additional cost of \$59,758. The total cost of
27 VCOR was \$2,727,570 (discounted). Hence the net cost of VCOR from the perspective of the
28 Australian health care system was \$2,304,233 (discounted). The ICER associated with VCOR
29 was \$10,902 per YoLS. From a broader, societal perspective, the savings attributed to VCOR
30 were \$46,552,376 based on an assumed VoSLY of \$220,262. The return on investment (ROI)
31 ratio, which is the ratio of the total cost savings to the total costs of VCOR, was 17.2 that is,
32 for every \$1.00 invested in VCOR, a return of \$17.2 was delivered.
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50 Table 4 presents the results of sensitivity analyses in terms of ICERs, net societal costs
51 attributed to VCOR operation, and ROI.
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Table 4: Results of deterministic scenario analyses

Scenario	Net cost *	ROI ratio *	ICER (\$/YoLS) *
Base case †	\$48,856,609	17.2	\$10,902
Time horizon (starting year 2014)			
1 year	\$3,145,626	4.7	\$38,053
2 years	\$10,788,317	8.6	\$20,767
3 years	\$21,594,469	12.0	\$15,217
4 years	\$34,542,066	14.8	\$12,491
Time horizon (starting year 2015)			
1 year	\$3,146,671	4.7	\$38,032
2 years	\$10,712,650	8.6	\$21,030
3 years	\$21,347,420	11.8	\$15,465
4 years	\$34,032,828	14.6	\$12,757
5 years	\$48,204,588	17.0	\$11,052
Contribution to trends (base case: 0.5%)			
Lower (0.25%)	\$25,792,797	8.6	\$23,807
Upper (0.75%)	\$71,919,005	25.8	\$6,601
VoSLY (base case: \$220,262)			
Lower (-25%)	\$37,218,515	13.0	\$10,902

Scenario	Net cost *	ROI ratio *	ICER (\$/YoLS) *
Upper (+25%)	\$60,494,703	21.5	\$10,902
Cost of VCOR (base case: \$600,000)			
Lower (-25%)	\$48,174,716	23.0	\$7,676
Upper (+25%)	\$49,538,502	13.8	\$14,129

ICER = incremental cost-effectiveness ratio; ROI = return-on-investment; VCOR = Victorian Cardiac Outcomes Registry; VoSLY = value of statistical life year

All costs are expressed in Australian dollars (AU\$)

* Results discounted at an annual rate of 5%

† Starting year 2014, 5 year time horizon

The model was most sensitive to the assumed time horizon, and the extent to which VCOR contributed to mortality trends in Victoria. Across each scenario, VCOR remained cost-effective and led to a positive ROI.

Discussion

Our economic evaluation has demonstrated that, from the perspective of the Australian health care system, VCOR is likely cost-effective and represents a sound investment over time. This is based on a conservative assumption that this CQR contributed to 0.5% of the proportional reduction in patient mortality occurring across Victoria over the period from 2014 to 2019.

VCOR data are used for the purposes of ongoing benchmarking in the setting of cardiac care.

Notably, since VCOR was established, there has been a considerable increase in hospital

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2
3 uptake of PCI via radial access. Furthermore, the likelihood of STEMI patients being
4 managed with timely reperfusion has increased annually. Such improvements in evidence-
5 based outcomes are likely to be in part attributed to VCOR, and are likely to contribute to the
6 reduction in cardiac mortality across Victoria ^{6 17 31}.

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13 Our findings are in accordance with similar economic evaluations previously conducted in
14 Australia and New Zealand ^{11 32}. The ROI estimated for five CQRs in Australia varied from
15 2.0 to 7.0 based on improvements in key performance indicators (KPIs) unique to each
16 registry ³². Similarly, a cost-effectiveness analysis of the All New Zealand Quality
17 Improvement (ANZACS-QI) program found a positive ROI (1.53) over one year of
18 evaluation, which improved considerably after expanding the time horizon to five years
19 (7.49) ¹¹. The collection of data by ANZACS-QI has been used for addressing sub-optimal
20 adherence to guidelines in the management of ACS identified across New Zealand district
21 health boards. Such initiatives contributed to reductions in patient mortality and readmissions
22 observed over the period of evaluation (2013 to 2016) ^{11 33}.

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37 Additionally, there is considerable evidence of improved patient outcomes as a result of
38 interventions attributed to cardiac CQR benchmarking and health systems feedback in the UK
39 and Sweden ³⁴⁻³⁶. Data collected by the British Cardiovascular Intervention Society
40 demonstrated considerable utility of informing clinical practice in the setting of PCI,
41 including the identification of variable uptake in radial access across hospitals, delays in PCI
42 for NSTEMI patients, and a low rate of same-day discharge for patients undergoing elective
43 PCI ³⁴. Changes to these parameters are likely to improve patient outcomes and efficiency in
44 the delivery of health services for cardiac care ^{16 31 37}. Similarly, mortality from CHD in
45 Sweden declined considerably between 1995 and 2014 due to changes in the evidence-based
46 management of NSTEMI and STEMI ^{35 36}. Such changes have been facilitated through
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3 ongoing quality improvement and benchmarking through SWEDHEART and other, well-
4 established CQRs ^{35 36}.

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8 In Australia alone, several cardiac CQRs have been established across a variety of settings.
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10 These include condition-specific registries, such as the Australian Resuscitation Outcomes
11 Consortium (AUS-ROC) for out-of-hospital cardiac arrest, and the Australian and New
12 Zealand Society of Cardiac and Thoracic Surgeons Database Program (ANZSCTS) as well as
13 VCOR, a cardiac devices or procedures-focused registry ³⁸. The considerable VoSLY
14 assumed in our methodology, coupled with the high mortality burden of cardiovascular
15 diseases globally, is likely to offset the substantial costs attributed to establishing and
16 maintaining cardiac CQRs. Our findings set precedence for similar evaluations to be
17 performed internationally to support CQR uptake and investment, and emphasises the
18 importance of registry development in consideration of KPIs which contribute to improved
19 patient outcomes and ultimately, ROI ³⁸.

37 **Limitations**

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40 A key limitation to our analysis was the uncertainty around the clinical benefit conferred by
41 VCOR with respect to the observed trend in mortality. Hence, we assumed a conservative
42 estimate of the mortality benefits attributed to benchmarking and feedback through VCOR.
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44 Importantly, in scenario analyses whereby the benefit of VCOR was lowered from an already
45 conservative value, the registry remained cost-effective and was still associated with positive
46 ROI. Secondly, it was not possible to assess the impact of VCOR on readmissions for
47 recurrent ACS, and on patient morbidity and quality-of-life through ABS data. Hence, our
48 analyses were limited to capturing the mortality benefit attributed to VCOR. However, KPIs
49 pertaining to patient morbidity, including such as MACCE, hospital length-of-stay and in-
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3 hospital unplanned revascularisation, had remained stable and were relatively low throughout
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5 the period of evaluation ^{21 39}. Readmissions for ACS in Victoria had also remained stable
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7 over time ^{6 40}. Therefore, incorporating the potential cost and clinical impacts attributed to
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9 other trends in clinical practice or the reporting of KPIs outside of DBDT for STEMI patients
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11 by VCOR, would not have changed our findings in a substantial manner. Additionally, there
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13 is a lack of robust data pertaining to quality-of-life following ACS in Australia which limited
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15 analyses on the impact of VCOR on patient morbidity ⁴¹. Thirdly, cost inputs for patient
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17 mortality were based on DRG estimates that were constant across age, sex, and ACS
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19 indications. This was in lieu of robust, bottom-up cost data ^{11 24 42}. However, sensitivity
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21 analyses found that the economic model was robust to the costs of hospitalisations.
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30 **Conclusion**

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32 VCOR represents a sound investment for the Victorian health care system. Based on the
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34 conservative assumption that VCOR benchmarking and feedback contributed to a proportion
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36 of the observed reduction in CHD mortality over time, the registry is associated with cost
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38 savings at the societal level. Additionally, VCOR is cost-effective from the perspective of the
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40 healthcare system.
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11 to disclose.
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28 **Author Contributions:** PL and DL had full access to all of the data in this study and take
29 responsibility for the integrity of the data and accuracy of the data analysis. PL, EZ and DL
30 were responsible for the study concept and design, the acquisition, analysis and interpretation
31 of data and drafting of the manuscript. All authors provided critical revision of the
32 manuscript for important intellectual content.
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6 **Ethics approval:**
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9 This study received ethical approval from Monash University Human Research Ethics
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11 Committee (13882).
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17 **Data availability statement:**
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20 All data are incorporated into the article and its online supplementary material.
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Supplementary Table 1: Trends in CHD mortality over time

CHD mortality		Year									
Sex	Age group (years)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019 ^a
Males	25 - 34	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	35 - 44	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%
	45 - 54	0.04%	0.04%	0.03%	0.03%	0.04%	0.04%	0.04%	0.03%	0.03%	0.04%
	55 - 64	0.10%	0.10%	0.07%	0.07%	0.10%	0.08%	0.08%	0.07%	0.08%	0.11%
	65 - 74	0.24%	0.22%	0.18%	0.19%	0.21%	0.18%	0.17%	0.17%	0.17%	0.22%
	75 - 84	0.78%	0.72%	0.63%	0.58%	0.61%	0.57%	0.59%	0.54%	0.47%	0.52%
	85+	2.87%	2.90%	2.47%	2.40%	2.24%	2.38%	2.24%	2.06%	2.04%	1.90%
All	0.10%	0.10%	0.09%	0.09%	0.09%	0.09%	0.09%	0.08%	0.08%	0.09%	
Females	25 - 34	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	35 - 44	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	45 - 54	0.01%	0.01%	0.00%	0.01%	0.01%	0.01%	0.01%	0.00%	0.01%	0.01%
	55 - 64	0.02%	0.02%	0.01%	0.01%	0.02%	0.02%	0.02%	0.02%	0.01%	0.02%

CHD mortality		Year									
Sex	Age group (years)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019 ^a
	65 - 74	0.08%	0.08%	0.07%	0.06%	0.06%	0.06%	0.06%	0.06%	0.05%	0.06%
	75 - 84	0.43%	0.41%	0.34%	0.32%	0.32%	0.30%	0.27%	0.28%	0.22%	0.24%
	85+	2.37%	2.25%	2.11%	1.92%	1.90%	1.90%	1.71%	1.68%	1.42%	1.41%
	All	0.09%	0.09%	0.08%	0.07%	0.07%	0.07%	0.06%	0.06%	0.05%	0.06%

CHD = coronary heart disease

1 **Supplementary Table 2: VCOR funding over time**

Fund	Year			
	2014	2015	2016	2017
Medibank Private	\$300,000	-	-	-
DHHS	\$509,466	\$460,202	\$834,815	\$616,900
Total	\$809,466	\$460,202	\$834,815	\$616,900

2 DHHS = department of health and human services

3 Source: VCOR Annual Report 2018 ²³

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5 **Supplementary Table 3: Derivation of costs associated with mortality**

Source	DRG	DRG Description	Number of discharges	Cost
NHCDC Round 22 ²⁶	F05A	CRNRY BYPASS+INV INVES, MAJC	602	\$72,146
	F05B	CRNRY BYPASS+INV INVES, MINC	1,010	\$51,816
	F06A	CRNRY BYPASS-INV INVES, MAJC	831	\$62,580
	F06B	CRNRY BYPASS-INV INVES, INTC	1,683	\$44,195
	F06C	CRNRY BYPASS-INV INVES, MINC	1,594	\$37,227
	F10A	INTERVENTIONAL CRNRY PR + AMI, MAJC	2,884	\$22,632
	F10B	INTERVENTIONAL CRNRY PR + AMI, MINC	12,581	\$11,613
	F60A	CIRC DIS+AMI-INVA INV PR	9,435	\$8,089
	F60B	CIRC DIS+AMI-INVA INV PR,T<5D	7,920	\$3,667
	F66A	CORONARY ATHEROSCLEROSIS, MAJC	1,771	\$6,911
	F66B	CORONARY ATHEROSCLEROSIS, MINC	8,825	\$1,908
	F72A	UNSTABLE ANGINA, MAJC	1,713	\$5,845
	F72B	UNSTABLE ANGINA, MINC	7,567	\$2,382

6 AMI = acute myocardial infarction; CIRC = circulatory; CRNRY = coronary; INV =
7 invasive; INVES = investigation; DRG = diagnosis-related group; MAJC = major
8 complexity; MINC = minor complexity; PR = procedure

9

Supplementary Table 4: Characteristics of patients undergoing PCI across Victorian hospitals (VCOR)

Variable	Year					P-value *
	2014 (N = 7,007)	2015 (N = 7,661)	2016 (N = 8,417)	2017 (N = 9,113)	Total (N = 32,198)	
Age						<0.001
Mean (SD)	65 (11.59)	65 (11.50)	66 (11.80)	66 (11.64)	66 (11.6)	
Median (IQR)	66 (17)	66 (17)	66 (17)	67 (17)	66 (16)	
Age group (years), n (%N)						
< 75	5,392 (77.0%)	5,881 (76.8%)	6,291 (74.7%)	6,725 (73.8%)	24,289 (75.4%)	
≥ 75	1,615 (23.1%)	1,780 (23.2%)	2,126 (25.3%)	2,388 (26.2%)	7,909 (24.6%)	
Aboriginal/Torres strait Islander, n (%N)						<0.001
Yes	31 (0.4%)	28 (0.4%)	28 (0.3%)	52 (0.6%)	139 (0.4%)	
No	6,814 (97.3%)	7,266 (94.8%)	8,107 (96.3%)	8,356 (91.7%)	30,543 (94.9%)	
Unknown	162 (2.3%)	367 (4.8%)	282 (3.4%)	705 (7.7%)	1,516 (4.7%)	
Sex, n (%N)						0.039

Variable	Year					P-value *
	2014 (N = 7,007)	2015 (N = 7,661)	2016 (N = 8,417)	2017 (N = 9,113)	Total (N = 32,198)	
Male	5,462 (78.0%)	5,936 (77.5%)	6,482 (77.0%)	6,938 (76.1%)	24,818 (77.1%)	
Female	1,545 (22.0%)	1,725 (22.5%)	1,935 (23.0%)	2,175 (23.8%)	7,380 (22.9%)	
BMI, n (%N)						<0.001
Underweight (<18.5 kg/m ²)	37 (0.5%)	40 (0.5%)	72 (0.9%)	59 (0.7%)	208 (0.7%)	
Normal (18.5 -24.9 kg/m ²)	1,533 (21.9%)	1,678 (21.9%)	1,778 (21.1%)	2,017 (22.1%)	7,006 (21.8%)	
Overweight (25 – 29.9 kg/m ²)	2,882 (41.1%)	3,014 (39.3%)	3,335 (39.6%)	3,596 (39.5%)	12,827 (39.8%)	
Obese (≥30 kg/m ²)	2,445 (34.9%)	2,777 (36.3%)	3,128 (37.2%)	3,368 (37.0%)	11,718 (36.4%)	
Missing	110 (1.6%)	152 (2.0%)	104 (1.2%)	73 (0.8%)	439 (1.4%)	
Public/private hospital status, n (%N)						0.027
Public	4,424 (63.1%)	4,838 (63.2%)	5,225 (62.1%)	5,858 (64.3%)	20,345 (63.2%)	
ACS type, n (%N)						0.024
UA	580 (8.3%)	590 (7.7%)	623 (7.4%)	577 (6.3%)	2,370 (7.4%)	
NSTEMI	1,663 (23.7%)	1,793 (23.4%)	2,026 (24.1%)	2,050 (22.5%)	7,532 (23.4%)	

Variable	Year					P-value *
	2014 (N = 7,007)	2015 (N = 7,661)	2016 (N = 8,417)	2017 (N = 9,113)	Total (N = 32,198)	
STEMI	1,465 (20.9%)	1,561 (20.4%)	1,674 (19.9%)	1,797 (19.7%)	6,497 (20.2%)	
Cardiogenic shock, n (%N)	142 (2.0%)	181 (2.4%)	214 (2.5%)	189 (2.1%)	726 (2.3%)	0.087
Intubated OHCA, n (%N)	72 (1.0%)	81 (1.1%)	100 (1.2%)	110 (1.2%)	363 (1.1%)	0.623
Pre-procedure cardiac arrest, n (%N)	123 (1.8%)	119 (1.6%)	128 (1.5%)	111 (1.2%)	481 (1.5%)	0.042
LVEF grade, n (%N)						0.003
Normal	3,488 (49.8%)	3,840 (50.1%)	4,382 (52.1%)	4,703 (51.6%)	16,413 (51.0%)	
Mild	1,008 (14.4%)	1,291 (16.9%)	1,238 (14.1%)	1,337 (14.7%)	4,874 (15.1%)	
Moderate	487 (7.0%)	551 (7.2%)	664 (7.9%)	642 (7.0%)	2,344 (7.3%)	
Severe	215 (3.1%)	241 (3.2%)	289 (3.4%)	296 (3.3%)	1,041 (3.2%)	
Missing	1,809 (25.8%)	1,738 (22.7%)	1,844 (21.9%)	2,135 (23.4%)	7,526 (23.4%)	
Medicated diabetes, n (%N)	1,532 (21.9%)	1,795 (23.4%)	1,848 (22.0%)	1,979 (21.7%)	7,154 (22.2%)	0.034
Peripheral vascular disease, n (%N)	244 (3.5%)	279 (3.6%)	326 (3.9%)	311 (3.4%)	1,160 (3.6%)	0.386
Cerebrovascular disease, n (%N)	228 (3.3%)	310 (4.1%)	272 (3.2%)	368 (4.0%)	1,178 (3.7%)	0.002

Variable	Year					P-value *
	2014 (N = 7,007)	2015 (N = 7,661)	2016 (N = 8,417)	2017 (N = 9,113)	Total (N = 32,198)	
Chronic oral anticoagulant therapy, n (%N)	294 (4.2%)	347 (4.5%)	465 (5.5%)	754 (8.3%)	1,860 (5.8%)	<0.001
Previous CABG, n (%N)	601 (8.6%)	625 (8.2%)	681 (8.1%)	689 (7.6%)	2,596 (8.1%)	0.126
Previous PCI, n (%N)	2,350 (33.5%)	2,805 (36.6%)	3,013 (35.8%)	3,284 (36.0%)	11,452 (35.6%)	0.001
Dialysis, n (%N)	72 (1.0%)	83 (1.1%)	121 (1.4%)	103 (1.1%)	379 (1.2 %)	0.072
Renal transplant, n (%N)	21 (0.3%)	21 (0.3%)	25 (0.3%)	29 (0.3%)	96 (0.3%)	0.965
Renal replacement therapy, n (%N)	2 (0.0%)	6 (0.1%)	7 (0.1%)	3 (0.0%)	18 (0.1%)	0.305
Fibrinolytic therapy, n (%N)	197 (2.8%)	240 (3.1%)	266 (3.2%)	259 (2.8%)	962 (3.0%)	0.417
eGFR						0.011
Mean (SD)	91.85 (37.11)	92.21 (37.78)	91.80 (38.61)	90.42 (38.04)	91.53 (37.9)	
Median (IQR)	87.47 (47.34)	88.26 (48.28)	87.47 (47.71)	86.35 (46.73)	87.36 (47.6)	
eGFR, n (%N)						0.039
Normal (≥ 90 ml/min/1.73m ²)	5,255 (75.0%)	5,752 (75.1%)	6,277 (74.6%)	6,596 (72.4%)	23,880 (74.2%)	
Moderate (30 – 89 ml/min/1.73m ²)	1,133 (16.2%)	1,251 (16.3%)	1,338 (15.9%)	1,488 (16.3%)	5,210 (16.2%)	

Variable	Year					P-value *
	2014 (N = 7,007)	2015 (N = 7,661)	2016 (N = 8,417)	2017 (N = 9,113)	Total (N = 32,198)	
Severe (<30 ml/min/1.73m ²)	133 (1.9%)	163 (2.1%)	216 (2.6%)	227 (2.5%)	739 (2.4%)	
Missing	486 (6.9%)	495 (6.5%)	586 (7.0%)	802 (8.8%)	2,369 (7.4%)	

ACS = acute coronary syndrome; BMI = body mass index; CABG = coronary artery bypass graft; eGFR = estimated glomerular filtration rate;

LVEF = left ventricular ejection fraction; NSTEMI = Non-ST-elevation myocardial infarction; OHCA = out-of-hospital cardiac arrest; STEMI =

ST-elevation myocardial infarction; UA = unstable angina;

There were 1 missing case for medicated diabetes status, 4 for out-of-hospital cardiac arrest, 1 for in-hospital pre-procedure cardiac arrest, 3 for peripheral vascular disease, 2 for cerebrovascular disease or chronic oral anticoagulant therapy and 1 for renal transplant.

* P-value for year-to-year trend

Supplementary Table 5: Procedural characteristics of PCI across Victorian hospitals (VCOR)

Variable	Year					P-value*
	2014	2015	2016	2017	Total	
Access site, n (%N)						<0.001
Brachial	17 (0.2%)	11 (0.1%)	7 (0.1%)	11 (0.1%)	46 (0.1%)	
Radial	2,608 (37.2%)	3,443 (44.9%)	4,626 (55.0%)	5,555 (60.0%)	16,232 (50.4%)	
Femoral	4,382 (62.5%)	4,207 (54.9%)	3,784 (45.0%)	3,547 (38.9%)	15,920 (49.4%)	
Medications (pre/during procedure), n (%N)						<0.001
Glycoprotein IIb/IIIa inhibitor	915 (13.1%)	853 (11.1%)	768 (9.1%)	737 (8.1%)	3,273 (10.2%)	
Thienopyridine or Ticagrelor	5,843 (83.4%)	6,240 (81.5%)	6,729 (80.0%)	7,113 (78.1%)	25,925 (80.5%)	
Aspirin	5,751 (82.3%)	6,754 (88.5%)	7,707 (91.9%)	8,666 (94.4%)	28,878 (90.0%)	
Antithrombin	6,057 (87.5%)	6,815 (90.3%)	7,452 (89.2%)	8,389 (92.8%)	28,713 (90.1%)	
Lesion characteristics						
Multi-lesion disease, n (%N)	1,275 (18.2%)	1,557 (20.3%)	1,714 (20.4%)	2,001 (22.0%)	6,547 (20.3%)	<0.001

Variable	Year					P-value*
	2014	2015	2016	2017	Total	
Treated vessel(s), n (%N)						
Left main coronary artery	111 (1.6%)	122 (1.6%)	160 (1.9%)	180 (2.0%)	573 (1.8%)	0.123
Multivessel disease, n (%N)	425 (6.07%)	525 (6.85%)	593 (7.05%)	708 (7.7%)	2,251 (6.99%)	<0.001
Unprotected left main PCI, n (%N)	58 (0.8%)	66 (0.8%)	103 (1.2%)	120 (1.3%)	347 (1.1%)	0.003
Chronic total occlusion, n (%N)	290 (4.1%)	358 (4.7%)	334 (4.0%)	342 (3.8%)	1,324 (4.1%)	0.023
In-stent restenosis, n (%N)	440 (6.3%)	501 (6.5%)	515 (6.1%)	519 (5.7%)	1,975 (6.1%)	0.139
Device used, n (%N)						
BMS only	1,277 (18.2%)	1,056 (13.8%)	663 (7.9%)	359 (3.9%)	3,355 (10.4%)	<0.001
Any DES	5,256 (75.0%)	5,934 (77.5%)	7,211 (85.7%)	8,139 (89.3%)	26,540 (82.4%)	<0.001
POBA only	451 (6.4%)	580 (7.6%)	493 (5.9%)	603 (6.6%)	2,127 (6.6%)	<0.001
Door to balloon time metrics †						
Door-to-balloon time [minutes, median (IQR)]	68 (40)	71 (53)	67 (49)	62 (44)	67 (49)	<0.001

Variable	Year					P-value*
	2014	2015	2016	2017	Total	
Door-to-balloon/device time group, n (%N)						<0.001
≤ 90 min	259 (29.8%)	286 (31.3%)	268 (27.6%)	247 (21.4%)	1,060 (27.2%)	
>90 min	607 (69.9%)	624 (68.3%)	704 (72.4%)	888 (78.2%)	2,823 (72.6%)	
Missing	3 (0.35%)	4 (0.4%)	0 (0.0%)	1 (0.09%)	8 (0.2%)	
Post-procedural characteristics						
Lesion success, n (%N)	406 (5.8%)	568 (7.4%)	471 (5.6%)	575 (6.3%)	2,020 (6.3%)	<0.001
Procedure success, n (%N)	6,381 (91.1%)	6,861 (89.6%)	7,688 (91.3%)	8,294 (91.0%)	29,224 (90.8%)	<0.001
New renal impairment, n (%N)	138 (2.6%)	186 (3.3%)	179 (3.0%)	260 (4.1%)	763 (3.3%)	<0.001
Discharge characteristics						
Length-of-stay						
Median (IQR)	2 (3)	2 (3)	3 (3)	2 (3)	2 (3)	0.208

Variable	Year					P-value*
	2014	2015	2016	2017	Total	
Referred to cardiac rehab, n (%N)	4,684 (68.2%)	5,669 (75.2%)	6,284 (76.1%)	6,529 (77.9%)	23,166 (73.3%)	<0.001

BMS = bare metal stent; DES = drug-eluting stent; PCI = percutaneous coronary intervention; POBA = plain old balloon angioplasty; STEMI = ST-elevation myocardial infarction

* P-value for year-to-year trend

† Excluding all inter-hospital transfer arrivals and patients with STEMI onset while a current in-patient

Reporting checklist for economic evaluation of health interventions.

Based on the CHEERS guidelines.

Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

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In your methods section, say that you used the CHEERS reporting guidelines, and cite them as:

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	Reporting Item	Page Number
Title	#1 Identify the study as an economic evaluation or use more specific terms such as "cost-effectiveness analysis", and describe the interventions compared.	1
Abstract	#2 Provide a structured summary of objectives, perspective, setting, methods (including study design and inputs), results (including base case and uncertainty analyses), and conclusions	3
Introduction		
Background and objectives	#3 Provide an explicit statement of the broader context for the study. Present the study question and its relevance for health policy or practice decisions	6

1 **Methods**

2			
3	Target population and	#4	Describe characteristics of the base case population and
4	subgroups		subgroups analysed, including why they were chosen.
5			8
6			
7	Setting and location	#5	State relevant aspects of the system(s) in which the
8			decision(s) need(s) to be made.
9			8
10			
11	Study perspective	#6	Describe the perspective of the study and relate this to
12			the costs being evaluated.
13			13
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15	Comparators	#7	Describe the interventions or strategies being compared
16			and state why they were chosen.
17			13
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19	Time horizon	#8	State the time horizon(s) over which costs and
20			consequences are being evaluated and say why
21			appropriate.
22			8
23			
24	Discount rate	#9	Report the choice of discount rate(s) used for costs and
25			outcomes and say why appropriate
26			12
27			
28	Choice of health	#10	Describe what outcomes were used as the measure(s)
29	outcomes		of benefit in the evaluation and their relevance for the
30			type of analysis performed
31			13
32			
33	Measurement of	#11a	Single study-based estimates: Describe fully the design
34	effectiveness		features of the single effectiveness study and why the
35			single study was a sufficient source of clinical
36			effectiveness data
37			N/A
38			
39			
40	Measurement of	#11b	Synthesis-based estimates: Describe fully the methods
41	effectiveness		used for identification of included studies and synthesis
42			of clinical effectiveness data
43			7-14
44			
45	Measurement and	#12	If applicable, describe the population and methods used
46	valuation of		to elicit preferences for outcomes.
47	preference based		N/A
48	outcomes		
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52	**Estimating		
53	resources		
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N/A

[#13a](#) Single study-based economic evaluation: Describe approaches used to estimate resource use associated with the alternative interventions. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs

Methods

Estimating resources and costs [#13b](#) Model-based economic evaluation: Describe approaches and data sources used to estimate resource use associated with model health states. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.

Currency, price date, and conversion [#14](#) Report the dates of the estimated resource quantities and unit costs. Describe methods for adjusting estimated unit costs to the year of reported costs if necessary. Describe methods for converting costs into a common currency base and the exchange rate.

Choice of model [#15](#) Describe and give reasons for the specific type of decision analytical model used. Providing a figure to show model structure is strongly recommended.

Assumptions [#16](#) Describe all structural or other assumptions underpinning the decision-analytical model.

Analytical methods [#17](#) Describe all analytical methods supporting the evaluation. This could include methods for dealing with skewed, missing, or censored data; extrapolation methods; methods for pooling data; approaches to validate or make adjustments (such as half cycle corrections) to a model; and methods for handling population heterogeneity and uncertainty.

Results

Study parameters [#18](#) Report the values, ranges, references, and, if used, probability distributions for all parameters. Report reasons or sources for distributions used to represent

Page 8,
Table 1

uncertainty where appropriate. Providing a table to show the input values is strongly recommended.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60	Incremental costs and outcomes Characterising uncertainty Characterising uncertainty Characterising heterogeneity Discussion Study findings, limitations, generalisability, and current knowledge Other Source of funding Conflict of interest	#19 #20a #20b #21 #22 #23 #24	For each intervention, report mean values for the main categories of estimated costs and outcomes of interest, as well as mean differences between the comparator groups. If applicable, report incremental cost-effectiveness ratios. Single study-based economic evaluation: Describe the effects of sampling uncertainty for the estimated incremental cost and incremental effectiveness parameters, together with the impact of methodological assumptions (such as discount rate, study perspective). Model-based economic evaluation: Describe the effects on the results of uncertainty for all input parameters, and uncertainty related to the structure of the model and assumptions. If applicable, report differences in costs, outcomes, or cost effectiveness that can be explained by variations between subgroups of patients with different baseline characteristics or other observed variability in effects that are not reducible by more information. Summarise key study findings and describe how they support the conclusions reached. Discuss limitations and the generalisability of the findings and how the findings fit with current knowledge. Describe how the study was funded and the role of the funder in the identification, design, conduct, and reporting of the analysis. Describe other non-monetary sources of support Describe any potential for conflict of interest of study contributors in accordance with journal policy. In the absence of a journal policy, we recommend authors	Page 17, Table 3 N/A Page 18, Table 4 N/A 20-23 24 24
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comply with International Committee of Medical Journal
Editors recommendations

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made by the [EQUATOR Network](#) in collaboration with [Penelope.ai](#)

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BMJ Open

Estimating the Cost-Effectiveness and Return on Investment of the Victorian Cardiac Outcomes Registry in Australia: a Minimum Threshold Analysis

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2022-066106.R1
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Date Submitted by the Author:	28-Feb-2023
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Primary Subject Heading:	Health economics
Secondary Subject Heading:	Cardiovascular medicine, Health economics
Keywords:	CARDIOLOGY, Coronary intervention < CARDIOLOGY, Myocardial infarction < CARDIOLOGY, HEALTH ECONOMICS, PUBLIC HEALTH

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2
3 **1 Estimating the Cost-Effectiveness and Return on Investment of the Victorian Cardiac**
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5 **2 Outcomes Registry in Australia: a Minimum Threshold Analysis**
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8 **3 Running title: An economic evaluation of VCOR**
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40 14 ¹ This author takes responsibility for all aspects of the reliability and freedom from bias of the
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42 15 data presented and their discussed interpretation.
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25 **Word count:** 4,222

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1
2
3 **28 Abstract**
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5

6 **29 Objectives:** We sought to establish the minimum level of clinical benefit attributable to the
7
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9 **30** Victorian Cardiac Outcomes Registry (VCOR) for the registry to be cost-effective.

10
11 **31 Design:** A modelled cost-effectiveness study of VCOR was conducted from the Australian
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14 **32** health care system and societal perspectives.

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16 **33 Setting:** Observed deaths and costs attributed to coronary heart disease (CHD) over a five-
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19 **34** year period (2014 to 2018) were compared to deaths and costs arising from a hypothetical
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21
22 **35** situation which assumed that VCOR did not exist. Data from the Australian Bureau of
23
24 **36** Statistics and published sources were used to construct a decision analytic life table model to
25
26 **37** simulate the follow-up of Victorians aged ≥ 25 years for five years, or until death. The
27
28 **38** assumed contribution of VCOR to the proportional change in CHD mortality trend observed
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30 **39** over the study period was varied to quantify the minimum level of clinical benefits required
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32
33 **40** for the registry to be cost-effective. The marginal costs of VCOR operation and years of life
34
35 **41** saved (YoLS) were estimated.

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38 **42 Primary outcome measures:** The return on investment (ROI) ratio and the incremental cost-
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41 **43** effectiveness ratio (ICER).

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43 **44 Results** The minimum proportional change in CHD mortality attributed to VCOR required
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45
46 **45** for the registry to be considered cost-effective was 0.125%. Assuming this clinical benefit, a
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48 **46** net return of \$4.30 for every dollar invested in VCOR was estimated (ROI ratio over five
49
50 **47** years: 4.3 (95% confidence interval (CI): 3.6 – 5.0). The ICER estimated for VCOR was
51
52 **48** \$49,616 (95% CI: \$42,228 – \$59,608) per YoLS. Sensitivity analyses found that the model
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55 **49** was sensitive to the time horizon assumed and the extent of registry contribution to CHD
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57 **50** mortality trends.

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60 **51 Conclusions**

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52 VCOR is likely cost-effective and represents a sound investment for the Victorian health care
53 system. Our evaluation highlights the value of clinical quality registries in Australia.

For peer review only

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3 54 **Key words:** Cost-effectiveness; acute coronary syndrome; cardiovascular disease; clinical
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6 55 quality registries; quality improvement.
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3 57 **Strengths and limitations of this study**
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- 6 58 • Real-world registry data from VCOR captured temporal changes in the management
7
8 59 of patients undergoing PCI in Victoria, Australia.
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11 60 • Improvements in the uptake of radial access PCI and in timely reperfusion of STEMI
12
13 61 patients were, in part, attributed to VCOR.
14
15 62 • There was uncertainty around the clinical benefit conferred by VCOR with respect to
16
17 63 trends in mortality.
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20 64 • It was not possible to assess the impact of VCOR on readmissions or patient
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22 65 morbidity or quality-of-life using ABS data.
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45 68 **Introduction**
6
78 69 Coronary heart disease (CHD) is a significant cause of morbidity and mortality in Australia.
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10 70 In 2020-2021, the prevalence of CHD in Australia was estimated to be 3% (571,000) of the
11
12 71 adult population ¹. Although mortality from CHD has declined significantly since the 1960s,
13
14 72 it remains the leading cause of death (approximately 10%) in Australia ^{1 2}. With regard to
15
16 73 disease burden, CHDs had contributed to 6.3% (10.4 disability adjusted life years (DALYs)
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18 74 per 10,000 population) of the total disease burden and 2% of hospitalisations in Australia in
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22 75 2018 ^{1 3}.

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25 76 Of the prevalent adult population with CHD in 2020-2021, it is estimated that 40% had
26
27 77 experienced angina and 74% had suffered acute coronary syndrome (ACS) ¹. Percutaneous
28
29 78 coronary intervention (PCI) is the preferred means of revascularisation therapy for many
30
31
32 79 patients presenting with ACS based on Australian and international guidelines ^{4 5}. Across
33
34 80 Australia, 48,034 PCIs were performed between 2020-2021¹; in Victoria alone, 48% of all
35
36 81 PCIs across Victoria in 2021 were performed for the management of ACS ⁶.

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38
39 82 The cost burden attributed to the management of CHD, including costs of PCI, are
40
41 83 correspondingly high. Based on estimates from the Australian Institute of Health and Welfare
42
43 84 (AIHW), in 2018-2019, CHD accounted for \$2.35 billion in health expenditure in Australia,
44
45 85 representing 2% of total health expenditure ⁷. The considerable volume of procedures
46
47 86 performed annually, at an estimated average cost per procedure of \$13,293 ⁸, indicates that
48
49 87 PCIs contribute to a significant proportion of costs in the management of CHD. In Victoria
50
51 88 alone, the cost burden attributed to PCIs across public hospitals was estimated to be
52
53 89 \$72,179,656 Australian Dollars (AU\$) in 2017 ⁹. Importantly, increasing PCI case
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57 90 complexity and procedural volume over time warrants greater adherence to evidence-based
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3 91 guidelines for the management of ACS to improve health systems efficiency and patient
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5 92 outcomes ⁹.
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7
8 93 Clinical quality registries (CQRs) are increasingly utilised to inform projects for the
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10 94 improvement of health care processes, adherence to evidence-based guidelines and standards,
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12 95 and reducing the costs attributed to care delivery ¹⁰⁻¹³. Through the collection of patient
13
14 96 outcomes data for cardiovascular procedures, it is possible to benchmark a hospitals'
15
16 97 performance to its peers and adherence to national standards of care and evidence-based
17
18 98 guidelines ¹⁰. Additionally, CQRs have significant utility in medical research ¹⁰⁻¹². Previous
19
20 99 studies have demonstrated that major improvements to patient outcomes may be attributed to
21
22 100 the existence of CQRs ¹⁰. In the context of ACS, patient outcomes have improved
23
24 101 considerably over time following the establishment of cardiac CQRs in Sweden, New
25
26 102 Zealand, the US and the UK which have been attributed, in part, to registry operation ¹⁴⁻¹⁸.
27
28 103 However, although there are many studies utilising data from CQRs, few have assessed the
29
30 104 clinical and cost impacts attributed to a CQR ¹¹. This is likely due to difficulties in
31
32 105 distinguishing the extent of contribution of CQRs to improved patient outcomes over time
33
34 106 versus secular trends in patient management, and in the nomination of an appropriate
35
36 107 comparator arm to assess the true costs and benefits attributed to registry operation ¹¹. In this
37
38 108 context, we explored the minimum level of contribution to improved patient outcomes
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40 109 required for the Victorian Cardiac Outcomes Registry (VCOR), a cardiac CQR, to be cost-
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42 110 effective and represent a sound investment for the health care system.
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112 **Methods**

113 *Model structure*

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3 114 Life table modelling and decision analysis were used to explore the clinical and cost impacts
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5 115 of VCOR against a hypothetical scenario which assumed that VCOR did not exist (No
6
7 116 VCOR) ¹⁹. Life tables were constructed using age and sex-specific mortality rates for adults
8
9 117 aged ≥ 25 years, based on Victorian population data sourced from the Australian Bureau of
10
11 118 Statistics (ABS) ^{20 21}. Each cohort was followed until death, or up to five years in the base
12
13 119 case. Within each cohort (VCOR or No VCOR), separate life tables were created for 14 age
14
15 120 and sex subgroups. Age was stratified into seven 10-year age bands (25 – 34, 35 – 44, 45 –
16
17 121 54, 55 – 64, 65 – 74, 75 – 84, 85+), with the starting age in each subgroup being the weighted
18
19 122 average age in the age band.
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24 123 The clinical and cost outputs for each model were totalled to determine the overall cost-
25
26 124 effectiveness attributed to VCOR from the perspective of the Australian health care system,
27
28 125 assuming a cost-effectiveness threshold of \$50,000 per year of life saved (YoLS). The
29
30 126 commonly used willingness-to-pay threshold of \$50,000 per YoLS gained in determining
31
32 127 cost-effectiveness ²² was used in lieu of an official willingness to pay threshold in Australia.
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34 128 We also explored the return-on-investment (ROI) attributed to the registry from a societal
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36 129 perspective.
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42 131 *Model population*

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47 132 Our base case modelled population was profiled on the total Victorian population aged ≥ 25
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49 133 years in each year from 2014 to 2018 using ABS inputs. Data pertaining to the total Victorian
50
51 134 population, and mortality in each year from 2010 to 2019, were sourced from the ABS (see
52
53 135 Supplemental Table 1) ^{20 21}. Although ABS data were available for 2010 to 2019, our
54
55 136 modelled population was profiled to reflect PCIs performed between January 2014 to
56
57 137 December 2017 in VCOR. A separate, linked dataset of patient, clinical and procedural
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3 138 characteristics collected by VCOR was made available for the analysis of trends in clinical
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5 139 practice across Victorian hospitals. This dataset was used to inform the extent to which the
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7
8 140 registry had contributed to changes in CHD mortality over time in the economic model
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10 141 informed by ABS data (see '*Effectiveness of VCOR*' below).
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16 143 *Transition probabilities*

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19 144 Data for estimating the incidence of all-cause mortality, and mortality attributed to CHD
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21 145 (based on International Classification of Diseases version 10 (ICD-10) codes: I20 – I25),
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23 146 were sourced for each age and sex subgroup from the ABS^{20 21} (Table 1 and Supplemental
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25
26 147 Tables 1 and 2).
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149 **Table 1: Input parameters used in the economic model, including trends in CHD mortality over time, costs and the assumed**
 150 **contribution of VCOR to reductions in CHD mortality.**

Parameter	Value				Distribution (variance)
CHD Mortality rate by age group (years)	Males (2014 – 2018)	P-value*	Females (2014 – 2018)	P-value*	Uniform ($\pm 20\%$)
25 - 34	0.00% – 0.00%	0.382	0.00% – 0.00%	0.357	
35 - 44	0.01% – 0.01%	0.013	0.00% – 0.00%	0.071	
45 - 54	0.04% – 0.03%	0.006	0.01% – 0.01%	0.283	
55 - 64	0.10% – 0.08%	0.051	0.02% – 0.01%	0.073	
65 - 74	0.21% – 0.17%	0.092	0.06% – 0.05%	0.121	
75 - 84	0.61% – 0.47%	0.033	0.32% – 0.22%	0.023	
85+	2.24% – 2.04%	0.106	1.90% – 1.42%	0.016	
All	0.09% – 0.08%	0.001	0.07% – 0.05%	0.016	
Cost of mortality	\$5,609				Gamma ($\alpha = 5,609$; $\beta =$

Parameter	Value	Distribution (variance)
		1)
VCOR annual costs	\$600,000	Gamma ($\alpha=600,000$; $\beta = 1$)
VoSLY	\$220,262	Gamma ($\alpha = 220,262$; $\beta = 1$)
Assumed contribution of VCOR to CHD mortality trends [†]	0.125%	Uniform (0.100, 0.150)

151 CHD = coronary heart disease; VCOR = Victorian Cardiac Outcomes Registry; VoSLY = value of statistical life year

152 * Based on simple linear regression analyses

153 † Based on varying the assumed contribution by increments of 0.025%

154

155 The likelihood of all-cause or CHD mortality was estimated by dividing the number of deaths
156 (all-cause or CHD-related) in each sex and age subgroup by the Victorian population for each
157 subgroup^{20 21}. The likelihood of non-CHD mortality was estimated by subtracting the
158 likelihood of CHD mortality from the likelihood of all-cause mortality^{20 21}.

159

160 *Effectiveness of VCOR*

161 VCOR is a state-wide, ongoing population based CQR. It was established in 2012 to monitor
162 the performance of cardiac services in hospitals across Victoria^{6 13}. The key focus of VCOR
163 currently is on patients undergoing PCI and cardiac implanted electronic devices^{6 13}. The
164 economic evaluation was based on estimating the downstream clinical and cost impacts of
165 VCOR relative to a hypothetical scenario in which VCOR did not exist (No VCOR). That is,
166 without VCOR contributing to reductions in CHD mortality over time, the extent to which
167 CHD mortality declined over time would be less. In the absence of efficacy data, the assumed
168 contribution of VCOR to reductions in CHD mortality over time was varied in the economic
169 model to establish the minimum contribution required for VCOR to be cost-effective. This is
170 justified based on current literature demonstrating that the registry data collection for the
171 purposes of routine health systems benchmarking and feedback is, of itself, likely to
172 contribute to reductions in mortality over time through improvements in clinical practice^{10 12}.

173 A similar approach whereby the benefits of the All New Zealand Quality Improvement
174 (ANZACS-QI) Programme, a cardiac CQR, was assumed to contribute to temporal trends in
175 patient mortality has been published elsewhere¹². In brief, this evaluation assumed that the
176 registry contributed to 15% of temporal trends in myocardial infarction (MI)-related mortality

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3 177 and readmissions, based on improved adherence to medications indicated for the secondary
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5 178 prevention of ACS and reductions in time-to-treatment parameters ¹².
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8 179 Based on data from the ABS, the risk of CHD mortality in Victoria has decreased steadily
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10 180 over the period from 2014 to 2018 (Table 1). Notably, the clinical management of CHD has
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12 181 also evolved over time. This may in part be attributed to ongoing benchmarking and feedback
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14 182 through VCOR. First, in the period since VCOR was established, implementation of PCI via
15
16 183 radial access (instead of femoral access) has improved considerably ⁶. A Cochrane review of
17
18 184 PCI via radial versus femoral access concluded that radial access was associated with
19
20 185 reductions in major bleeding events, access site complications and mortality in the setting of
21
22 186 ACS ²³. This is supported by data from cardiac registries in the US, UK and Australia;
23
24 187 importantly, a propensity-score matched analysis of radial versus femoral access using
25
26 188 VCOR data found that mortality benefits attributed to radial access were maintained over
27
28 189 time and for patients with high-acuity (STEMI) and non-ACS indications for PCI ²⁴⁻²⁷.
29
30 190 Secondly, in addition to improved uptake of radial access PCI, hospital adherence to a door-
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32 191 to-balloon/device time (DBDT) has improved, with all PCI-capable hospitals across Victoria
33
34 192 achieving a median DBDT of ≤ 90 minutes for STEMI patients ⁶. As with improved uptake
35
36 193 of radial access, improved hospital adherence to a DBDT ≤ 90 minutes is associated with
37
38 194 considerable survival benefits for STEMI patients ²⁸. However, it is not possible to quantify
39
40 195 the direct contribution of VCOR to the uptake of radial access PCI and improvements to
41
42 196 DBDT, and the subsequent reduction in mortality trends downstream. As such, our model
43
44 197 estimated the minimum contribution of VCOR to temporal trends in CHD mortality required
45
46 198 for VCOR to be considered cost-effective. In brief, the assumed contribution of VCOR to the
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48 199 proportional change in CHD mortality was varied in increments of 0.025% until the
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50 200 incremental cost-effectiveness ratio (ICER) for VCOR versus No VCOR was cost-effective.
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3 202 *Cost inputs*
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6 203 Table 1 summarises the cost inputs used in the economic model. All costs were updated to
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8 204 2021 values using the Australian Health Price Index and were expressed as AU\$²⁹.
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14 206 *Cost of VCOR*
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17 207 VCOR is funded through the Victorian Department of Health, Medibank Private and in-kind
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19 208 funding through Monash University⁶. Based on the VCOR annual report for 2018, the
20
21 209 average annual cost borne by the Victorian Department of Health was \$605,346 for the
22
23 210 period from 2014 to 2018 (see Supplemental Table 3)³⁰. We therefore assumed the annual
24
25 211 cost of registry operation to be \$600,000; this was varied in scenario analyses (see below).
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32 212
33 213 *Cost of mortality*
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35 214 There was an absence of relevant data pertaining to the costs of death. As per previous
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37 215 analyses^{12 31 32}, we assumed that deaths due to CHD incurred 50% of the costs of CHD
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39 216 hospitalisations. The cost of hospitalisations for CHD was estimated using data pertaining to
40
41 217 diagnosis-related groups (DRGs) and their costs for publicly-funded casemix hospitalisations
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43 218 in 2017/18 (see Supplemental Table 4)³³. This method has been used in similar economic
44
45 219 evaluations^{12 31 32}. The same cost was applied to deaths due to non-CHD causes.
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53 221 *Cost of a year of life*
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3 222 The value of a statistical life year (VoSLY) was assumed to be \$220,262. This was based on
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5 223 the VoSLY estimated by the Australian Government's Office of Best Practice Regulation of
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8 224 \$213,000 in 2019, adjusted to 2021 values ³⁴.
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12 13 14 226 *Discounting*

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16 227 A discount rate of 5% per annum was applied to years of life lived and costs incurred beyond
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18 228 the first year ²².
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23 24 25 230 *Economic evaluation*

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28 231 The base case economic evaluation involved 14 separate life table models created using ABS
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30 232 data, stratified by sex and age band to represent five years of coverage (2014 – 2018
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32 233 inclusive) of VCOR. The expected values across sex and age subgroups for the VCOR and
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34 234 No VCOR were aggregated to represent the clinical and cost impacts of VCOR over five
35
36 235 years for the total Victorian population at risk of mortality from CHD.
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40 236 The primary cost-benefit analysis estimated differences between the two groups regarding net
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42 237 societal costs. This was defined as the cost of VCOR operation, minus the cost savings
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44 238 attributed to reduced CHD mortality, added to the costs saved by prolonging years of life
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46 239 lived in the cohort. The primary outcome was the net cost attributed to VCOR operation. A
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48 240 key secondary outcome for our study was the ICER for VCOR compared with No VCOR in
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50 241 terms of cost per YoLS.
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55 56 57 243 *Statistical analyses* 58 59 60

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3 244 A linked dataset of 32,198 consecutive PCIs conducted in VCOR over a period of four years
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5 245 (1 January 2014 to 31 December 2017) was made available for the analysis of changes in
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8 246 clinical practice over time in Victoria. Pearson's chi-square tests for categorical variables,
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10 247 and univariate linear regression modelling or generalized linear regression modelling (GLM)
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12 248 for continuous variables, were used to explore differences in patient or procedural trends over
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15 249 time.

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18 250 To explore changes in clinical practice over time, the population was stratified by sex and
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20 251 indication for PCI: non-ACS reasons, unstable angina, non-ST elevation myocardial
21
22 252 infarction (NSTEMI) and ST elevation myocardial infarction (STEMI). Backward stepwise
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24 253 logistic regression with a P-value threshold of 0.10 was used to identify the following
25
26 254 potential confounders of radial access, and DBDT ≤ 90 minutes: age (< 75 years and ≥ 75
27
28 255 years); in-hours hospital arrival (between 08:00 to 18:00 on a workday); cardiogenic shock or
29
30 256 intubated out-of-hospital cardiac arrest (OHCA); left ventricular ejection fraction (LVEF);
31
32 257 medicated diabetes mellitus; peripheral vascular disease; cerebrovascular disease; chronic
33
34 258 oral anticoagulation therapy; prior coronary artery bypass grafting; previous PCI; use of
35
36 259 glycoprotein IIb/IIIa inhibitors; use of thienopyridine or ticagrelor; estimated glomerular
37
38 260 filtration rate (eGFR); required mechanical ventricular support; lesion complexity (American
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40 261 College of Cardiology/American Heart Association type A/B1 versus type B2/C lesions);
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42 262 unprotected left main PCI; chronic total occlusion PCI and in-stent restenosis PCI^{35 36}.
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45 263 Multivariable logistic regression models with adjustment for key predictors identified in
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47 264 stepwise regression were used to explore annual trends in radial access and DBDT metrics.
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50 265 The results of these analyses were used to justify the assumption that VCOR is likely to
51
52 266 contribute to small reductions in CHD mortality over time.
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57 267 To explore trends in CHD mortality over time using mortality data from the ABS, simple
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59 268 linear regression modelling was performed with the year as the independent variable, and

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3 269 CHD mortality as the dependent variable. A P-value <0.05 was considered statistically
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5 270 significant.

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8 271 The economic evaluation was performed with Microsoft Excel®; STATA 14 (StataCorp LP,
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10 272 College Station, Texas) was used to explore changes in clinical practice over time.

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16 274 *Sensitivity analyses*

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19 275 A series of one-way sensitivity analyses were undertaken to determine the impact of
20
21 276 uncertainty around key model parameters. Input parameters were varied individually in
22
23 277 deterministic sensitivity analyses, while other variables were maintained at base case values
24
25 278 to estimate the impact of parameters on cost-benefit/effectiveness. Key parameters assessed
26
27 279 were the time horizon, the assumed contribution of VCOR to CHD mortality trends, costs
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29 280 assumed for CHD mortality, and the VoSLY. Additionally, a scenario analysis was
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31 281 performed, whereby the proportional contribution of VCOR to temporal trends in CHD
32
33 282 mortality was assumed to be equivalent to the mortality benefit attributed to ANZACS-QI.
34
35 283 Based on the assumed contribution of 15% to the observed temporal trend in MI-related
36
37 284 mortality, ANZACS-QI prevented 36 MI-related deaths over a four-year period in the total
38
39 285 New Zealand ACS population (N = 59,280)¹². Upon extrapolation of this benefit to the wider
40
41 286 population at risk of CHD mortality in Victoria (N = 4,017,397), the assumed contribution to
42
43 287 the temporal reduction in CHD mortality was set to 0.5% for VCOR in this scenario analysis.

44
45 288 A probabilistic sensitivity analysis (PSA) was undertaken using 10,000 iterations to assess
46
47 289 uncertainty in the model input parameters simultaneously. The input parameters, variations
48
49 290 and corresponding distributions are presented in Table 1. As variance in mortality rates and
50
51 291 costs were not available, methodology employed by Briggs *et al* was applied¹⁹. CHD
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53 292 mortality rates assumed uniform distributions (applying 20% variance from the input
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3 293 variable), while gamma distributions were applied to costs (where the variance was equal to
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5 294 the mean/input value).
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10 11 296 *Patient and public involvement*

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14 297 No patients or the public were involved in this study.
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18 19 20 299 **Results**

21 22 23 300 *VCOR population*

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26 301 Data from 32,198 consecutive PCIs in Victoria over a four-year period (1 January 2014 to 31
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28 302 December 2017) was used to explore the impact of VCOR on clinical practice. Baseline and
29
30 303 procedural characteristics of the VCOR population are presented in the Supplementary
31
32 304 material (Supplemental Tables 5 and 6).
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35
36 305 The cohort was predominately male (77%), overweight or obese (76.2%) undergoing PCI for
37
38 306 ACS (50.9%) in public hospitals (63.2%).
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41 307 The results of multivariable modelling on changes in radial access and DBDT over time are
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43 308 presented in Supplemental Table 7.
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46 309 The likelihood of patients managed through femoral access decreased annually across all
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48 310 non-ACS and ACS indications for PCI ($P < 0.001$). For patients undergoing primary PCI for
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50 311 STEMI, the likelihood of timely reperfusion ($DBDT \leq 90$ minutes) increased annually by at
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52 312 least 15% across both sexes ($P < 0.05$).
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57 58 59 314 *Economic analysis of the total Victorian population*

315 The impact of varying the assumed contribution of VCOR on the ICER and the ROI are
 316 presented in Figure 1 and Supplemental Figure 1, respectively.

317

318 The minimum proportional change in CHD mortality attributed to VCOR required for the
 319 registry to be considered cost-effective was 0.125% (see Figure 1). Table 2 presents the base-
 320 case analysis in terms of the overall clinical and cost impacts attributed to five years of full
 321 coverage of VCOR for the Victorian population aged ≥ 25 years from 2014 to 2018 at this
 322 level of registry contribution (0.125%) to CHD mortality trends.

323

324 **Table 2: Results of the base case economic model, assuming that VCOR contributed to**
 325 **0.125% of the temporal change in CHD mortality**

Parameter	Overall (N = 4,017,397)		Difference
	VCOR	No VCOR	
Clinical outcomes, n (%N)			
CHD mortality	19,065 (0.47%)	19,089 (0.48%)	-23
Non-CHD mortality	140,455 (3.50%)	140,452 (3.50%)	3
Total	159,520 (3.97%)	159,540 (3.97%)	-20
Years lived *	17,887,125	17,887,072	53
Cost outcomes			
VCOR *	\$2,727,570	-	\$2,727,570
CHD mortality *	\$98,517,938	\$98,638,721	-\$120,783
Non-CHD mortality *	\$722,495,795	\$722,480,855	\$14,941
Total health cost *	\$823,741,304	\$821,119,575	\$2,621,728

Parameter	Overall (N = 4,017,397)		Difference
	VCOR	No VCOR	
VoSLY *	\$3,939,854,066,111	\$3,939,842,427,479	\$11,638,633
ICER (\$/YoLS) *(Point value, 95% CI [†])	\$49,616 (\$42,228 – \$59,608)		
ROI ratio *(Point value, 95% CI [†])	4.3 (3.6 – 5.0)		

326 CHD = coronary heart disease; CI = confidence interval; ICER = incremental cost-
 327 effectiveness ratio; ROI = return-on-investment; VCOR = Victorian cardiac outcomes
 328 registry; VoSLY = value of statistical life year

329 All costs are expressed in Australian dollars (AU\$)

330 * Results discounted at an annual rate of 5%

331 † Estimated from PSA

332

333 Over this period, a total of 19,065 CHD-related deaths occurred across Victoria. Based on the
 334 assumption that VCOR contributed to 0.125% of the temporal change in CHD mortality over
 335 time, the clinical benefit attributed to VCOR was the prevention of 23 CHD-related deaths
 336 and 53 (discounted) years of life saved. A total of \$120,783 was saved over this period due to
 337 the prevention of CHD mortality. This was balanced against a higher incidence of non-CHD
 338 mortality in the VCOR cohort (because the risk of non-CHD death was not assumed to have
 339 changed by VCOR), which incurred an additional cost of \$14,941. The total cost of VCOR
 340 was \$2,727,570 (discounted). Hence the net cost of VCOR from the perspective of the
 341 Australian health care system was \$2,621,728 (discounted). The ICER associated with VCOR
 342 was \$49,616 per YoLS (95% confidence interval (CI): \$42,228 – \$59,608). From a broader,

343 societal perspective, the savings attributed to VCOR were \$11,638,633 based on an assumed
 344 VoSLY of \$220,262. The return on investment (ROI) ratio, which is the ratio of the total cost
 345 savings to the total costs of VCOR, was 4.3 (95% CI: 3.6 – 5.0); that is, for every \$1.00
 346 invested in VCOR, a return of \$4.30 was delivered.

347 Table 3 presents the results of sensitivity analyses in terms of ICERs, net societal costs
 348 attributed to VCOR operation, and ROI.

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 350 **Table 3: Results of deterministic scenario analyses**

Scenario	Net cost *	ROI ratio *	ICER (\$/YoLS) *
Base case †	\$14,260,361	4.3	\$49,616
Time horizon (starting year 2014)			
1 year	\$1,236,407	1.2	\$185,866
2 years	\$3,575,677	2.2	\$99,280
3 years	\$6,685,471	3.0	\$71,341
4 years	\$10,311,267	3.7	\$57,648
Time horizon (starting year 2015)			
1 year	\$1,236,668	1.2	\$185,785
2 years	\$3,556,760	2.1	\$100,185
3 years	\$6,623,705	3.0	\$72,297
4 years	\$10,183,945	3.6	\$58,642
5 years	\$14,097,331	4.2	\$50,315

Scenario	Net cost *	ROI ratio *	ICER (\$/YoLS) *
Contribution to trends (base case: 0.125%)			
Lower (0.10%)	\$11,953,831	3.4	\$62,521
Upper (0.15%)	\$16,566,876	5.2	\$41,013
ANZACS-QI (0.50%)	\$48,856,609	17.2	\$10,902
VoSLY (base case: \$220,262)			
Lower (-25%)	\$11,350,703	3.2	\$49,616
Upper (+25%)	\$17,170,019	5.4	\$49,616
Cost of VCOR (base case: \$600,000)			
Lower (-25%)	\$13,578,468	5.7	\$36,712
Upper (+25%)	\$14,942,253	3.4	\$62,521

351 ANZACS-QI = All New Zealand Acute Coronary Syndrome Quality Improvement
 352 programme; ICER = incremental cost-effectiveness ratio; ROI = return-on-investment;
 353 VCOR = Victorian Cardiac Outcomes Registry; VoSLY = value of statistical life year
 354 All costs are expressed in Australian dollars (AU\$)

355 * Results discounted at an annual rate of 5%

356 † Starting year 2014, 5 year time horizon

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3 358 The model was most sensitive to the assumed time horizon, and the extent to which VCOR
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5 359 contributed to mortality trends in Victoria. Across each scenario, VCOR represented a
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8 360 positive ROI. The results of the additional PSA are presented in Figure 2 below.
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16 363 Based on the results of the PSA, the majority (97.5%) of iterations fell below an ICER of
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19 364 \$60,000 per YoLS.
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23 24 25 366 **Discussion**

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28 367 Our economic evaluation found that the minimum contribution to the proportional change in
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30 368 CHD mortality over time required for VCOR to be cost-effective was 0.125%. That is, for
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32 369 VCOR to be considered cost-effective from the perspective of the Australian health care
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34 370 system, the registry would need to prevent 23 CHD-related deaths between 2014 to 2018
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36 371 (five years inclusive), through benchmarking and health systems quality improvement. In lieu
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38 372 of data pertaining to the direct impacts of VCOR operation on CHD mortality, our analyses
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40 373 suggest that VCOR is likely to be cost-effective on the basis of the comparatively small CHD
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42 374 mortality benefits (23 deaths over five years) required for the registry to fall within the
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44 375 widely-established willingness-to-pay threshold of \$50,000 per YoLS²². Since the
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46 376 establishment of VCOR, there has been a considerable increase in hospital uptake of PCI via
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48 377 radial access^{37 38}. Furthermore, the likelihood of STEMI patients being managed with timely
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50 378 reperfusion had increased annually throughout the period of 2014-2018^{37 38}. These trends in
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52 379 improved patient management are facilitated through VCOR benchmarking and health
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54 380 systems feedback, and are likely to contribute to the reduction in cardiac mortality observed
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56 381 across Victoria^{6 24 39}. Lastly, data from VCOR has informed research exploring disparities in
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3 382 the management of ACS to further drive improvements in cardiac care and subsequently,
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5 383 reduce CHD mortality across Victoria^{40 41}.
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8 384 Our findings are in accordance with similar economic evaluations previously conducted in
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10 385 Australia and New Zealand^{12 42}. The ROI estimated for five CQRs in Australia varied from
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12 386 2.0 to 7.0 based on improvements in key performance indicators (KPIs) unique to each
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14 387 registry⁴². Similarly, a cost-effectiveness analysis of the ANZACS-QI program found a
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16 388 positive ROI (1.53) over one year of evaluation, which improved considerably after
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18 389 expanding the time horizon to five years (7.49)¹². The collection of data by ANZACS-QI has
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20 390 been used for addressing sub-optimal adherence to guidelines in the management of ACS
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22 391 identified across New Zealand district health boards. In evaluating the cost-effectiveness and
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24 392 ROI attributed to ANZACS-QI, improvements in KPIs contributed to reductions in patient
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26 393 mortality and readmissions observed over the period of evaluation (2013 to 2016), and the
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28 394 registry was both cost-effective and represented a sound investment for the New Zealand
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30 395 health care system^{12 43}.
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36 396 Additionally, there is considerable evidence of improved patient outcomes as a result of
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38 397 interventions attributed to cardiac CQR benchmarking and health systems feedback in the UK
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40 398 and Sweden^{15 44 45}. Data collected by the British Cardiovascular Intervention Society (BCIS)
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42 399 was of considerable utility for informing clinical practice in the setting of PCI, allowing for
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44 400 the identification of variable uptake in radial access across hospitals, delays in PCI for
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46 401 NSTEMI patients, and a low rate of same-day discharge for patients undergoing elective PCI
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48 402⁴⁴. Changes to these parameters are likely to improve patient outcomes and efficiency in the
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50 403 delivery of health services for cardiac care^{23 39 46}. Similarly, mortality from CHD in Sweden
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52 404 declined considerably between 1995 and 2014 due to changes in the evidence-based
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54 405 management of NSTEMI and STEMI based on data collected as part of the Swedish Web-
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56 406 system for Enhancement and Development of Evidence-based care in Heart disease

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3 407 Evaluated According to Recommended Therapies (SWEDEHEART) CQR^{15 45}. Such
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5 408 changes have been facilitated through ongoing quality improvement and benchmarking
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7 409 through SWEDEHEART and other, well-established CQRs^{15 45}.
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10 410 In Australia alone, several cardiac CQRs have been established across a variety of settings.
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12 411 These include condition-specific registries, such as the Australian Resuscitation Outcomes
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14 412 Consortium (AUS-ROC) for out-of-hospital cardiac arrest, and the Australian and New
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16 413 Zealand Society of Cardiac and Thoracic Surgeons Database Program (ANZSCTS) as well as
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18 414 VCOR, a cardiac devices or procedures-focused registry⁴⁷. The considerable VoSLY
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20 415 assumed in our methodology, coupled with the high mortality burden of cardiovascular
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22 416 diseases globally, is likely to offset the substantial costs attributed to establishing and
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24 417 maintaining cardiac CQRs. Our findings set precedence for similar evaluations to be
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26 418 performed internationally to support CQR uptake and investment, and emphasises the
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28 419 importance of registry development in consideration of KPIs which contribute to improved
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30 420 patient outcomes and ultimately, ROI⁴⁷.
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40 **Limitations**

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42 423 A key limitation to our analysis was the uncertainty around the clinical benefit conferred by
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44 424 VCOR with respect to the observed trend in mortality. Hence, we explored the minimum
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46 425 contribution to temporal reductions in CHD mortality required for VCOR to be cost-
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48 426 effective, based on the assumption that registry benchmarking and feedback contribute to a
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50 427 small proportion of temporal reductions in CHD mortality. Importantly, in scenario analyses
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52 428 whereby the benefit of VCOR was lowered from an already small value, the ICER increased
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54 429 slightly (\$49,616 per YoLS to \$62,521 per YoLS) and was still associated with positive ROI.
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56 430 Furthermore, 97.5% of iterated ICERs in the PSA fell below \$60,000 per YoLS; while no
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3 431 formally published value for cost-effectiveness has been established in Australia, the
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5 432 Choosing Interventions that are Cost-Effective (CHOICE) programme of the World Health
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7 433 Organisation (WHO) defines interventions with a cost per quality-adjusted life year (QALY)
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9 434 or YoLS less than one gross domestic product (GDP) per capita as ‘very cost-effective’⁴⁸. As
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11 435 the current GDP per capita in Australia is AU\$89,743 (or US dollars (US\$) 61,977 assuming
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13 436 1 US\$ = 1.45 AU\$ in 2021), our analyses demonstrate that VCOR is likely to be very cost-
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15 437 effective⁴⁸⁻⁵⁰. Secondly, it was not possible to assess the impact of VCOR on readmissions
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17 438 for recurrent ACS, and on patient morbidity and quality-of-life through ABS data. Hence, our
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19 439 analyses were limited to capturing the mortality benefit attributed to VCOR. However, KPIs
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21 440 pertaining to patient morbidity, including major adverse cardiac and cerebrovascular events,
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23 441 hospital length-of-stay and in-hospital unplanned revascularisation, had remained stable and
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25 442 were relatively low throughout the period of evaluation^{37 51}. Readmissions for ACS in
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27 443 Victoria had also remained stable over time^{6 52}. Therefore, incorporating the potential cost
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29 444 and clinical impacts attributed to other trends in clinical practice or the reporting of KPIs
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31 445 outside of DBDT for STEMI patients by VCOR, would not have changed our findings in a
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33 446 substantial manner. Additionally, there is a lack of robust data pertaining to quality-of-life
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35 447 following ACS in Australia which limited analyses on the impact of VCOR on patient
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37 448 morbidity⁵³. Thirdly, cost inputs for patient mortality were based on DRG estimates that
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39 449 were constant across age, sex, and ACS indications. This was in lieu of robust, bottom-up
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41 450 cost data^{12 31 54}. However, sensitivity analyses found that the economic model was robust to
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43 451 the costs of hospitalisations.
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55 453 **Conclusion**

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3 454 VCOR represents a sound investment for the Victorian health care system. Based on the
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5 455 assumption that VCOR benchmarking and feedback contributed to a small proportion of the
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7 456 observed reduction in CHD mortality over time, the registry is associated with cost savings at
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10 457 the societal level. Additionally, VCOR is cost-effective from the perspective of the healthcare
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8
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18
19 468 to disclose.
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26
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28
29 471 responsibility for the integrity of the data and accuracy of the data analysis. PL, EZ and DL
30
31 472 were responsible for the study concept and design, the acquisition, analysis and interpretation
32
33 473 of data and drafting of the manuscript. PL, ALB, DS, DD, JL, CMR, EZ, and DL made
34
35 474 significant contribution to drafting the work, or revising it critically for intellectual content.
36
37 475 PL, ALB, DS, DD, JL, CMR, EZ, and DL provided final approval of the version to be
38
39 476 published. PL is the guarantor of this paper.
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14 487 This study received ethical approval from Monash University Human Research Ethics
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16 488 Committee (13882).
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22 490 **Data availability statement:**
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25 491 All data are incorporated into the article and its online supplementary material.
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7 675 **Figure 1: Relative contribution of VCOR to CHD mortality trends versus VCOR cost-**
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12 677 ICER = incremental cost-effectiveness ratio; YoLS = year of life saved
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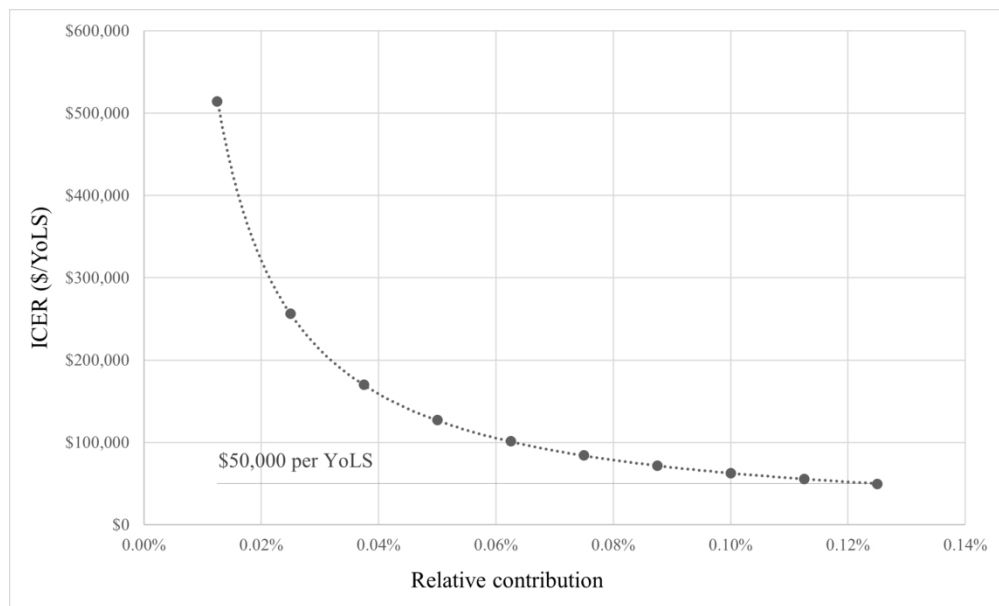


Figure 1: Relative contribution of VCOR to CHD mortality trends versus VCOR cost-effectiveness
 ICER = incremental cost-effectiveness ratio; YoLS = year of life saved

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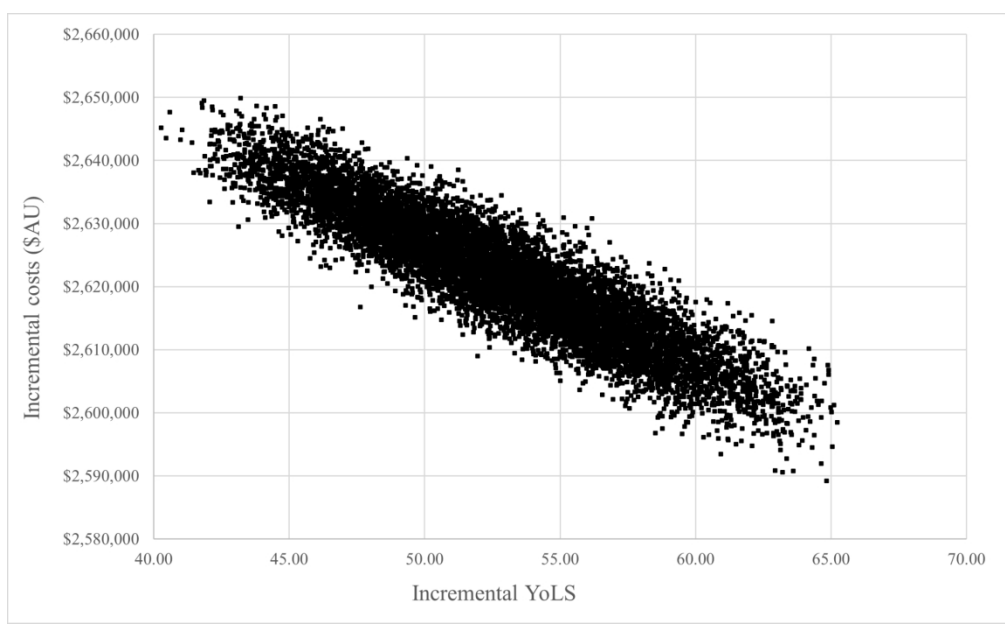


Figure 2: Results of the probabilistic sensitivity analysis
\$AU = Australian dollars; YoLS = year of life saved

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Supplementary table 1: Trends in CHD mortality over time CHD mortality

CHD mortality		Year									
Sex	Age group (years)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Males	25 - 34	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	35 - 44	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%
	45 - 54	0.04%	0.04%	0.03%	0.03%	0.04%	0.04%	0.04%	0.03%	0.03%	0.04%
	55 - 64	0.10%	0.10%	0.07%	0.07%	0.10%	0.08%	0.08%	0.07%	0.08%	0.11%
	65 - 74	0.24%	0.22%	0.18%	0.19%	0.21%	0.18%	0.19%	0.17%	0.17%	0.22%
	75 - 84	0.78%	0.72%	0.63%	0.58%	0.61%	0.57%	0.59%	0.54%	0.47%	0.52%
	85+	2.87%	2.90%	2.47%	2.40%	2.24%	2.38%	2.24%	2.06%	2.04%	1.90%
	All	0.10%	0.10%	0.09%	0.09%	0.09%	0.09%	0.09%	0.08%	0.08%	0.09%
Females	25 - 34	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	35 - 44	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	45 - 54	0.01%	0.01%	0.00%	0.01%	0.01%	0.01%	0.01%	0.00%	0.01%	0.01%
	55 - 64	0.02%	0.02%	0.01%	0.01%	0.02%	0.02%	0.02%	0.02%	0.01%	0.02%
	65 - 74	0.08%	0.08%	0.07%	0.06%	0.06%	0.06%	0.06%	0.06%	0.05%	0.06%

CHD mortality		Year									
Sex	Age group (years)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
	75 - 84	0.43%	0.41%	0.34%	0.32%	0.32%	0.30%	0.27%	0.28%	0.22%	0.24%
	85+	2.37%	2.25%	2.11%	1.92%	1.90%	1.90%	1.72%	1.68%	1.42%	1.41%
	All	0.09%	0.09%	0.08%	0.07%	0.07%	0.07%	0.06%	0.06%	0.05%	0.06%

CHD = coronary heart disease

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Supplemental Table 2: Trends in CHD mortality over time used in the economic model.

Parameter	Value						
	Age group (years)	Year					P-value*
		2014	2015	2016	2017	2018	
CHD Mortality Trend (Males)	25 - 34	0.00%	0.00%	0.00%	0.00%	0.00%	0.382
	35 - 44	0.01%	0.01%	0.01%	0.01%	0.01%	0.013
	45 - 54	0.04%	0.04%	0.04%	0.03%	0.03%	0.006
	55 - 64	0.10%	0.08%	0.08%	0.07%	0.08%	0.051
	65 - 74	0.21%	0.18%	0.17%	0.17%	0.17%	0.092
	75 - 84	0.61%	0.57%	0.59%	0.54%	0.47%	0.033
	85+	2.24%	2.38%	2.24%	2.06%	2.04%	0.106
	All	0.09%	0.09%	0.09%	0.08%	0.08%	0.001
CHD Mortality Trend (Females)	25 - 34	0.00%	0.00%	0.00%	0.00%	0.00%	0.357
	35 - 44	0.00%	0.00%	0.00%	0.00%	0.00%	0.071
	45 - 54	0.01%	0.01%	0.01%	0.00%	0.01%	0.283

Parameter	Value						
	Age group (years)	Year					P-value*
		2014	2015	2016	2017	2018	
	55 - 64	0.02%	0.02%	0.02%	0.02%	0.01%	0.073
	65 - 74	0.06%	0.06%	0.06%	0.06%	0.05%	0.121
	75 - 84	0.32%	0.30%	0.27%	0.28%	0.22%	0.023
	85+	1.90%	1.90%	1.71%	1.68%	1.42%	0.016
	All	0.07%	0.07%	0.06%	0.06%	0.05%	0.016

CHD = coronary heart disease

* Based on simple linear regression analyses

Supplementary Table 3: VCOR funding over time

Fund	Year			
	2014	2015	2016	2017
Medibank Private	\$300,000	-	-	-
DHHS	\$509,466	\$460,202	\$834,815	\$616,900
Total	\$809,466	\$460,202	\$834,815	\$616,900

DHHS = Department of Health and Human Services

Source: VCOR Annual Report 2018 ³⁰

Supplementary Table 4: Derivation of costs associated with mortality

Source	DRG	DRG Description	Number of discharges	Cost
NHCDC Round 22 ³²	F05A	CRNRY BYPASS+INV INVES, MAJC	602	\$72,146
	F05B	CRNRY BYPASS+INV INVES, MINC	1,010	\$51,816
	F06A	CRNRY BYPASS-INV INVES, MAJC	831	\$62,580
	F06B	CRNRY BYPASS-INV INVES, INTC	1,683	\$44,195
	F06C	CRNRY BYPASS-INV INVES, MINC	1,594	\$37,227
	F10A	INTERVENTIONAL CRNRY PR + AMI, MAJC	2,884	\$22,632
	F10B	INTERVENTIONAL CRNRY PR + AMI, MINC	12,581	\$11,613
	F60A	CIRC DIS+AMI-INVA INV PR	9,435	\$8,089
	F60B	CIRC DIS+AMI-INVA INV PR,T<5D	7,920	\$3,667
	F66A	CORONARY ATHEROSCLEROSIS, MAJC	1,771	\$6,911
	F66B	CORONARY ATHEROSCLEROSIS, MINC	8,825	\$1,908
	F72A	UNSTABLE ANGINA, MAJC	1,713	\$5,845

	F72B	UNSTABLE ANGINA, MINC	7,567	\$2,382
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AMI = acute myocardial infarction; CIRC = circulatory; CRNRY = coronary; INV =
invasive; INVES = investigation; DRG = diagnosis-related group; MAJC = major
complexity; MINC = minor complexity; PR = procedure

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Supplementary Table 5: Characteristics of patients undergoing PCI across Victorian hospitals (VCOR)

Variable	Year					P-value ^a
	2014 (N = 7,007)	2015 (N = 7,661)	2016 (N = 8,417)	2017 (N = 9,113)	Total (N = 32,198)	
Age						<0.001
Mean (SD)	65 (11.59)	65 (11.50)	66 (11.80)	66 (11.64)	66 (11.6)	
Median (IQR)	66 (17)	66 (17)	66 (17)	67 (17)	66 (16)	
Age group (years), n (%N)						
< 75	5,392 (77.0%)	5,881 (76.8%)	6,291 (74.7%)	6,725 (73.8%)	24,289 (75.4%)	
≥ 75	1,615 (23.1%)	1,780 (23.2%)	2,126 (25.3%)	2,388 (26.2%)	7,909 (24.6%)	
Aboriginal/Torres strait Islander, n (%N)						<0.001
Yes	31 (0.4%)	28 (0.4%)	28 (0.3%)	52 (0.6%)	139 (0.4%)	
No	6,814 (97.3%)	7,266 (94.8%)	8,107 (96.3%)	8,356 (91.7%)	30,543 (94.9%)	
Unknown	162 (2.3%)	367 (4.8%)	282 (3.4%)	705 (7.7%)	1,516 (4.7%)	

Variable	Year					P-value ^a
	2014 (N = 7,007)	2015 (N = 7,661)	2016 (N = 8,417)	2017 (N = 9,113)	Total (N = 32,198)	
Sex, n(%N)						0.039
Male	5,462 (78.0%)	5,936 (77.5%)	6,482 (77.0%)	6,938 (76.1%)	24,818 (77.1%)	
Female	1,545 (22.0%)	1,725 (22.5%)	1,935 (23.0%)	2,175 (23.8%)	7,380 (22.9%)	
BMI, n (%N)						<0.001
Underweight (<18.5 kg/m ²)	37 (0.5%)	40 (0.5%)	72 (0.9%)	59 (0.7%)	208 (0.7%)	
Normal (18.5 -24.9 kg/m ²)	1,533 (21.9%)	1,678 (21.9%)	1,778 (21.1%)	2,017 (22.1%)	7,006 (21.8%)	
Overweight (25 – 29.9 kg/m ²)	2,882 (41.1%)	3,014 (39.3%)	3,335 (39.6%)	3,596 (39.5%)	12,827 (39.8%)	
Obese (≥30 kg/m ²)	2,445 (34.9%)	2,777 (36.3%)	3,128 (37.2%)	3,368 (37.0%)	11,718 (36.4%)	
Missing	110 (1.6%)	152 (2.0%)	104 (1.2%)	73 (0.8%)	439 (1.4%)	
Public/private hospital status, n (%N)						
Public	4,424 (63.1%)	4,838 (63.2%)	5,225 (62.1%)	5,858 (64.3%)	20,345 (63.2%)	0.027
ACS type, n (%N)						0.024

Variable	Year					P-value ^a
	2014 (N = 7,007)	2015 (N = 7,661)	2016 (N = 8,417)	2017 (N = 9,113)	Total (N = 32,198)	
UA	580 (8.3%)	590 (7.7%)	623 (7.4%)	577 (6.3%)	2,370 (7.4%)	
NSTEMI	1,663 (23.7%)	1,793 (23.4%)	2,026 (24.1%)	2,050 (22.5%)	7,532 (23.4%)	
STEMI	1,465 (20.9%)	1,561 (20.4%)	1,674 (19.9%)	1,797 (19.7%)	6,497 (20.2%)	
Cardiogenic shock, n (%N)	142 (2.0%)	181 (2.4%)	214 (2.5%)	189 (2.1%)	726 (2.3%)	0.087
Intubated OHCA, n (%N)	72 (1.0%)	81 (1.1%)	100 (1.2%)	110 (1.2%)	363 (1.1%)	0.623
Pre-procedure cardiac arrest, n (%N)	123 (1.8%)	119 (1.6%)	128 (1.5%)	111 (1.2%)	481 (1.5%)	0.042
LVEF grade, n (%N)						0.003
Normal	3,488 (49.8%)	3,840 (50.1%)	4,382 (52.1%)	4,703 (51.6%)	16,413 (51.0%)	
Mild	1,008 (14.4%)	1,291 (16.9%)	1,238 (14.1%)	1,337 (14.7%)	4,874 (15.1%)	
Moderate	487 (7.0%)	551 (7.2%)	664 (7.9%)	642 (7.0%)	2,344 (7.3%)	
Severe	215 (3.1%)	241 (3.2%)	289 (3.4%)	296 (3.3%)	1,041 (3.2%)	
Missing	1,809 (25.8%)	1,738 (22.7%)	1,844 (21.9%)	2,135 (23.4%)	7,526 (23.4%)	

Variable	Year					P-value ^a
	2014 (N = 7,007)	2015 (N = 7,661)	2016 (N = 8,417)	2017 (N = 9,113)	Total (N = 32,198)	
Medicated diabetes, n (%N)	1,532 (21.9%)	1,795 (23.4%)	1,848 (22.0%)	1,979 (21.7%)	7,154 (22.2%)	0.034
Peripheral vascular disease, n (%N)	244 (3.5%)	279 (3.6%)	326 (3.9%)	311 (3.4%)	1,160 (3.6%)	0.386
Cerebrovascular disease, n (%N)	228 (3.3%)	310 (4.1%)	272 (3.2%)	368 (4.0%)	1,178 (3.7%)	0.002
Chronic oral anticoagulant therapy, n (%N)	294 (4.2%)	347 (4.5%)	465 (5.5%)	754 (8.3%)	1,860 (5.8%)	<0.001
Previous CABG, n (%N)	601 (8.6%)	625 (8.2%)	681 (8.1%)	689 (7.6%)	2,596 (8.1%)	0.126
Previous PCI, n (%N)	2,350 (33.5%)	2,805 (36.6%)	3,013 (35.8%)	3,284 (36.0%)	11,452 (35.6%)	0.001
Dialysis, n (%N)	72 (1.0%)	83 (1.1%)	121 (1.4%)	103 (1.1%)	379 (1.2%)	0.072
Renal transplant, n (%N)	21 (0.3%)	21 (0.3%)	25 (0.3%)	29 (0.3%)	96 (0.3%)	0.965
Renal replacement therapy, n (%N)	2 (0.0%)	6 (0.1%)	7 (0.1%)	3 (0.0%)	18 (0.1%)	0.305
Fibrinolytic therapy, n (%N)	197 (2.8%)	240 (3.1%)	266 (3.2%)	259 (2.8%)	962 (3.0%)	0.417
eGFR						0.011
Mean (SD)	91.85 (37.11)	92.21 (37.78)	91.80 (38.61)	90.42 (38.04)	91.53 (37.9)	

Variable	Year					P-value ^a
	2014 (N = 7,007)	2015 (N = 7,661)	2016 (N = 8,417)	2017 (N = 9,113)	Total (N = 32,198)	
Median (IQR)	87.47 (47.34)	88.26 (48.28)	87.47 (47.71)	86.35 (47.73)	87.36 (47.6)	
eGFR, n (%N)						0.039
Normal (≥ 90 ml/min/1.73m ²)	5,255 (75.0%)	5,752 (75.1%)	6,277 (74.6%)	6,596 (72.4%)	23,880 (74.2%)	
Moderate (30 – 89 ml/min/1.73m ²)	1,133 (16.2%)	1,251 (16.3%)	1,338 (15.9%)	1,488 (16.3%)	5,210 (16.2%)	
Severe (<30 ml/min/1.73m ²)	133 (1.9%)	163 (2.1%)	216 (2.6%)	227 (2.5%)	739 (2.4%)	
Missing	486 (6.9%)	495 (6.5%)	586 (7.0%)	802 (8.8%)	2,369 (7.4%)	

ACS = acute coronary syndrome; BMI = body mass index; CABG = coronary artery bypass graft; eGFR = estimated glomerular filtration rate;

LVEF = left ventricular ejection fraction; NSTEMI = Non-ST-elevation myocardial infarction; OHCA = out-of-hospital cardiac arrest; STEMI =

ST-elevation myocardial infarction; UA = unstable angina;

There were 1 missing case for medicated diabetes status, 4 for out-of-hospital cardiac arrest, 1 for in-hospital pre-procedure cardiac arrest, 3 for

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peripheral vascular disease, 2 for cerebrovascular disease or chronic oral anticoagulant therapy and 1 for renal transplant.

^a P-value for year-to-year trend

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Supplementary Table 6: Procedural characteristics of PCI across Victorian hospitals (VCOR)

Variable	Year					P-value ^a
	2014 (N = 7,007)	2015 (N = 7,661)	2016 (N = 8,417)	2017 (N = 9,113)	Total (N = 32,198)	
Access site, n (%N)						<0.001
Brachial	17 (0.2%)	11 (0.1%)	7 (0.1%)	11 (0.1%)	46 (0.1%)	
Radial	2,608 (37.2%)	3,443 (44.9%)	4,626 (55.0%)	5,555 (61.0%)	16,232 (50.4%)	
Femoral	4,382 (62.5%)	4,207 (54.9%)	3,784 (45.0%)	3,547 (38.9%)	15,920 (49.4%)	
Medications (pre/during procedure), n (%N)						<0.001
Glycoprotein IIb/IIIa inhibitor	915 (13.1%)	853 (11.1%)	768 (9.1%)	737 (8.1%)	3,273 (10.2%)	
Thienopyridine or Ticagrelor	5,843 (83.4%)	6,240 (81.5%)	6,729 (80.0%)	7,113 (78.0%)	25,925 (80.5%)	
Aspirin	5,751 (82.3%)	6,754 (88.5%)	7,707 (91.9%)	8,666 (95.0%)	28,878 (90.0%)	
Antithrombin	6,057 (87.5%)	6,815 (90.3%)	7,452 (89.2%)	8,389 (92.0%)	28,713 (90.1%)	
Lesion characteristics						

Multi-lesion disease, n (%N)	1,275 (18.2%)	1,557 (20.3%)	1,714 (20.4%)	2,001 (22.0%)	6,547 (20.3 %)	<0.001
Treated vessel(s), n (%N)						
Left main coronary artery	111 (1.6%)	122 (1.6%)	160 (1.9%)	180 (2.0%)	573 (1.8%)	0.123
Multivessel disease, n (%N)	425 (6.07%)	525 (6.85%)	593 (7.05%)	708 (7.77%)	2,251 (6.99%)	<0.001
Unprotected left main PCI, n (%N)	58 (0.8%)	66 (0.8%)	103 (1.2%)	120 (1.3%)	347 (1.1%)	0.003
Chronic total occlusion, n (%N)	290 (4.1%)	358 (4.7%)	334 (4.0%)	342 (3.8%)	1,324 (4.1%)	0.023
In-stent restenosis, n (%N)	440 (6.3%)	501 (6.5%)	515 (6.1%)	519 (5.7%)	1,975 (6.1%)	0.139
Device used, n (%N)						
BMS only	1,277 (18.2%)	1,056 (13.8%)	663 (7.9%)	359 (3.9%)	3,355 (10.4%)	<0.001
Any DES	5,256 (75.0%)	5,934 (77.5%)	7,211 (85.7%)	8,139 (89.0%)	26,540 (82.4%)	<0.001
POBA only	451 (6.4%)	580 (7.6%)	493 (5.9%)	603 (6.6%)	2,127 (6.6%)	<0.001
Door to balloon time metrics^b						
Door-to-balloon time [minutes, median (IQR)]	68 (40)	71 (53)	67 (49)	62 (44)	67 (49)	<0.001
Door-to-balloon/device time group, n (%N)						

≤ 90 min	259 (29.8%)	286 (31.3%)	268 (27.6%)	247 (21.7%)	1,060 (27.2%)	<0.001
>90 min	607 (69.9%)	624 (68.3%)	704 (72.4%)	888 (78.2%)	2,823 (72.6%)	
Missing	3 (0.35%)	4 (0.4%)	0 (0.0%)	1 (0.09%)	8 (0.2%)	
Post-procedural characteristics						
Lesion success, n (%N)	406 (5.8%)	568 (7.4%)	471 (5.6%)	575 (6.3%)	2,020 (6.3%)	<0.001
Procedure success, n (%N)	6,381 (91.1%)	6,861 (89.6%)	7,688 (91.3%)	8,294 (91.9%)	29,224 (90.8%)	<0.001
New renal impairment, n (%N)	138 (2.6%)	186 (3.3%)	179 (3.0%)	260 (4.1%)	763 (3.3%)	<0.001
Length-of-stay						
Median (IQR)	2 (3)	2 (3)	3 (3)	2 (3)	2 (3)	0.208
Referred to cardiac rehab, n (%N)	4,684 (68.2%)	5,669 (75.2%)	6,284 (76.1%)	6,529 (72.9%)	23,166 (73.3%)	<0.001

BMS = bare metal stent; DES = drug-eluting stent; PCI = percutaneous coronary intervention; POBA = plain old balloon angioplasty; STEMI =

ST-elevation myocardial infarction

^a P-value for year-to-year trend

^b Excluding all inter-hospital transfer arrivals and patients with STEMI onset while a current in-patient

Supplementary Table 7: Changes in radial access and DBDT over time

Parameter	OR (95% CI)*	P-value
Likelihood of Femoral Access		
STEMI		
Males	0.65 (0.62 0.69)	<0.001
Females	0.73 (0.66 0.82)	<0.001
NSTEMI		
Males	0.70 (0.66 0.74)	<0.001
Females	0.74 (0.67 0.81)	<0.001
UA		
Males	0.72 (0.65 0.80)	<0.001
Females	0.73 (0.63 0.85)	<0.001
Non-ACS		
Males	0.72 (0.70 0.75)	<0.001
Females	0.74 (0.70 0.80)	<0.001
Likelihood of DBDT \leq 90 minutes †		
Males	1.15 (1.07 1.24)	<0.001
Females	1.17 (1.01 1.36)	0.035

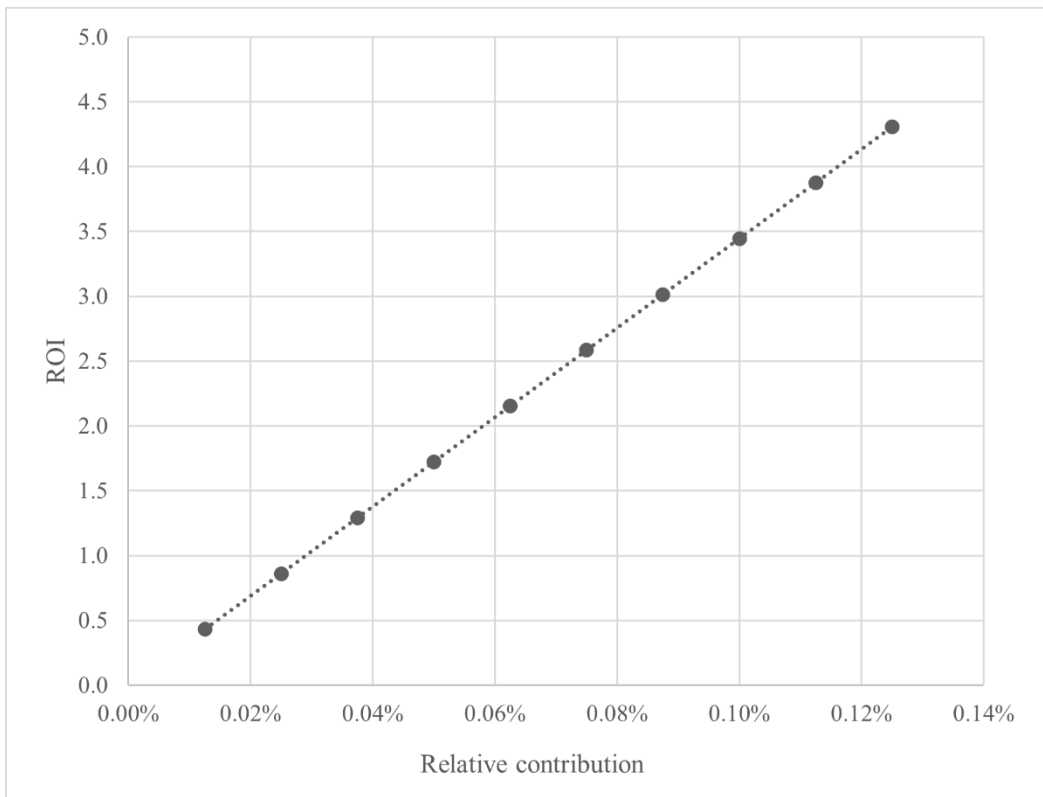
ACS = acute coronary syndrome; DBDT = door-to-balloon/device time; NSTEMI = non-ST-elevation myocardial infarction; OR = odds ratio; STEMI = ST-elevation myocardial infarction; UA = unstable angina

* Adjusted for key confounding variables

† Primary PCI for STEMI presentations excluding all inter-hospital transfer arrivals and patients with STEMI onset while a current in-patient

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Supplementary Figure 1: Return on investment versus relative contribution to CHD mortality trends



ROI = return on investment

CHEERS 2022 Checklist

Topic	No.	Item	Location where item is reported
Title			
	1	Identify the study as an economic evaluation and specify the interventions being compared.	Page 1
Abstract			
	2	Provide a structured summary that highlights context, key methods, results, and alternative analyses.	Page 3
Introduction			
Background and objectives	3	Give the context for the study, the study question, and its practical relevance for decision making in policy or practice.	Page 7
Methods			
Health economic analysis plan	4	Indicate whether a health economic analysis plan was developed and where available.	Page 9
Study population	5	Describe characteristics of the study population (such as age range, demographics, socioeconomic, or clinical characteristics).	Page 9
Setting and location	6	Provide relevant contextual information that may influence findings.	Page 9
Comparators	7	Describe the interventions or strategies being compared and why chosen.	Page 9
Perspective	8	State the perspective(s) adopted by the study and why chosen.	Page 9
Time horizon	9	State the time horizon for the study and why appropriate.	Page 16
Discount rate	10	Report the discount rate(s) and reason chosen.	Page 16
Selection of outcomes	11	Describe what outcomes were used as the measure(s) of benefit(s) and harm(s).	Pages 13-14
Measurement of outcomes	12	Describe how outcomes used to capture benefit(s) and harm(s) were measured.	Pages 13-14

Topic	No.	Item	Location where item is reported
Valuation of outcomes	13	Describe the population and methods used to measure and value outcomes.	Pages 15-16
Measurement and valuation of resources and costs	14	Describe how costs were valued.	Pages 15-16
Currency, price date, and conversion	15	Report the dates of the estimated resource quantities and unit costs, plus the currency and year of conversion.	Pages 15-16
Rationale and description of model	16	If modelling is used, describe in detail and why used. Report if the model is publicly available and where it can be accessed.	Pages 8-13
Analytics and assumptions	17	Describe any methods for analysing or statistically transforming data, any extrapolation methods, and approaches for validating any model used.	Pages 14-15
Characterising heterogeneity	18	Describe any methods used for estimating how the results of the study vary for subgroups.	N/A
Characterising distributional effects	19	Describe how impacts are distributed across different individuals or adjustments made to reflect priority populations.	N/A
Characterising uncertainty	20	Describe methods to characterise any sources of uncertainty in the analysis.	Pages 18-19
Approach to engagement with patients and others affected by the study	21	Describe any approaches to engage patients or service recipients, the general public, communities, or stakeholders (such as clinicians or payers) in the design of the study.	N/A
Results			
Study parameters	22	Report all analytic inputs (such as values, ranges, references) including uncertainty or distributional assumptions.	Table 1, page 13
Summary of main results	23	Report the mean values for the main categories of costs and outcomes of interest and summarise them in the most appropriate overall measure.	Pages 20-23
Effect of uncertainty	24	Describe how uncertainty about analytic judgments, inputs, or projections affect findings. Report the effect of choice of discount rate and time horizon, if applicable.	Table 3, pages 22-23

Topic	No.	Item	Location where item is reported
Effect of engagement with patients and others affected by the study	25	Report on any difference patient/service recipient, general public, community, or stakeholder involvement made to the approach or findings of the study	N/A
Discussion			
Study findings, limitations, generalisability, and current knowledge	26	Report key findings, limitations, ethical or equity considerations not captured, and how these could affect patients, policy, or practice.	Pages 24-27
Other relevant information			
Source of funding	27	Describe how the study was funded and any role of the funder in the identification, design, conduct, and reporting of the analysis	Page 29
Conflicts of interest	28	Report authors conflicts of interest according to journal or International Committee of Medical Journal Editors requirements.	Page 29

From: Husereau D, Drummond M, Augustovski F, et al. Consolidated Health Economic Evaluation Reporting Standards 2022 (CHEERS 2022) Explanation and Elaboration: A Report of the ISPOR CHEERS II Good Practices Task Force. *Value Health* 2022;25. doi:10.1016/j.jval.2021.10.008

BMJ Open

Estimating the Cost-Effectiveness and Return on Investment of the Victorian Cardiac Outcomes Registry in Australia: a Minimum Threshold Analysis

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Primary Subject Heading:	Health economics
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3 1 **Estimating the Cost-Effectiveness and Return on Investment of the Victorian Cardiac**
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5 2 **Outcomes Registry in Australia: a Minimum Threshold Analysis**
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8 3 **Running title: An economic evaluation of VCOR**
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40 14 ¹ This author takes responsibility for all aspects of the reliability and freedom from bias of the
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42 15 data presented and their discussed interpretation.
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25 **Word count:** 4,224

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For peer review only

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3 **28 Abstract**
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6 **29 Objectives:** We sought to establish the minimum level of clinical benefit attributable to the
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9 **30** Victorian Cardiac Outcomes Registry (VCOR) for the registry to be cost-effective.

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11 **31 Design:** A modelled cost-effectiveness study of VCOR was conducted from the Australian
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14 **32** health care system and societal perspectives.

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16 **33 Setting:** Observed deaths and costs attributed to coronary heart disease (CHD) over a five-
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19 **34** year period (2014 to 2018) were compared to deaths and costs arising from a hypothetical
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22 **35** situation which assumed that VCOR did not exist. Data from the Australian Bureau of
23
24 **36** Statistics and published sources were used to construct a decision analytic life table model to
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26 **37** simulate the follow-up of Victorians aged ≥ 25 years for five years, or until death. The
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28 **38** assumed contribution of VCOR to the proportional change in CHD mortality trend observed
29
30 **39** over the study period was varied to quantify the minimum level of clinical benefits required
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33 **40** for the registry to be cost-effective. The marginal costs of VCOR operation and years of life
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35 **41** saved (YoLS) were estimated.

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38 **42 Primary outcome measures:** The return on investment (ROI) ratio and the incremental cost-
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41 **43** effectiveness ratio (ICER).

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43 **44 Results** The minimum proportional change in CHD mortality attributed to VCOR required
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46 **45** for the registry to be considered cost-effective was 0.125%. Assuming this clinical benefit, a
47
48 **46** net return of \$4.30 for every dollar invested in VCOR was estimated (ROI ratio over five
49
50 **47** years: 4.3 (95% confidence interval (CI): 3.6 – 5.0). The ICER estimated for VCOR was
51
52 **48** \$49,616 (95% CI: \$42,228 – \$59,608) per YoLS. Sensitivity analyses found that the model
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55 **49** was sensitive to the time horizon assumed and the extent of registry contribution to CHD
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57 **50** mortality trends.

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60 **51 Conclusions**

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52 VCOR is likely cost-effective and represents a sound investment for the Victorian health care
53 system. Our evaluation highlights the value of clinical quality registries in Australia.

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3 54 **Key words:** Cost-effectiveness; acute coronary syndrome; cardiovascular disease; clinical
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5 55 quality registries; quality improvement.
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3 57 **Article summary**
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6 58 **Strengths and limitations of this study**
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- 9 59 • Real-world registry data from VCOR captured temporal changes in the management
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11 60 of patients undergoing PCI in Victoria, Australia.
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14 61 • Improvements in the uptake of radial access PCI and in timely reperfusion of STEMI
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16 62 patients were, in part, attributed to VCOR.
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19 63 • There was uncertainty around the clinical benefit conferred by VCOR with respect to
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21 64 trends in mortality.
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24 65 • It was not possible to assess the impact of VCOR on readmissions or patient
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26 66 morbidity or quality-of-life using ABS data.
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69 Introduction

70 Coronary heart disease (CHD) is a significant cause of morbidity and mortality in Australia.

71 In 2020-2021, the prevalence of CHD in Australia was estimated to be 3% (571,000) of the
72 adult population ¹. Although mortality from CHD has declined significantly since the 1960s,
73 it remains the leading cause of death (approximately 10%) in Australia ^{1 2}. With regard to
74 disease burden, CHDs had contributed to 6.3% (10.4 disability adjusted life years (DALYs)
75 per 10,000 population) of the total disease burden and 2% of hospitalisations in Australia in
76 2018 ^{1 3}.

77 Of the prevalent adult population with CHD in 2020-2021, it is estimated that 40% had
78 experienced angina and 74% had suffered acute coronary syndrome (ACS) ¹. Percutaneous
79 coronary intervention (PCI) is the preferred means of revascularisation therapy for many
80 patients presenting with ACS based on Australian and international guidelines ^{4 5}. Across
81 Australia, 48,034 PCIs were performed between 2020-2021¹; in Victoria alone, 48% of all
82 PCIs across Victoria in 2021 were performed for the management of ACS ⁶.

83 The cost burden attributed to the management of CHD, including costs of PCI, are
84 correspondingly high. Based on estimates from the Australian Institute of Health and Welfare
85 (AIHW), in 2018-2019, CHD accounted for \$2.35 billion Australian Dollars (AU\$) in health
86 expenditure in Australia, representing 2% of total health expenditure ⁷. The considerable
87 volume of procedures performed annually, at an estimated average cost per procedure of
88 \$13,293 ⁸, indicates that PCIs contribute to a significant proportion of costs in the
89 management of CHD. In Victoria alone, the cost burden attributed to PCIs across public
90 hospitals was estimated to be \$72,179,656 in 2017 ⁹. Importantly, increasing PCI case
91 complexity and procedural volume over time warrants greater adherence to evidence-based

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3 92 guidelines for the management of ACS to improve health systems efficiency and patient
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5 93 outcomes ⁹.
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8 94 Clinical quality registries (CQRs) are increasingly utilised to improve health care processes
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10 95 and adherence to evidence-based guidelines and standards, and reduce the costs attributed to
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12 96 care delivery ¹⁰⁻¹³. Through the collection of patient outcomes data for cardiovascular
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14 97 procedures, it is possible to benchmark a hospitals' performance to its peers and adherence to
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16 98 national standards of care and evidence-based guidelines ¹⁰. Additionally, CQRs have
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18 99 significant utility in medical research ¹⁰⁻¹². Previous studies have demonstrated that major
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20 100 improvements to patient outcomes may be attributed to the existence of CQRs ¹⁰. In the
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22 101 context of ACS, patient outcomes have improved considerably over time following the
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24 102 establishment of cardiac CQRs in Sweden, New Zealand, the US and the UK which have
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26 103 been attributed, in part, to registry operation ¹⁴⁻¹⁸. However, although there are many studies
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28 104 utilising data from CQRs, few have assessed the clinical and cost impacts attributed to a CQR
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30 105 ¹¹. This is likely due to difficulties in distinguishing the extent of contribution of CQRs to
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32 106 improved patient outcomes over time versus secular trends in patient management, and in the
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34 107 nomination of an appropriate comparator arm to assess the true costs and benefits attributed
35
36 108 to registry operation ¹¹. In this context, we explored the minimum level of contribution to
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38 109 improved patient outcomes required for the Victorian Cardiac Outcomes Registry (VCOR), a
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40 110 cardiac CQR, to be cost-effective and represent a sound investment for the health care
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42 111 system.

112

113 **Methods**

114 *Model structure*

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3 115 Life table modelling and decision analysis were used to explore the clinical and cost impacts
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5 116 of VCOR against a hypothetical scenario which assumed that VCOR did not exist (No
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7 117 VCOR) ¹⁹. Life tables were constructed using age and sex-specific mortality rates for adults
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9 118 aged ≥ 25 years, based on Victorian population data sourced from the Australian Bureau of
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11 119 Statistics (ABS) ^{20 21}. Each cohort was followed until death, or up to five years in the base
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13 120 case. Within each cohort (VCOR or No VCOR), separate life tables were created for 14 age
14
15 121 and sex subgroups. Age was stratified into seven 10-year age bands (25 – 34, 35 – 44, 45 –
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17 122 54, 55 – 64, 65 – 74, 75 – 84, 85+), with the starting age in each subgroup being the weighted
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19 123 average age in the age band.

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24 124 The clinical and cost outputs for each model were totalled to determine the overall cost-
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26 125 effectiveness attributed to VCOR from the perspective of the Australian health care system,
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28 126 assuming a cost-effectiveness threshold of \$50,000 per year of life saved (YoLS). The
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30 127 commonly used willingness-to-pay threshold of \$50,000 per YoLS gained in determining
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32 128 cost-effectiveness ²² was used in lieu of an official willingness to pay threshold in Australia.
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34 129 We also explored the return-on-investment (ROI) attributed to the registry from a societal
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36 130 perspective.

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42 43 44 132 *Model population*

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47 133 Our base case modelled population was profiled on the total Victorian population aged ≥ 25
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49 134 years in each year from 2014 to 2018 using ABS inputs. Data pertaining to the total Victorian
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51 135 population, and mortality in each year from 2010 to 2019, were sourced from the ABS (see
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53 136 Supplemental Table 1) ^{20 21}. Although ABS data were available for 2010 to 2019, our
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55 137 modelled population was profiled to reflect PCIs performed between January 2014 to
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57 138 December 2017 in VCOR. A separate, linked dataset of patient, clinical and procedural
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3 139 characteristics collected by VCOR was made available for the analysis of trends in clinical
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5 140 practice across Victorian hospitals. This dataset was used to inform the extent to which the
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7 141 registry had contributed to changes in CHD mortality over time in the economic model
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9 142 informed by ABS data (see '*Effectiveness of VCOR*' below).
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16 144 *Transition probabilities*

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19 145 Data for estimating the incidence of all-cause mortality, and mortality attributed to CHD
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21 146 (based on International Classification of Diseases version 10 (ICD-10) codes: I20 – I25),
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23 147 were sourced for each age and sex subgroup from the ABS^{20 21} (Table 1 and Supplemental
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25 148 Tables 1 and 2).
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150 **Table 1: Input parameters used in the economic model, including trends in CHD mortality over time, costs and the assumed**
 151 **contribution of VCOR to reductions in CHD mortality.**

Parameter	Value				Distribution (variance)
CHD Mortality rate by age group (years)	Males (2014 – 2018)	P-value*	Females (2014 – 2018)	P-value*	Uniform ($\pm 20\%$)
25 - 34	0.00% – 0.00%	0.382	0.00% – 0.00%	0.357	
35 - 44	0.01% – 0.01%	0.013	0.00% – 0.00%	0.071	
45 - 54	0.04% – 0.03%	0.006	0.01% – 0.01%	0.283	
55 - 64	0.10% – 0.08%	0.051	0.02% – 0.01%	0.073	
65 - 74	0.21% – 0.17%	0.092	0.06% – 0.05%	0.121	
75 - 84	0.61% – 0.47%	0.033	0.32% – 0.22%	0.023	
85+	2.24% – 2.04%	0.106	1.90% – 1.42%	0.016	
All	0.09% – 0.08%	0.001	0.07% – 0.05%	0.016	
Cost of mortality	\$5,609				Gamma ($\alpha = 5,609$; $\beta =$

Parameter	Value	Distribution (variance)
		1)
VCOR annual costs	\$600,000	Gamma ($\alpha=600,000$; $\beta = 1$)
VoSLY	\$220,262	Gamma ($\alpha = 220,262$; $\beta = 1$)
Assumed contribution of VCOR to CHD mortality trends [†]	0.125%	Uniform (0.100, 0.150)

152 CHD = coronary heart disease; VCOR = Victorian Cardiac Outcomes Registry; VoSLY = value of statistical life year

153 * Based on simple linear regression analyses

154 † Based on varying the assumed contribution by increments of 0.025%

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156 The likelihood of all-cause or CHD mortality was estimated by dividing the number of deaths
157 (all-cause or CHD-related) in each sex and age subgroup by the Victorian population for each
158 subgroup^{20 21}. The likelihood of non-CHD mortality was estimated by subtracting the
159 likelihood of CHD mortality from the likelihood of all-cause mortality^{20 21}.

160

161 *Effectiveness of VCOR*

162 VCOR is a state-wide, ongoing population based CQR. It was established in 2012 to monitor
163 the performance of cardiac services in hospitals across Victoria^{13 23}. The key focus of VCOR
164 currently is on patients undergoing PCI and cardiac implanted electronic devices^{13 23}. The
165 economic evaluation was based on estimating the downstream clinical and cost impacts of
166 VCOR relative to a hypothetical scenario in which VCOR did not exist (No VCOR). That is,
167 without VCOR contributing to reductions in CHD mortality over time, the extent to which
168 CHD mortality declined over time would be less. In the absence of efficacy data, the assumed
169 contribution of VCOR to reductions in CHD mortality over time was varied in the economic
170 model to establish the minimum contribution required for VCOR to be cost-effective. This is
171 justified based on current literature demonstrating that the registry data collection for the
172 purposes of routine health systems benchmarking and feedback is, of itself, likely to
173 contribute to reductions in mortality over time through improvements in clinical practice^{10 12}.

174 A similar approach whereby the benefits of the All New Zealand Quality Improvement
175 (ANZACS-QI) Programme, a cardiac CQR, was assumed to contribute to temporal trends in
176 patient mortality has been published elsewhere¹². In brief, this evaluation assumed that the
177 registry contributed to 15% of temporal trends in myocardial infarction (MI)-related mortality

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3 178 and readmissions, based on improved adherence to medications indicated for the secondary
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5 179 prevention of ACS and reductions in time-to-treatment parameters ¹².
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8 180 Based on data from the ABS, the risk of CHD mortality in Victoria has decreased steadily
9
10 181 over the period from 2014 to 2018 (Table 1). Notably, the clinical management of CHD has
11
12 182 also evolved over time. This may in part be attributed to ongoing benchmarking and feedback
13
14 183 through VCOR. First, in the period since VCOR was established, implementation of PCI via
15
16 184 radial access (instead of femoral access) has improved considerably ²³. A Cochrane review of
17
18 185 PCI via radial versus femoral access concluded that radial access was associated with
19
20 186 reductions in major bleeding events, access site complications and mortality in the setting of
21
22 187 ACS ²⁴. This is supported by data from cardiac registries in the US, UK and Australia;
23
24 188 importantly, a propensity-score matched analysis of radial versus femoral access using
25
26 189 VCOR data found that mortality benefits attributed to radial access were maintained over
27
28 190 time and for patients with high-acuity (STEMI) and non-ACS indications for PCI ²⁵⁻²⁸.
29
30 191 Secondly, in addition to improved uptake of radial access PCI, hospital adherence to a door-
31
32 192 to-balloon/device time (DBDT) has improved, with all PCI-capable hospitals across Victoria
33
34 193 achieving a median DBDT of ≤ 90 minutes for STEMI patients ²³. As with improved uptake
35
36 194 of radial access, improved hospital adherence to a DBDT ≤ 90 minutes is associated with
37
38 195 considerable survival benefits for STEMI patients ²⁹. However, it is not possible to quantify
39
40 196 the direct contribution of VCOR to the uptake of radial access PCI and improvements to
41
42 197 DBDT, and the subsequent reduction in mortality trends downstream. As such, our model
43
44 198 estimated the minimum contribution of VCOR to temporal trends in CHD mortality required
45
46 199 for VCOR to be considered cost-effective. In brief, the assumed contribution of VCOR to the
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48 200 proportional change in CHD mortality was varied in increments of 0.025% until the
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50 201 incremental cost-effectiveness ratio (ICER) for VCOR versus No VCOR was cost-effective.
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3 203 *Cost inputs*
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6 204 Table 1 summarises the cost inputs used in the economic model. All costs were updated to
7
8 205 2021 values using the Australian Health Price Index and were expressed as AU\$³⁰.
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11 206

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14 207 *Cost of VCOR*
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16
17 208 VCOR is funded through the Victorian Department of Health, Medibank Private and in-kind
18
19 209 funding through Monash University²³. Based on the VCOR annual report for 2018, the
20
21 210 average annual cost borne by the Victorian Department of Health was \$605,346 for the
22
23 211 period from 2014 to 2018 (see Supplemental Table 3)³¹. We therefore assumed the annual
24
25 212 cost of registry operation to be \$600,000; this was varied in scenario analyses (see below).
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32 214 *Cost of mortality*
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35 215 There was an absence of relevant data pertaining to the costs of death. As per previous
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37 216 analyses^{12 32 33}, we assumed that deaths due to CHD incurred 50% of the costs of CHD
38
39 217 hospitalisations. The cost of hospitalisations for CHD was estimated using data pertaining to
40
41 218 diagnosis-related groups (DRGs) and their costs for publicly-funded casemix hospitalisations
42
43 219 in 2017/18 (see Supplemental Table 4)³⁴. This method has been used in similar economic
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45 220 evaluations^{12 32 33}. The same cost was applied to deaths due to non-CHD causes.
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52 222 *Cost of a year of life*
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3 223 The value of a statistical life year (VoSLY) was assumed to be \$220,262. This was based on
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5 224 the VoSLY estimated by the Australian Government's Office of Best Practice Regulation of
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7
8 225 \$213,000 in 2019, adjusted to 2021 values ³⁵.
9
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11 226

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14 227 *Discounting*

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16 228 A discount rate of 5% per annum was applied to years of life lived and costs incurred beyond
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18
19 229 the first year ²².
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22 230

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25 231 *Economic evaluation*

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27
28 232 The base case economic evaluation involved 14 separate life table models created using ABS
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30 233 data, stratified by sex and age band to represent five years of coverage (2014 – 2018
31
32 234 inclusive) of VCOR. The expected values across sex and age subgroups for the VCOR and
33
34
35 235 No VCOR were aggregated to represent the clinical and cost impacts of VCOR over five
36
37 236 years for the total Victorian population at risk of mortality from CHD.

38
39
40 237 The primary cost-benefit analysis estimated differences between the two groups regarding net
41
42 238 societal costs. This was defined as the cost of VCOR operation, minus the cost savings
43
44 239 attributed to reduced CHD mortality, added to the costs saved by prolonging years of life
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46
47 240 lived in the cohort. The primary outcome was the net cost attributed to VCOR operation. A
48
49 241 key secondary outcome for our study was the ICER for VCOR compared with No VCOR in
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51 242 terms of cost per YoLS.
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57 244 *Statistical analyses*
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3 245 A linked dataset of 32,198 consecutive PCIs conducted in VCOR over a period of four years
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5 246 (1 January 2014 to 31 December 2017) was made available for the analysis of changes in
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7 247 clinical practice over time in Victoria. Pearson's chi-square tests for categorical variables,
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9 248 and univariate linear regression modelling or generalized linear regression modelling (GLM)
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11 249 for continuous variables, were used to explore differences in patient or procedural trends over
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13 250 time.
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17 251 To explore changes in clinical practice over time, the population was stratified by sex and
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19 252 indication for PCI: non-ACS reasons, unstable angina, non-ST elevation myocardial
20
21 253 infarction (NSTEMI) and ST elevation myocardial infarction (STEMI). Backward stepwise
22
23 254 logistic regression with a P-value threshold of 0.10 was used to identify the following
24
25 255 potential confounders of radial access, and DBDT ≤ 90 minutes: age (< 75 years and ≥ 75
26
27 256 years); in-hours hospital arrival (between 08:00 to 18:00 on a workday); cardiogenic shock or
28
29 257 intubated out-of-hospital cardiac arrest (OHCA); left ventricular ejection fraction (LVEF);
30
31 258 medicated diabetes mellitus; peripheral vascular disease; cerebrovascular disease; chronic
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33 259 oral anticoagulation therapy; prior coronary artery bypass grafting; previous PCI; use of
34
35 260 glycoprotein IIb/IIIa inhibitors; use of thienopyridine or ticagrelor; estimated glomerular
36
37 261 filtration rate (eGFR); required mechanical ventricular support; lesion complexity (American
38
39 262 College of Cardiology/American Heart Association type A/B1 versus type B2/C lesions);
40
41 263 unprotected left main PCI; chronic total occlusion PCI and in-stent restenosis PCI^{36 37}.
42
43 264 Multivariable logistic regression models with adjustment for key predictors identified in
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45 265 stepwise regression were used to explore annual trends in radial access and DBDT metrics.
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47 266 The results of these analyses were used to justify the assumption that VCOR is likely to
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49 267 contribute to small reductions in CHD mortality over time.
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53 268 To explore trends in CHD mortality over time using mortality data from the ABS, simple
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55 269 linear regression modelling was performed with the year as the independent variable, and
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3 270 CHD mortality as the dependent variable. A P-value <0.05 was considered statistically
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5 271 significant.

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8 272 The economic evaluation was performed with Microsoft Excel®; STATA 14 (StataCorp LP,
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10 273 College Station, Texas) was used to explore changes in clinical practice over time.

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16 275 *Sensitivity analyses*

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19 276 A series of one-way sensitivity analyses were undertaken to determine the impact of
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21 277 uncertainty around key model parameters. Input parameters were varied individually in
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23 278 deterministic sensitivity analyses, while other variables were maintained at base case values
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25 279 to estimate the impact of parameters on cost-benefit/effectiveness. Key parameters assessed
26
27 280 were the time horizon, the assumed contribution of VCOR to CHD mortality trends, costs
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29 281 assumed for CHD mortality, and the VoSLY. Additionally, a scenario analysis was
30
31 282 performed, whereby the proportional contribution of VCOR to temporal trends in CHD
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33 283 mortality was assumed to be equivalent to the mortality benefit attributed to ANZACS-QI.
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35 284 Based on the assumed contribution of 15% to the observed temporal trend in MI-related
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37 285 mortality, ANZACS-QI prevented 36 MI-related deaths over a four-year period in the total
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39 286 New Zealand ACS population (N = 59,280)¹². Upon extrapolation of this benefit to the wider
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41 287 population at risk of CHD mortality in Victoria (N = 4,017,397), the assumed contribution to
42
43 288 the temporal reduction in CHD mortality was set to 0.5% for VCOR in this scenario analysis.

44
45 289 A probabilistic sensitivity analysis (PSA) was undertaken using 10,000 iterations to assess
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47 290 uncertainty in the model input parameters simultaneously. The input parameters, variations
48
49 291 and corresponding distributions are presented in Table 1. As variance in mortality rates and
50
51 292 costs were not available, methodology employed by Briggs *et al* was applied¹⁹. CHD
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53 293 mortality rates assumed uniform distributions (applying 20% variance from the input
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3 294 variable), while gamma distributions were applied to costs (where the variance was equal to
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5 295 the mean/input value).
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11 297 *Patient and public involvement*
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14 298 No patients or the public were involved in this study.
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20 300 **Results**
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23 301 *VCOR population*
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26 302 Data from 32,198 consecutive PCIs in Victoria over a four-year period (1 January 2014 to 31
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28 303 December 2017) was used to explore the impact of VCOR on clinical practice. Baseline and
29
30 304 procedural characteristics of the VCOR population are presented in the Supplementary
31
32 305 material (Supplemental Tables 5 and 6).
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36 306 The cohort was predominately male (77.0%), overweight or obese (76.2%) undergoing PCI
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38 307 for ACS (50.9%) in public hospitals (63.2%).
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41 308 The results of multivariable modelling on changes in radial access and DBDT over time are
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43 309 presented in Supplemental Table 7.
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46 310 The likelihood of patients managed through femoral access decreased annually across all
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48 311 non-ACS and ACS indications for PCI ($P < 0.001$). For patients undergoing primary PCI for
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50 312 STEMI, the likelihood of timely reperfusion ($DBDT \leq 90$ minutes) increased annually by at
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52 313 least 15% across both sexes ($P < 0.05$).
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59 315 *Economic analysis of the total Victorian population*
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316 The impact of varying the assumed contribution of VCOR on the ICER and the ROI are
 317 presented in Figure 1 and Supplemental Figure 1, respectively.

318
 319 The minimum proportional change in CHD mortality attributed to VCOR required for the
 320 registry to be considered cost-effective was 0.125% (see Figure 1). Table 2 presents the base-
 321 case analysis in terms of the overall clinical and cost impacts attributed to five years of full
 322 coverage of VCOR for the Victorian population aged ≥ 25 years from 2014 to 2018 at this
 323 level of registry contribution (0.125%) to CHD mortality trends.

324
 325 **Table 2: Results of the base case economic model, assuming that VCOR contributed to**
 326 **0.125% of the temporal change in CHD mortality**

Parameter	Overall (N = 4,017,397)		Difference
	VCOR	No VCOR	
Clinical outcomes, n (%N)			
CHD deaths	19,065 (0.47%)	19,089 (0.48%)	-23
Non-CHD deaths	140,455 (3.50%)	140,452 (3.50%)	3
Total deaths	159,520 (3.97%)	159,540 (3.97%)	-20
Years lived *	17,887,125	17,887,072	53
Cost outcomes			
VCOR *	\$2,727,570	-	\$2,727,570
CHD deaths *	\$98,517,938	\$98,638,721	-\$120,783
Non-CHD deaths *	\$722,495,795	\$722,480,855	\$14,941
Total health cost *	\$823,741,304	\$821,119,575	\$2,621,728

Parameter	Overall (N = 4,017,397)		Difference
	VCOR	No VCOR	
VoSLY *	\$3,939,854,066,111	\$3,939,842,427,479	\$11,638,633
ICER (\$/YoLS) * (Point value, 95% CI [†])	\$49,616 (\$42,228 – \$59,608)		
ROI ratio * (Point value, 95% CI [†])	4.3 (3.6 – 5.0)		

327 CHD = coronary heart disease; CI = confidence interval; ICER = incremental cost-
 328 effectiveness ratio; ROI = return-on-investment; VCOR = Victorian cardiac outcomes
 329 registry; VoSLY = value of statistical life year

330 All costs are expressed in Australian dollars (AU\$)

331 * Results discounted at an annual rate of 5%

332 † Estimated from PSA

333

334 Over this period, a total of 19,065 CHD-related deaths occurred across Victoria. Based on the
 335 assumption that VCOR contributed to 0.125% of the temporal change in CHD mortality over
 336 time, the clinical benefit attributed to VCOR was the prevention of 23 CHD-related deaths
 337 and 53 (discounted) years of life saved. A total of \$120,783 was saved over this period due to
 338 the prevention of CHD mortality. This was balanced against a higher incidence of non-CHD
 339 mortality in the VCOR cohort (because the risk of non-CHD death was not assumed to have
 340 changed by VCOR), which incurred an additional cost of \$14,941. The total cost of VCOR
 341 was \$2,727,570 (discounted). Hence the net cost of VCOR from the perspective of the
 342 Australian health care system was \$2,621,728 (discounted). The ICER associated with VCOR
 343 was \$49,616 per YoLS (95% confidence interval (CI): \$42,228 – \$59,608). From a broader,

344 societal perspective, the savings attributed to VCOR were \$11,638,633 based on an assumed
 345 VoSLY of \$220,262. The return on investment (ROI) ratio, which is the ratio of the total cost
 346 savings to the total costs of VCOR, was 4.3 (95% CI: 3.6 – 5.0); that is, for every \$1.00
 347 invested in VCOR, a return of \$4.30 was delivered.

348 Table 3 presents the results of sensitivity analyses in terms of ICERs, net societal costs
 349 attributed to VCOR operation, and ROI.

350

351 **Table 3: Results of deterministic scenario analyses**

Scenario	Net cost *	ROI ratio *	ICER (\$/YoLS) *
Base case †	\$14,260,361	4.3	\$49,616
Time horizon (starting year 2014)			
1 year	\$1,236,407	1.2	\$185,866
2 years	\$3,575,677	2.2	\$99,280
3 years	\$6,685,471	3.0	\$71,341
4 years	\$10,311,267	3.7	\$57,648
Time horizon (starting year 2015)			
1 year	\$1,236,668	1.2	\$185,785
2 years	\$3,556,760	2.1	\$100,185
3 years	\$6,623,705	3.0	\$72,297
4 years	\$10,183,945	3.6	\$58,642
5 years	\$14,097,331	4.2	\$50,315

Scenario	Net cost *	ROI ratio *	ICER (\$/YoLS) *
Contribution to trends (base case: 0.125%)			
Lower (0.10%)	\$11,953,831	3.4	\$62,521
Upper (0.15%)	\$16,566,876	5.2	\$41,013
ANZACS-QI (0.50%)	\$48,856,609	17.2	\$10,902
VoSLY (base case: \$220,262)			
Lower (-25%)	\$11,350,703	3.2	\$49,616
Upper (+25%)	\$17,170,019	5.4	\$49,616
Cost of VCOR (base case: \$600,000)			
Lower (-25%)	\$13,578,468	5.7	\$36,712
Upper (+25%)	\$14,942,253	3.4	\$62,521

352 ANZACS-QI = All New Zealand Acute Coronary Syndrome Quality Improvement
 353 programme; ICER = incremental cost-effectiveness ratio; ROI = return-on-investment;
 354 VCOR = Victorian Cardiac Outcomes Registry; VoSLY = value of statistical life year
 355 All costs are expressed in Australian dollars (AU\$)

356 * Results discounted at an annual rate of 5%

357 † Starting year 2014, 5 year time horizon

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3 359 The model was most sensitive to the assumed time horizon, and the extent to which VCOR
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5 360 contributed to mortality trends in Victoria. Across each scenario, VCOR represented a
6
7 361 positive ROI. The results of the additional PSA are presented in Figure 2 below.
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13 363 Based on the results of the PSA, the majority (97.5%) of iterations fell below an ICER of
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15 364 \$60,000 per YoLS.
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22 366 **Discussion**

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25 367 Our economic evaluation found that the minimum contribution to the proportional change in
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27 368 CHD mortality over time required for VCOR to be cost-effective was 0.125%. That is, for
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29 369 VCOR to be considered cost-effective from the perspective of the Australian health care
30
31 370 system, the registry would need to prevent 23 CHD-related deaths between 2014 to 2018
32
33 371 (five years inclusive), through benchmarking and health systems quality improvement. In lieu
34
35 372 of data pertaining to the direct impacts of VCOR operation on CHD mortality, our analyses
36
37 373 suggest that VCOR is likely to be cost-effective on the basis of the comparatively small CHD
38
39 374 mortality benefits (23 deaths over five years) required for the registry to fall within the
40
41 375 widely-established willingness-to-pay threshold of \$50,000 per YoLS²². Since the
42
43 376 establishment of VCOR, there has been a considerable increase in hospital uptake of PCI via
44
45 377 radial access^{6 38}. Furthermore, the likelihood of STEMI patients being managed with timely
46
47 378 reperfusion had increased annually throughout the period of 2014-2018^{6 38}. These trends in
48
49 379 improved patient management are facilitated through VCOR benchmarking and health
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51 380 systems feedback and are likely to contribute to the reduction in cardiac mortality observed
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53 381 across Victoria^{23 25 39}. Lastly, data from VCOR has informed research exploring disparities in
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3 382 the management of ACS to further drive improvements in cardiac care and subsequently,
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5 383 reduce CHD mortality across Victoria^{40 41}.
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8 384 Our findings are in accordance with similar economic evaluations previously conducted in
9
10 385 Australia and New Zealand^{12 42}. The ROI estimated for five CQRs in Australia varied from
11
12 386 2.0 to 7.0 based on improvements in key performance indicators (KPIs) unique to each
13
14 387 registry⁴². Similarly, a cost-effectiveness analysis of the ANZACS-QI program found a
15
16 388 positive ROI (1.53) over one year of evaluation, which improved considerably after
17
18 389 expanding the time horizon to five years (7.49)¹². The collection of data by ANZACS-QI has
19
20 390 been used for addressing sub-optimal adherence to guidelines in the management of ACS
21
22 391 identified across New Zealand district health boards. In evaluating the cost-effectiveness and
23
24 392 ROI attributed to ANZACS-QI, improvements in KPIs contributed to reductions in patient
25
26 393 mortality and readmissions observed over the period of evaluation (2013 to 2016), and the
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28 394 registry was both cost-effective and represented a sound investment for the New Zealand
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30 395 health care system^{12 43}.
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36 396 Additionally, there is considerable evidence of improved patient outcomes as a result of
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38 397 interventions attributed to cardiac CQR benchmarking and health systems feedback in the UK
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40 398 and Sweden^{15 44 45}. Data collected by the British Cardiovascular Intervention Society (BCIS)
41
42 399 was of considerable utility for informing clinical practice in the setting of PCI, allowing for
43
44 400 the identification of variable uptake in radial access across hospitals, delays in PCI for
45
46 401 NSTEMI patients, and a low rate of same-day discharge for patients undergoing elective PCI
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48 402⁴⁴. Changes to these parameters are likely to improve patient outcomes and efficiency in the
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50 403 delivery of health services for cardiac care^{24 39 46}. Similarly, mortality from CHD in Sweden
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52 404 declined considerably between 1995 and 2014 due to changes in the evidence-based
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54 405 management of NSTEMI and STEMI based on data collected as part of the Swedish Web-
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56 406 system for Enhancement and Development of Evidence-based care in Heart disease

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3 407 Evaluated According to Recommended Therapies (SWEDEHEART) CQR^{15 45}. Such
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5 408 changes have been facilitated through ongoing quality improvement and benchmarking
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7 409 through SWEDEHEART and other, well-established CQRs^{15 45}.
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10 410 In Australia alone, several cardiac CQRs have been established across a variety of settings.
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12 411 These include condition-specific registries, such as the Australian Resuscitation Outcomes
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14 412 Consortium (AUS-ROC) for out-of-hospital cardiac arrest, and the Australian and New
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16 413 Zealand Society of Cardiac and Thoracic Surgeons Database Program (ANZSCTS) as well as
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18 414 VCOR, a cardiac devices or procedures-focused registry⁴⁷. The considerable VoSLY
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20 415 assumed in our methodology, coupled with the high mortality burden of cardiovascular
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22 416 diseases globally, is likely to offset the substantial costs attributed to establishing and
23
24 417 maintaining cardiac CQRs. Our findings set precedence for similar evaluations to be
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26 418 performed internationally to support CQR uptake and investment, and emphasises the
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28 419 importance of registry development in consideration of KPIs which contribute to improved
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30 420 patient outcomes and ultimately, ROI⁴⁷.
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40 422 **Limitations**

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42 423 A key limitation to our analysis was the uncertainty around the clinical benefit conferred by
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44 424 VCOR with respect to the observed trend in mortality. Hence, we explored the minimum
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46 425 contribution to temporal reductions in CHD mortality required for VCOR to be cost-
47
48 426 effective, based on the assumption that registry benchmarking and feedback contribute to a
49
50 427 small proportion of temporal reductions in CHD mortality. Importantly, in scenario analyses
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52 428 whereby the benefit of VCOR was lowered from an already small value, the ICER increased
53
54 429 slightly (\$49,616 per YoLS to \$62,521 per YoLS) and was still associated with positive ROI.
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56 430 Furthermore, 97.5% of iterated ICERs in the PSA fell below \$60,000 per YoLS; while no
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3 431 formally published value for cost-effectiveness has been established in Australia, the
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5 432 Choosing Interventions that are Cost-Effective (CHOICE) programme of the World Health
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7 433 Organisation (WHO) defines interventions with a cost per quality-adjusted life year (QALY)
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9 434 or YoLS less than one gross domestic product (GDP) per capita as ‘very cost-effective’⁴⁸. As
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11 435 the current GDP per capita in Australia is AU\$89,743 (or US dollars (US\$) 61,977 assuming
12
13 436 1 US\$ = 1.45 AU\$ in 2021), our analyses demonstrate that VCOR is likely to be very cost-
14
15 437 effective⁴⁸⁻⁵⁰. Secondly, it was not possible to assess the impact of VCOR on readmissions
16
17 438 for recurrent ACS, and on patient morbidity and quality-of-life through ABS data. Hence, our
18
19 439 analyses were limited to capturing the mortality benefit attributed to VCOR. However, KPIs
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21 440 pertaining to patient morbidity, including major adverse cardiac and cerebrovascular events,
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23 441 hospital length-of-stay and in-hospital unplanned revascularisation, had remained stable and
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25 442 were relatively low throughout the period of evaluation^{38 51}. Readmissions for ACS in
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27 443 Victoria had also remained stable over time^{23 52}. Therefore, incorporating the potential cost
28
29 444 and clinical impacts attributed to other trends in clinical practice or the reporting of KPIs
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31 445 outside of DBDT for STEMI patients by VCOR, would not have changed our findings in a
32
33 446 substantial manner. Additionally, there is a lack of robust data pertaining to quality-of-life
34
35 447 following ACS in Australia which limited analyses on the impact of VCOR on patient
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37 448 morbidity⁵³. Thirdly, cost inputs for patient mortality were based on DRG estimates that
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39 449 were constant across age, sex, and ACS indications. This was in lieu of robust, bottom-up
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41 450 cost data^{12 32 54}. However, sensitivity analyses found that the economic model was robust to
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43 451 the costs of hospitalisations.
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55 453 **Conclusion**

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3 454 VCOR represents a sound investment for the Victorian health care system. Based on the
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5 455 assumption that VCOR benchmarking and feedback contributed to a small proportion of the
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7 456 observed reduction in CHD mortality over time, the registry is associated with cost savings at
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9
10 457 the societal level. Additionally, VCOR is cost-effective from the perspective of the healthcare
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12 458 system.
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For peer review only

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2
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4
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8
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10
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12
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14
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18
19 468 to disclose.
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26
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28
29 471 responsibility for the integrity of the data and accuracy of the data analysis. PL, EZ and DL
30
31 472 were responsible for the study concept and design, the acquisition, analysis and interpretation
32
33 473 of data and drafting of the manuscript. PL, ALB, DS, DD, JL, CMR, EZ, and DL made
34
35 474 significant contribution to drafting the work, or revising it critically for intellectual content.
36
37 475 PL, ALB, DS, DD, JL, CMR, EZ, and DL provided final approval of the version to be
38
39 476 published. PL is the guarantor of this paper.
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52 480
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54
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5 484 Victorian Cardiac Clinical Network.
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11 486 **Ethics approval:**
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14 487 This study received ethical approval from Monash University Human Research Ethics
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16 488 Committee (13882).
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22 490 **Data availability statement:**
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25 491 All data are incorporated into the article and its online supplementary material.
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For peer review only

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3 674 **Figure Legends**
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7 676 **Figure 1: Relative contribution of VCOR to CHD mortality trends versus VCOR cost-**

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9 677 **effectiveness**
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12 678 ICER = incremental cost-effectiveness ratio; YoLS = year of life saved
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19 681 **Figure 2: Results of the probabilistic sensitivity analysis**
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22 682 \$AU = Australian dollars; YoLS = year of life saved
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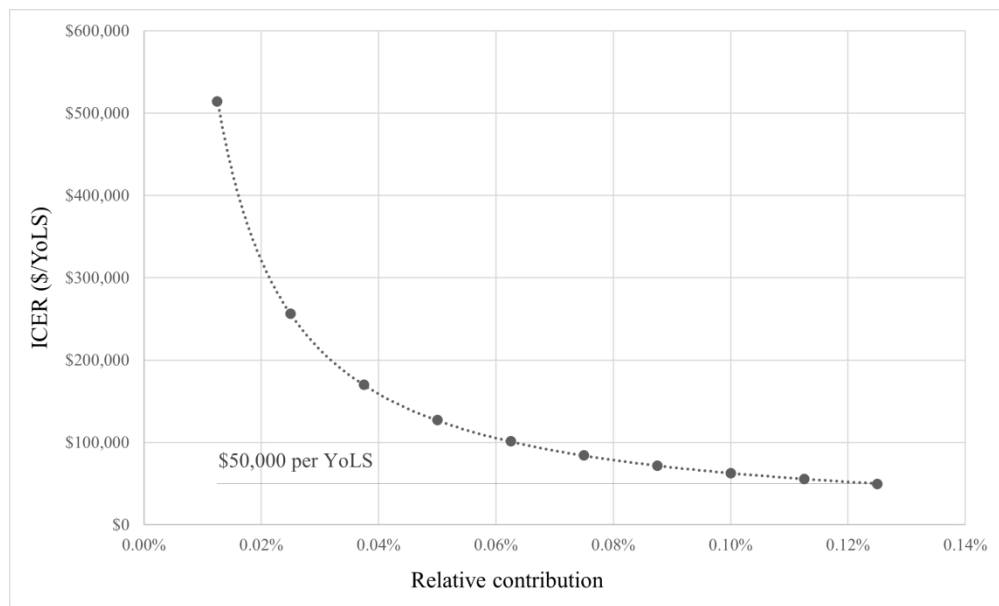


Figure 1: Relative contribution of VCOR to CHD mortality trends versus VCOR cost-effectiveness
 ICER = incremental cost-effectiveness ratio; YoLS = year of life saved

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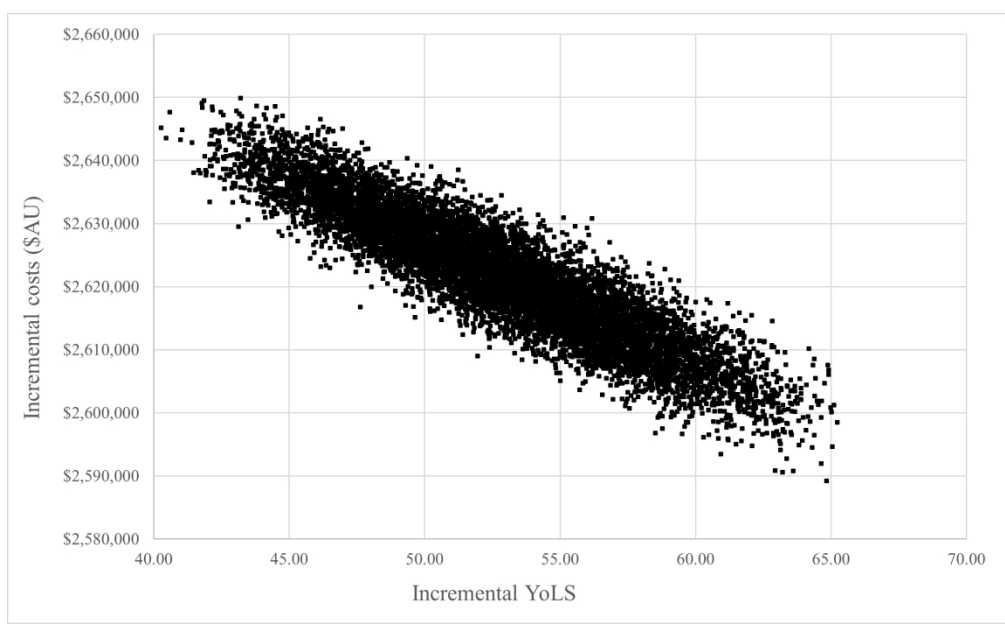


Figure 2: Results of the probabilistic sensitivity analysis
\$AU = Australian dollars; YoLS = year of life saved

187x114mm (330 x 330 DPI)

Supplementary Table 1: Trends in mortality over time

Mortality		Year									
Sex	Age group (years)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
CHD Mortality											
Males	25 - 34	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	35 - 44	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%
	45 - 54	0.04%	0.04%	0.03%	0.03%	0.04%	0.04%	0.04%	0.03%	0.03%	0.04%
	55 - 64	0.10%	0.10%	0.07%	0.07%	0.10%	0.08%	0.09%	0.07%	0.08%	0.11%
	65 - 74	0.24%	0.22%	0.18%	0.19%	0.21%	0.18%	0.17%	0.17%	0.17%	0.22%
	75 - 84	0.78%	0.72%	0.63%	0.58%	0.61%	0.57%	0.59%	0.54%	0.47%	0.52%
	85+	2.87%	2.90%	2.47%	2.40%	2.24%	2.38%	2.21%	2.06%	2.04%	1.90%
	All	0.10%	0.10%	0.09%	0.09%	0.09%	0.09%	0.09%	0.08%	0.08%	0.09%
Females	25 - 34	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	35 - 44	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	45 - 54	0.01%	0.01%	0.00%	0.01%	0.01%	0.01%	0.01%	0.00%	0.01%	0.01%
	55 - 64	0.02%	0.02%	0.01%	0.01%	0.02%	0.02%	0.02%	0.02%	0.01%	0.02%

Mortality		Year									
Sex	Age group (years)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
	65 - 74	0.08%	0.08%	0.07%	0.06%	0.06%	0.06%	0.06%	0.06%	0.05%	0.06%
	75 - 84	0.43%	0.41%	0.34%	0.32%	0.32%	0.30%	0.27%	0.28%	0.22%	0.24%
	85+	2.37%	2.25%	2.11%	1.92%	1.90%	1.90%	1.77%	1.68%	1.42%	1.41%
	All	0.09%	0.09%	0.08%	0.07%	0.07%	0.07%	0.06%	0.06%	0.05%	0.06%
Non-CHD Mortality *											
Males	25 - 34	0.07%	0.07%	0.07%	0.06%	0.07%	0.07%	0.06%	0.06%	0.05%	0.08%
	35 - 44	0.11%	0.11%	0.10%	0.09%	0.12%	0.12%	0.11%	0.10%	0.10%	0.15%
	45 - 54	0.23%	0.21%	0.19%	0.22%	0.22%	0.23%	0.22%	0.20%	0.19%	0.26%
	55 - 64	0.53%	0.51%	0.50%	0.48%	0.51%	0.51%	0.48%	0.46%	0.44%	0.53%
	65 - 74	1.37%	1.38%	1.25%	1.24%	1.27%	1.28%	1.17%	1.20%	1.15%	1.25%
	75 - 84	4.23%	4.23%	3.99%	3.87%	3.87%	3.87%	3.86%	3.52%	3.34%	3.72%
	85+	12.29%	12.63%	11.92%	11.48%	11.94%	12.54%	11.90%	12.19%	11.27%	12.56%
	All	0.56%	0.57%	0.54%	0.54%	0.57%	0.58%	0.57%	0.55%	0.52%	0.61%

Mortality		Year									
Sex	Age group (years)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Females	25 - 34	0.03%	0.03%	0.02%	0.03%	0.04%	0.02%	0.03%	0.03%	0.02%	0.03%
	35 - 44	0.06%	0.07%	0.07%	0.06%	0.07%	0.07%	0.07%	0.06%	0.06%	0.07%
	45 - 54	0.15%	0.17%	0.15%	0.15%	0.15%	0.15%	0.15%	0.15%	0.14%	0.17%
	55 - 64	0.35%	0.35%	0.34%	0.33%	0.35%	0.33%	0.33%	0.32%	0.33%	0.35%
	65 - 74	0.87%	0.87%	0.82%	0.80%	0.85%	0.85%	0.83%	0.83%	0.78%	0.85%
	75 - 84	2.88%	2.84%	2.85%	2.76%	2.74%	2.84%	2.77%	2.66%	2.42%	2.66%
	85+	10.80%	10.76%	10.83%	10.57%	10.75%	11.41%	10.80%	11.04%	10.41%	11.23%
	All	0.55%	0.56%	0.56%	0.55%	0.56%	0.58%	0.56%	0.56%	0.53%	0.58%

CHD = coronary heart disease

* Based on subtracting the likelihood of CHD mortality from the likelihood of all-cause mortality

Supplemental Table 2: Trends in CHD mortality over time used in the economic model.

Parameter	Value						
	Age group (years)	Year					
		2014	2015	2016	2017	2018	P-value*
CHD Mortality Trend (Males)	25 - 34	0.00%	0.00%	0.00%	0.00%	0.00%	0.382
	35 - 44	0.01%	0.01%	0.01%	0.01%	0.01%	0.013
	45 - 54	0.04%	0.04%	0.04%	0.03%	0.03%	0.006
	55 - 64	0.10%	0.08%	0.08%	0.07%	0.08%	0.051
	65 - 74	0.21%	0.18%	0.17%	0.17%	0.17%	0.092
	75 - 84	0.61%	0.57%	0.59%	0.54%	0.47%	0.033
	85+	2.24%	2.38%	2.24%	2.06%	2.04%	0.106
All	0.09%	0.09%	0.09%	0.08%	0.08%	0.001	
CHD Mortality Trend (Females)	25 - 34	0.00%	0.00%	0.00%	0.00%	0.00%	0.357
	35 - 44	0.00%	0.00%	0.00%	0.00%	0.00%	0.071
	45 - 54	0.01%	0.01%	0.01%	0.00%	0.01%	0.283

Parameter	Value						
	Age group (years)	Year					P-value*
		2014	2015	2016	2017	2018	
	55 - 64	0.02%	0.02%	0.02%	0.02%	0.01%	0.073
	65 - 74	0.06%	0.06%	0.06%	0.06%	0.05%	0.121
	75 - 84	0.32%	0.30%	0.27%	0.28%	0.22%	0.023
	85+	1.90%	1.90%	1.71%	1.68%	1.42%	0.016
	All	0.07%	0.07%	0.06%	0.06%	0.05%	0.016

CHD = coronary heart disease

* Based on simple linear regression analyses

Supplementary Table 3: VCOR funding over time

Fund	Year			
	2014	2015	2016	2017
Medibank Private	\$300,000	-	-	-
DHHS	\$509,466	\$460,202	\$834,815	\$616,900
Total	\$809,466	\$460,202	\$834,815	\$616,900

DHHS = Department of Health and Human Services

Source: VCOR Annual Report 2018 ³¹

Supplementary Table 4: Derivation of costs associated with mortality

Source	DRG	DRG Description	Number of discharges	Cost
NHCDC Round 22 ³⁴	F05A	CRNRY BYPASS+INV INVES, MAJC	602	\$72,146
	F05B	CRNRY BYPASS+INV INVES, MINC	1,010	\$51,816
	F06A	CRNRY BYPASS-INV INVES, MAJC	831	\$62,580
	F06B	CRNRY BYPASS-INV INVES, INTC	1,683	\$44,195
	F06C	CRNRY BYPASS-INV INVES, MINC	1,594	\$37,227
	F10A	INTERVENTIONAL CRNRY PR + AMI, MAJC	2,884	\$22,632
	F10B	INTERVENTIONAL CRNRY PR + AMI, MINC	12,581	\$11,613
	F60A	CIRC DIS+AMI-INVA INV PR	9,435	\$8,089
	F60B	CIRC DIS+AMI-INVA INV PR,T<5D	7,920	\$3,667
	F66A	CORONARY ATHEROSCLEROSIS, MAJC	1,771	\$6,911
	F66B	CORONARY ATHEROSCLEROSIS, MINC	8,825	\$1,908
	F72A	UNSTABLE ANGINA, MAJC	1,713	\$5,845

	F72B	UNSTABLE ANGINA, MINC	7,567	\$2,382
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AMI = acute myocardial infarction; CIRC = circulatory; CRNRY = coronary; INV =
invasive; INVES = investigation; DRG = diagnosis-related group; MAJC = major
complexity; MINC = minor complexity; PR = procedure

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Supplementary Table 5: Characteristics of patients undergoing PCI across Victorian hospitals (VCOR)

Variable	Year					P-value*
	2014 (N = 7,007)	2015 (N = 7,661)	2016 (N = 8,417)	2017 (N = 9,113)	Total (N = 32,198)	
Age						<0.001
Mean (SD)	65 (11.59)	65 (11.50)	66 (11.80)	66 (11.64)	66 (11.6)	
Median (IQR)	66 (17)	66 (17)	66 (17)	67 (17)	66 (16)	
Age group (years), n (%N)						
< 75	5,392 (77.0%)	5,881 (76.8%)	6,291 (74.7%)	6,725 (73.8%)	24,289 (75.4%)	
≥ 75	1,615 (23.1%)	1,780 (23.2%)	2,126 (25.3%)	2,388 (26.2%)	7,909 (24.6%)	
Aboriginal/Torres strait Islander, n (%N)						<0.001
Yes	31 (0.4%)	28 (0.4%)	28 (0.3%)	52 (0.6%)	139 (0.4%)	
No	6,814 (97.3%)	7,266 (94.8%)	8,107 (96.3%)	8,356 (91.7%)	30,543 (94.9%)	
Unknown	162 (2.3%)	367 (4.8%)	282 (3.4%)	705 (7.7%)	1,516 (4.7%)	

Variable	Year					P-value*
	2014 (N = 7,007)	2015 (N = 7,661)	2016 (N = 8,417)	2017 (N = 9,113)	Total (N = 32,198)	
Sex, n(%N)						0.039
Male	5,462 (78.0%)	5,936 (77.5%)	6,482 (77.0%)	6,938 (76.1%)	24,818 (77.1%)	
Female	1,545 (22.0%)	1,725 (22.5%)	1,935 (23.0%)	2,175 (23.8%)	7,380 (22.9%)	
BMI, n (%N)						<0.001
Underweight (<18.5 kg/m ²)	37 (0.5%)	40 (0.5%)	72 (0.9%)	59 (0.7%)	208 (0.7%)	
Normal (18.5 -24.9 kg/m ²)	1,533 (21.9%)	1,678 (21.9%)	1,778 (21.1%)	2,017 (22.1%)	7,006 (21.8%)	
Overweight (25 – 29.9 kg/m ²)	2,882 (41.1%)	3,014 (39.3%)	3,335 (39.6%)	3,596 (39.5%)	12,827 (39.8%)	
Obese (≥30 kg/m ²)	2,445 (34.9%)	2,777 (36.3%)	3,128 (37.2%)	3,368 (37.0%)	11,718 (36.4%)	
Missing	110 (1.6%)	152 (2.0%)	104 (1.2%)	73 (0.8%)	439 (1.4%)	
Public/private hospital status, n (%N)						
Public	4,424 (63.1%)	4,838 (63.2%)	5,225 (62.1%)	5,858 (64.3%)	20,345 (63.2%)	0.027
ACS type, n (%N)						0.024

Variable	Year					P-value*
	2014 (N = 7,007)	2015 (N = 7,661)	2016 (N = 8,417)	2017 (N = 9,113)	Total (N = 32,198)	
UA	580 (8.3%)	590 (7.7%)	623 (7.4%)	577 (6.3%)	2,370 (7.4%)	
NSTEMI	1,663 (23.7%)	1,793 (23.4%)	2,026 (24.1%)	2,050 (22.5%)	7,532 (23.4%)	
STEMI	1,465 (20.9%)	1,561 (20.4%)	1,674 (19.9%)	1,797 (19.7%)	6,497 (20.2%)	
Cardiogenic shock, n (%N)	142 (2.0%)	181 (2.4%)	214 (2.5%)	189 (2.1%)	726 (2.3%)	0.087
Intubated OHCA, n (%N)	72 (1.0%)	81 (1.1%)	100 (1.2%)	110 (1.2%)	363 (1.1%)	0.623
Pre-procedure cardiac arrest, n (%N)	123 (1.8%)	119 (1.6%)	128 (1.5%)	111 (1.2%)	481 (1.5%)	0.042
LVEF grade, n (%N)						0.003
Normal	3,488 (49.8%)	3,840 (50.1%)	4,382 (52.1%)	4,703 (51.6%)	16,413 (51.0%)	
Mild	1,008 (14.4%)	1,291 (16.9%)	1,238 (14.1%)	1,337 (14.7%)	4,874 (15.1%)	
Moderate	487 (7.0%)	551 (7.2%)	664 (7.9%)	642 (7.0%)	2,344 (7.3%)	
Severe	215 (3.1%)	241 (3.2%)	289 (3.4%)	296 (3.3%)	1,041 (3.2%)	
Missing	1,809 (25.8%)	1,738 (22.7%)	1,844 (21.9%)	2,135 (23.4%)	7,526 (23.4%)	

Variable	Year					P-value*
	2014 (N = 7,007)	2015 (N = 7,661)	2016 (N = 8,417)	2017 (N = 9,113)	Total (N = 32,198)	
Medicated diabetes, n (%N)	1,532 (21.9%)	1,795 (23.4%)	1,848 (22.0%)	1,979 (21.7%)	7,154 (22.2%)	0.034
Peripheral vascular disease, n (%N)	244 (3.5%)	279 (3.6%)	326 (3.9%)	311 (3.4%)	1,160 (3.6%)	0.386
Cerebrovascular disease, n (%N)	228 (3.3%)	310 (4.1%)	272 (3.2%)	368 (4.0%)	1,178 (3.7%)	0.002
Chronic oral anticoagulant therapy, n (%N)	294 (4.2%)	347 (4.5%)	465 (5.5%)	754 (8.3%)	1,860 (5.8%)	<0.001
Previous CABG, n (%N)	601 (8.6%)	625 (8.2%)	681 (8.1%)	689 (7.6%)	2,596 (8.1%)	0.126
Previous PCI, n (%N)	2,350 (33.5%)	2,805 (36.6%)	3,013 (35.8%)	3,284 (36.0%)	11,452 (35.6%)	0.001
Dialysis, n (%N)	72 (1.0%)	83 (1.1%)	121 (1.4%)	103 (1.1%)	379 (1.2 %)	0.072
Renal transplant, n (%N)	21 (0.3%)	21 (0.3%)	25 (0.3%)	29 (0.3%)	96 (0.3%)	0.965
Renal replacement therapy, n (%N)	2 (0.0%)	6 (0.1%)	7 (0.1%)	3 (0.0%)	18 (0.1%)	0.305
Fibrinolytic therapy, n (%N)	197 (2.8%)	240 (3.1%)	266 (3.2%)	259 (2.8%)	962 (3.0%)	0.417
eGFR						0.011
Mean (SD)	91.85 (37.11)	92.21 (37.78)	91.80 (38.61)	90.42 (38.04)	91.53 (37.9)	

Variable	Year					P-value*
	2014 (N = 7,007)	2015 (N = 7,661)	2016 (N = 8,417)	2017 (N = 9,113)	Total (N = 32,198)	
Median (IQR)	87.47 (47.34)	88.26 (48.28)	87.47 (47.71)	86.35 (47.73)	87.36 (47.6)	
eGFR, n (%N)						0.039
Normal (≥ 90 ml/min/1.73m ²)	5,255 (75.0%)	5,752 (75.1%)	6,277 (74.6%)	6,596 (72.4%)	23,880 (74.2%)	
Moderate (30 – 89 ml/min/1.73m ²)	1,133 (16.2%)	1,251 (16.3%)	1,338 (15.9%)	1,488 (16.3%)	5,210 (16.2%)	
Severe (<30 ml/min/1.73m ²)	133 (1.9%)	163 (2.1%)	216 (2.6%)	227 (2.5%)	739 (2.4%)	
Missing	486 (6.9%)	495 (6.5%)	586 (7.0%)	802 (8.8%)	2,369 (7.4%)	

ACS = acute coronary syndrome; BMI = body mass index; CABG = coronary artery bypass graft; eGFR = estimated glomerular filtration rate;

LVEF = left ventricular ejection fraction; NSTEMI = Non-ST-elevation myocardial infarction; OHCA = out-of-hospital cardiac arrest; STEMI =

ST-elevation myocardial infarction; UA = unstable angina;

There were 1 missing case for medicated diabetes status, 4 for out-of-hospital cardiac arrest, 1 for in-hospital pre-procedure cardiac arrest, 3 for

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3 peripheral vascular disease, 2 for cerebrovascular disease or chronic oral anticoagulant therapy and 1 for renal transplant.
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6 * P-value for year-to-year trend
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Supplementary Table 6: Procedural characteristics of PCI across Victorian hospitals (VCOR)

Variable	Year					P-value*
	2014 (N = 7,007)	2015 (N = 7,661)	2016 (N = 8,417)	2017 (N = 9,113)	Total (N = 32,198)	
Access site, n (%N)						<0.001
Brachial	17 (0.2%)	11 (0.1%)	7 (0.1%)	11 (0.1%)	46 (0.1%)	
Radial	2,608 (37.2%)	3,443 (44.9%)	4,626 (55.0%)	5,555 (61.0%)	16,232 (50.4%)	
Femoral	4,382 (62.5%)	4,207 (54.9%)	3,784 (45.0%)	3,547 (38.9%)	15,920 (49.4%)	
Medications (pre/during procedure), n (%N)						<0.001
Glycoprotein IIb/IIIa inhibitor	915 (13.1%)	853 (11.1%)	768 (9.1%)	737 (8.1%)	3,273 (10.2%)	
Thienopyridine or Ticagrelor	5,843 (83.4%)	6,240 (81.5%)	6,729 (80.0%)	7,113 (78.0%)	25,925 (80.5%)	
Aspirin	5,751 (82.3%)	6,754 (88.5%)	7,707 (91.9%)	8,666 (95.0%)	28,878 (90.0%)	
Antithrombin	6,057 (87.5%)	6,815 (90.3%)	7,452 (89.2%)	8,389 (92.0%)	28,713 (90.1%)	
Lesion characteristics						

Multi-lesion disease, n (%N)	1,275 (18.2%)	1,557 (20.3%)	1,714 (20.4%)	2,001 (22.0%)	6,547 (20.3 %)	<0.001
Treated vessel(s), n (%N)						
Left main coronary artery	111 (1.6%)	122 (1.6%)	160 (1.9%)	180 (2.0%)	573 (1.8%)	0.123
Multivessel disease, n (%N)	425 (6.07%)	525 (6.85%)	593 (7.05%)	708 (7.77%)	2,251 (6.99%)	<0.001
Unprotected left main PCI, n (%N)	58 (0.8%)	66 (0.8%)	103 (1.2%)	120 (1.3%)	347 (1.1%)	0.003
Chronic total occlusion, n (%N)	290 (4.1%)	358 (4.7%)	334 (4.0%)	342 (3.8%)	1,324 (4.1%)	0.023
In-stent restenosis, n (%N)	440 (6.3%)	501 (6.5%)	515 (6.1%)	519 (5.7%)	1,975 (6.1%)	0.139
Device used, n (%N)						
BMS only	1,277 (18.2%)	1,056 (13.8%)	663 (7.9%)	359 (3.9%)	3,355 (10.4%)	<0.001
Any DES	5,256 (75.0%)	5,934 (77.5%)	7,211 (85.7%)	8,139 (89.0%)	26,540 (82.4%)	<0.001
POBA only	451 (6.4%)	580 (7.6%)	493 (5.9%)	603 (6.6%)	2,127 (6.6%)	<0.001
Door to balloon time metrics[†]						
Door-to-balloon time [minutes, median (IQR)]	68 (40)	71 (53)	67 (49)	62 (44)	67 (49)	<0.001
Door-to-balloon/device time group, n (%N)						

≤ 90 min	259 (29.8%)	286 (31.3%)	268 (27.6%)	247 (21.7%)	1,060 (27.2%)	<0.001
>90 min	607 (69.9%)	624 (68.3%)	704 (72.4%)	888 (78.2%)	2,823 (72.6%)	
Missing	3 (0.35%)	4 (0.4%)	0 (0.0%)	1 (0.09%)	8 (0.2%)	
Post-procedural characteristics						
Lesion success, n (%N)	406 (5.8%)	568 (7.4%)	471 (5.6%)	575 (6.3%)	2,020 (6.3%)	<0.001
Procedure success, n (%N)	6,381 (91.1%)	6,861 (89.6%)	7,688 (91.3%)	8,294 (91.9%)	29,224 (90.8%)	<0.001
New renal impairment, n (%N)	138 (2.6%)	186 (3.3%)	179 (3.0%)	260 (4.1%)	763 (3.3%)	<0.001
Length-of-stay						
Median (IQR)	2 (3)	2 (3)	3 (3)	2 (3)	2 (3)	0.208
Referred to cardiac rehab, n (%N)	4,684 (68.2%)	5,669 (75.2%)	6,284 (76.1%)	6,529 (72.9%)	23,166 (73.3%)	<0.001

BMS = bare metal stent; DES = drug-eluting stent; PCI = percutaneous coronary intervention; POBA = plain old balloon angioplasty; STEMI =

ST-elevation myocardial infarction

* P-value for year-to-year trend

† Excluding all inter-hospital transfer arrivals and patients with STEMI onset while a current in-patient

Supplementary Table 7: Changes in radial access and DBDT over time

Parameter	OR (95% CI)*	P-value
Likelihood of Femoral Access		
STEMI		
Males	0.65 (0.62 0.69)	<0.001
Females	0.73 (0.66 0.82)	<0.001
NSTEMI		
Males	0.70 (0.66 0.74)	<0.001
Females	0.74 (0.67 0.81)	<0.001
UA		
Males	0.72 (0.65 0.80)	<0.001
Females	0.73 (0.63 0.85)	<0.001
Non-ACS		
Males	0.72 (0.70 0.75)	<0.001
Females	0.74 (0.70 0.80)	<0.001
Likelihood of DBDT \leq 90 minutes †		
Males	1.15 (1.07 1.24)	<0.001
Females	1.17 (1.01 1.36)	0.035

ACS = acute coronary syndrome; DBDT = door-to-balloon/device time; NSTEMI = non-ST-

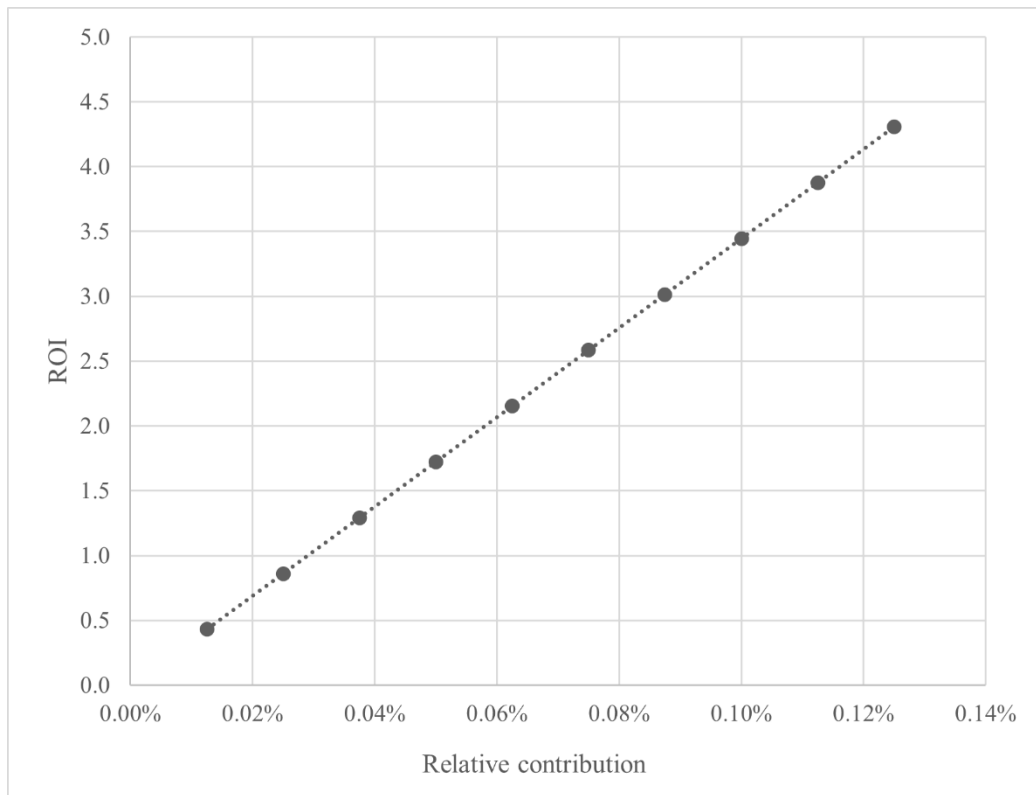
elevation myocardial infarction; OR = odds ratio; STEMI = ST-elevation myocardial

infarction; UA = unstable angina

* Adjusted for key confounding variables

† Primary PCI for STEMI presentations excluding all inter-hospital transfer arrivals and patients with STEMI onset while a current in-patient

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3 **Supplementary Figure 1: Return on investment versus relative contribution to CHD**
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5 **mortality trends**
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35 ROI = return on investment
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CHEERS 2022 Checklist

Topic	No.	Item	Location where item is reported
Title			
	1	Identify the study as an economic evaluation and specify the interventions being compared.	Page 1
Abstract			
	2	Provide a structured summary that highlights context, key methods, results, and alternative analyses.	Page 3
Introduction			
Background and objectives	3	Give the context for the study, the study question, and its practical relevance for decision making in policy or practice.	Page 7
Methods			
Health economic analysis plan	4	Indicate whether a health economic analysis plan was developed and where available.	Page 9
Study population	5	Describe characteristics of the study population (such as age range, demographics, socioeconomic, or clinical characteristics).	Page 9
Setting and location	6	Provide relevant contextual information that may influence findings.	Page 9
Comparators	7	Describe the interventions or strategies being compared and why chosen.	Page 9
Perspective	8	State the perspective(s) adopted by the study and why chosen.	Page 9
Time horizon	9	State the time horizon for the study and why appropriate.	Page 16
Discount rate	10	Report the discount rate(s) and reason chosen.	Page 16
Selection of outcomes	11	Describe what outcomes were used as the measure(s) of benefit(s) and harm(s).	Pages 13-14
Measurement of outcomes	12	Describe how outcomes used to capture benefit(s) and harm(s) were measured.	Pages 13-14

Topic	No.	Item	Location where item is reported
Valuation of outcomes	13	Describe the population and methods used to measure and value outcomes.	Pages 15-16
Measurement and valuation of resources and costs	14	Describe how costs were valued.	Pages 15-16
Currency, price date, and conversion	15	Report the dates of the estimated resource quantities and unit costs, plus the currency and year of conversion.	Pages 15-16
Rationale and description of model	16	If modelling is used, describe in detail and why used. Report if the model is publicly available and where it can be accessed.	Pages 8-13
Analytics and assumptions	17	Describe any methods for analysing or statistically transforming data, any extrapolation methods, and approaches for validating any model used.	Pages 14-15
Characterising heterogeneity	18	Describe any methods used for estimating how the results of the study vary for subgroups.	N/A
Characterising distributional effects	19	Describe how impacts are distributed across different individuals or adjustments made to reflect priority populations.	N/A
Characterising uncertainty	20	Describe methods to characterise any sources of uncertainty in the analysis.	Pages 18-19
Approach to engagement with patients and others affected by the study	21	Describe any approaches to engage patients or service recipients, the general public, communities, or stakeholders (such as clinicians or payers) in the design of the study.	N/A
Results			
Study parameters	22	Report all analytic inputs (such as values, ranges, references) including uncertainty or distributional assumptions.	Table 1, page 13
Summary of main results	23	Report the mean values for the main categories of costs and outcomes of interest and summarise them in the most appropriate overall measure.	Pages 20-23
Effect of uncertainty	24	Describe how uncertainty about analytic judgments, inputs, or projections affect findings. Report the effect of choice of discount rate and time horizon, if applicable.	Table 3, pages 22-23

Topic	No.	Item	Location where item is reported
Effect of engagement with patients and others affected by the study	25	Report on any difference patient/service recipient, general public, community, or stakeholder involvement made to the approach or findings of the study	N/A
Discussion			
Study findings, limitations, generalisability, and current knowledge	26	Report key findings, limitations, ethical or equity considerations not captured, and how these could affect patients, policy, or practice.	Pages 24-27
Other relevant information			
Source of funding	27	Describe how the study was funded and any role of the funder in the identification, design, conduct, and reporting of the analysis	Page 29
Conflicts of interest	28	Report authors conflicts of interest according to journal or International Committee of Medical Journal Editors requirements.	Page 29

From: Husereau D, Drummond M, Augustovski F, et al. Consolidated Health Economic Evaluation Reporting Standards 2022 (CHEERS 2022) Explanation and Elaboration: A Report of the ISPOR CHEERS II Good Practices Task Force. *Value Health* 2022;25. doi:10.1016/j.jval.2021.10.008