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

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.

Key words: Cost-effectiveness; acute coronary syndrome; cardiovascular disease; clinical quality registries; quality improvement.

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,

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

Methods

Model structure

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

The clinical and cost outputs for each model were totalled to determine the overall cost-effectiveness and return-on-investment (ROI) attributed to VCOR.

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 =

value of statistical life year

* Based on simple linear regression analyses

The likelihood of all-cause or CHD mortality was estimated by dividing the number of deaths (all-cause or CHD-related) in each sex and age subgroup by the Victorian population for each subgroup [14 15]. The likelihood of non-CHD mortality was estimated by subtracting the likelihood of CHD mortality from the likelihood of all-cause mortality [14 15].

Effectiveness of VCOR

VCOR is a state-wide, ongoing population based CQR. It was established in 2012 to monitor the performance of cardiac services in hospitals across Victoria [6 12]. The key focus of VCOR currently is on patients undergoing PCI and cardiac implanted electronic devices [6 12]. The economic evaluation was based on estimating the downstream clinical and cost impacts of VCOR relative to a hypothetical scenario in which VCOR did not exist (No VCOR). In the absence of efficacy data, VCOR was assumed to contribute to 0.5% of the reduction in CHD mortality over time observed in the economic model. That is, without VCOR contributing to reductions in CHD mortality over time, the extent to which CHD mortality declined over time had decreased by 0.5%. This represented a conservative estimate of the mortality benefits attributed to benchmarking and feedback through VCOR. The assumed contribution of VCOR was justified based on current literature demonstrating that the registry data collection for the purposes of routine health systems benchmarking and feedback is, of itself, likely to contribute to reductions in mortality over time [9 11]. A similar approach whereby the benefits of a cardiac CQR was assumed to contribute to temporal trends in patient mortality has been published elsewhere [11].

Based on data from the ABS, the risk of CHD mortality in Victoria has decreased steadily over the period from 2014 to 2018 (Table 1). Notably, the clinical management of CHD has also evolved over time. This may in part be attributed to ongoing benchmarking and feedback through VCOR. First, in the period since VCOR was established, implementation of PCI via radial access (instead of femoral access) had improved considerably [6]. A Cochrane review of PCI via radial versus femoral access concluded that radial access was associated with reductions in major bleeding events, access site complications and mortality in the setting of ACS [16]. This is supported by data from cardiac registries in the US, UK and Australia [17-19]. Secondly, in addition to improved uptake of radial access PCI, hospital adherence to a door-to-balloon/device time (DBDT) has improved, with all PCI-capable hospitals across Victoria achieving a median DBDT time of ≤ 90 minutes [6]. Such changes in clinical practice have been attributed, in part, to ongoing benchmarking and feedback through VCOR [6 20 21].

Cost inputs

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

Cost of VCOR

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

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 values [27].

Discounting

A discount rate of 5% per annum was applied to years of life lived and costs incurred beyond the first year [28].

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

No VCOR were aggregated to represent the clinical and cost impacts of VCOR over five years for the total Victorian population at risk of mortality from CHD.

The primary cost-benefit analysis estimated differences between the two groups with regard to net societal costs. This was defined as the cost of VCOR operation, minus the cost savings attributed to reduced CHD mortality, added to the costs saved by prolonging years of life lived in the cohort. The primary outcome was the net cost attributed to VCOR operation. A key secondary outcome for our study was the incremental cost-effectiveness ratio (ICER) for VCOR compared with No VCOR in terms of cost per year of life saved (YoLS). The commonly used willingness-to-pay threshold of $50,000 per QALY gained in determining cost-effectiveness [28] was used in lieu of an official willingness to pay threshold in Australia.

Statistical analyses

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

To explore changes in clinical practice over time, the population was stratified by sex and indication for PCI: non-ACS reasons, unstable angina, non-ST elevation myocardial infarction (NSTEMI) and ST elevation myocardial infarction (STEMI). Backward stepwise logistic regression with a P-value threshold of 0.10 was used to identify the following potential confounders of radial access, and DBDT ≤ 90 minutes: age (< 75 years and ≥ 75 years); in-hours hospital arrival (between 08:00 to 18:00 on a workday); cardiogenic shock or

intubated out-of-hospital cardiac arrest (OHCA); left ventricular ejection fraction (LVEF); medicated diabetes mellitus; peripheral vascular disease; cerebrovascular disease; chronic oral anticoagulation therapy; prior coronary artery bypass grafting; previous PCI; use of glycoprotein IIb/IIIa inhibitors; use of thienopyridine or ticagrelor; estimated glomerular filtration rate (eGFR); required mechanical ventricular support; lesion complexity (American College of Cardiology/American Heart Association type A/B1 versus type B2/C lesions); unprotected left main PCI; chronic total occlusion PCI and in-stent restenosis PCI [29 30]. Multivariable logistic regression models with adjustment for key predictors identified in stepwise regression were used to explore annual trends in radial access and DBDT metrics. The results of these analyses were used to inform the economic model drawn from ABS inputs.

To explore trends in CHD mortality over time using mortality data from the ABS, simple linear regression modelling was performed with the year as the independent variable, and CHD mortality as the dependent variable. A P-value <0.05 was considered statistically significant.

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

Sensitivity analyses

A series of one-way sensitivity analyses were undertaken to determine the impact of uncertainty around key model parameters. Input parameters were varied individually in deterministic sensitivity analyses, while other variables were maintained at base case values to estimate the impact of parameters on cost-benefit/effectiveness. Key parameters assessed

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 ≤ 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

CHD = coronary heart disease; 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%

Over this period, a total of 19,065 CHD-related deaths occurred across Victoria. Based on the assumption that VCOR contributed to 0.5% of the temporal change in CHD mortality over time, the clinical benefit attributed to VCOR was the prevention of 93 CHD-related deaths and 211 (discounted) years of life saved. A total of $483,096 was saved over this period due to the prevention of CHD mortality. This was balanced against a higher incidence of non-CHD mortality in the VCOR cohort (because the risk of non-CHD death was not assumed to have changed by VCOR), which incurred an additional cost of $59,758. The total cost of VCOR was $2,727,570 (discounted). Hence the net cost of VCOR from the perspective of the Australian health care system was $2,304,233 (discounted). The ICER associated with VCOR was $10,902 per YoLS. From a broader, societal perspective, the savings attributed to VCOR were $46,552,376 based on an assumed VoSLY of $220,262. The return on investment (ROI) ratio, which is the ratio of the total cost savings to the total costs of VCOR, was 17.2 that is, for every $1.00 invested in VCOR, a return of $17.2 was delivered.

Table 4 presents the results of sensitivity analyses in terms of ICERs, net societal costs attributed to VCOR operation, and ROI.

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

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

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

Additionally, there is considerable evidence of improved patient outcomes as a result of interventions attributed to cardiac CQR benchmarking and health systems feedback in the UK and Sweden [34-36]. Data collected by the British Cardiovascular Intervention Society demonstrated considerable utility of informing clinical practice in the setting of PCI, including the identification of variable uptake in radial access across hospitals, delays in PCI for NSTEMI patients, and a low rate of same-day discharge for patients undergoing elective PCI [34]. Changes to these parameters are likely to improve patient outcomes and efficiency in the delivery of health services for cardiac care [16 31 37]. Similarly, mortality from CHD in Sweden declined considerably between 1995 and 2014 due to changes in the evidence-based management of NSTEMI and STEMI [35 36]. Such changes have been facilitated through

ongoing quality improvement and benchmarking through SWEDEHEART and other, well-established CQRs [35 36].

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

Limitations

A key limitation to our analysis was the uncertainty around the clinical benefit conferred by VCOR with respect to the observed trend in mortality. Hence, we assumed a conservative estimate of the mortality benefits attributed to benchmarking and feedback through VCOR. Importantly, in scenario analyses whereby the benefit of VCOR was lowered from an already conservative value, the registry remained cost-effective and was still associated with positive ROI. Secondly, it was not possible to assess the impact of VCOR on readmissions for recurrent ACS, and on patient morbidity and quality-of-life through ABS data. Hence, our analyses were limited to capturing the mortality benefit attributed to VCOR. However, KPIs pertaining to patient morbidity, including such as MACCE, hospital length-of-stay and in-

hospital unplanned revascularisation, had remained stable and were relatively low throughout the period of evaluation [21 39]. Readmissions for ACS in Victoria had also remained stable over time [6 40]. Therefore, incorporating the potential cost and clinical impacts attributed to other trends in clinical practice or the reporting of KPIs outside of DBDT for STEMI patients by VCOR, would not have changed our findings in a substantial manner. Additionally, there is a lack of robust data pertaining to quality-of-life following ACS in Australia which limited analyses on the impact of VCOR on patient morbidity [41]. Thirdly, cost inputs for patient mortality were based on DRG estimates that were constant across age, sex, and ACS indications. This was in lieu of robust, bottom-up cost data [11 24 42]. However, sensitivity analyses found that the economic model was robust to the costs of hospitalisations.

Conclusion

VCOR represents a sound investment for the Victorian health care system. Based on the conservative assumption that VCOR benchmarking and feedback contributed to a proportion of the observed reduction in CHD mortality over time, the registry is associated with cost savings at the societal level. Additionally, VCOR is cost-effective from the perspective of the healthcare system.

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Author Contributions: PL and DL had full access to all of the data in this study and take responsibility for the integrity of the data and accuracy of the data analysis. PL, EZ and DL were responsible for the study concept and design, the acquisition, analysis and interpretation of data and drafting of the manuscript. All authors provided critical revision of the manuscript for important intellectual content.

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This study received ethical approval from Monash University Human Research Ethics Committee (13882).

Data availability statement:

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

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

DHHS = department of health and human services

Source: VCOR Annual Report 2018 [23]

Supplementary Table 3: Derivation of costs associated with mortality

Source	DRG	DRG Description	Number of discharges	Cost
NHCDC Round 22 [26]	F05A	CRNRY BYPSS+INV INVES, MAJC	602	$72,146
	F05B	CRNRY BYPSS+INV INVES, MINC	1,010	$51,816
	F06A	CRNRY BYPSS-INV INVES, MAJC	831	$62,580
	F06B	CRNRY BYPSS-INV INVES, INTC	1,683	$44,195
	F06C	CRNRY BYPSS-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

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

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 (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 (78.1%)	25,925 (80.5%)	
Aspirin	5,751 (82.3%)	6,754 (88.5%)	7,707 (91.9%)	8,666 (95.4%)	28,878 (90.0%)	
Antithrombin	6,057 (87.5%)	6,815 (90.3%)	7,452 (89.2%)	8,389 (93.8%)	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

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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 (21.7%)	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 (74.9%)	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.

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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

Methods

Target population and subgroups	#4	Describe characteristics of the base case population and subgroups analysed, including why they were chosen.	8
Setting and location	#5	State relevant aspects of the system(s) in which the decision(s) need(s) to be made.	8
Study perspective	#6	Describe the perspective of the study and relate this to the costs being evaluated.	13
Comparators	#7	Describe the interventions or strategies being compared and state why they were chosen.	13
Time horizon	#8	State the time horizon(s) over which costs and consequences are being evaluated and say why appropriate.	8
Discount rate	#9	Report the choice of discount rate(s) used for costs and outcomes and say why appropriate	12
Choice of health outcomes	#10	Describe what outcomes were used as the measure(s) of benefit in the evaluation and their relevance for the type of analysis performed	13
Meaurement of effectiveness	#11a	Single study-based estimates: Describe fully the design features of the single effectiveness study and why the single study was a sufficient source of clinical effectiveness data	N/A
Measurement of effectiveness	#11b	Synthesis-based estimates: Describe fully the methods used for identification of included studies and synthesis of clinical effectiveness data	7-14
Measurement and valuation of preference based outcomes	#12	If applicable, describe the population and methods used to elicit preferences for outcomes.	N/A
**Estimating resources and costs **			

	#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	N/A
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.	7-14
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.	7-14
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.	7-14
Assumptions	#16	Describe all structural or other assumptions underpinning the decision-analytical model.	7-14
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.	7-14
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.	
Incremental costs and outcomes	#19	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.	Page 17, Table 3
Characterising uncertainty	#20a	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).	N/A
Characterising uncertainty	#20b	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.	Page 18, Table 4
Characterising heterogeneity	#21	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.	N/A
Discussion			
Study findings, limitations, generalisability, and current knowledge	#22	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.	20-23
Other			
Source of funding	#23	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	24
Conflict of interest	#24	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	24

comply with International Committee of Medical Journal Editors recommendations

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

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

Running title: An economic evaluation of VCOR

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Abstract

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

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 a five-year period (2014 to 2018) were compared to deaths and costs arising from a hypothetical situation which assumed that VCOR did not exist. Data from the Australian Bureau of Statistics and published sources were used to construct a decision analytic life table model to simulate the follow-up of Victorians aged ≥25 years for five years, or until death. The assumed contribution of VCOR to the proportional change in CHD mortality trend observed over the study period was varied to quantify the minimum level of clinical benefits required for the registry to be cost-effective. 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 The minimum proportional change in CHD mortality attributed to VCOR required for the registry to be considered cost-effective was 0.125%. Assuming this clinical benefit, a net return of $4.30 for every dollar invested in VCOR was estimated (ROI ratio over five years: 4.3 (95% confidence interval (CI): 3.6 – 5.0). The ICER estimated for VCOR was $49,616 (95% CI: $42,228 – $59,608) per YoLS. Sensitivity analyses found that the model was sensitive to the time horizon assumed and the extent of registry contribution to CHD mortality trends.

Conclusions

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

Key words: Cost-effectiveness; acute coronary syndrome; cardiovascular disease; clinical quality registries; quality improvement.

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 2020-2021, the prevalence of CHD in Australia was estimated to be 3% (571,000) of the adult population [1]. Although mortality from CHD has declined significantly since the 1960s, it remains the leading cause of death (approximately 10%) in Australia [1 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 2020-2021, 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, 48,034 PCIs were performed between 2020-2021[1]; in Victoria alone, 48% of all PCIs across Victoria in 2021 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]. 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. In Victoria alone, the cost burden attributed to PCIs across public hospitals was estimated to be $72,179,656 Australian Dollars (AU$) in 2017 [9]. Importantly, increasing PCI case complexity and procedural volume over time warrants greater adherence to evidence-based

guidelines for the management of ACS to improve health systems efficiency and patient outcomes [9].

Clinical quality registries (CQRs) are increasingly utilised to inform projects for the improvement of health care processes, adherence to evidence-based guidelines and standards, and reducing the costs attributed to care delivery [10-13]. Through the collection of patient outcomes data for cardiovascular procedures, it is possible to benchmark a hospitals' performance to its peers and adherence to national standards of care and evidence-based guidelines [10]. Additionally, CQRs have significant utility in medical research [10-12]. Previous studies have demonstrated that major improvements to patient outcomes may be attributed to the existence of CQRs [10]. In the context of ACS, patient outcomes have improved considerably over time following the establishment of cardiac CQRs in Sweden, New Zealand, the US and the UK which have been attributed, in part, to registry operation [14-18]. However, although there are many studies utilising data from CQRs, few have assessed the clinical and cost impacts attributed to a CQR [11]. This is likely due to difficulties in distinguishing the extent of contribution of CQRs to improved patient outcomes over time versus secular trends in patient management, and in the nomination of an appropriate comparator arm to assess the true costs and benefits attributed to registry operation [11]. In this context, we explored the minimum level of contribution to improved patient outcomes required for the Victorian Cardiac Outcomes Registry (VCOR), a cardiac CQR, to be cost-effective and represent a sound investment for the health care system.

Methods

Model structure

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

The clinical and cost outputs for each model were totalled to determine the overall cost-effectiveness attributed to VCOR from the perspective of the Australian health care system, assuming a cost-effectiveness threshold of $50,000 per year of life saved (YoLS). The commonly used willingness-to-pay threshold of $50,000 per YoLS gained in determining cost-effectiveness [22] was used in lieu of an official willingness to pay threshold in Australia. We also explored the return-on-investment (ROI) attributed to the registry from a societal perspective.

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) [20 21]. 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 International Classification of Diseases version 10 (ICD-10) codes: 120 – I25), were sourced for each age and sex subgroup from the ABS [20 21] (Table 1 and Supplemental Tables 1 and 2).

Table 1: Input parameters used in the economic model, including trends in CHD mortality over time, costs and the assumed 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 (±20%)
25 - 34	0.00% – 0.00%	0.382	0.00% – 0.00%	0.257	
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 (α = 5,609; β =

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

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

* Based on simple linear regression analyses

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

The likelihood of all-cause or CHD mortality was estimated by dividing the number of deaths (all-cause or CHD-related) in each sex and age subgroup by the Victorian population for each subgroup [20 21]. The likelihood of non-CHD mortality was estimated by subtracting the likelihood of CHD mortality from the likelihood of all-cause mortality [20 21].

Effectiveness of VCOR

VCOR is a state-wide, ongoing population based CQR. It was established in 2012 to monitor the performance of cardiac services in hospitals across Victoria [6 13]. The key focus of VCOR currently is on patients undergoing PCI and cardiac implanted electronic devices [6 13]. The economic evaluation was based on estimating the downstream clinical and cost impacts of VCOR relative to a hypothetical scenario in which VCOR did not exist (No VCOR). That is, without VCOR contributing to reductions in CHD mortality over time, the extent to which CHD mortality declined over time would be less. In the absence of efficacy data, the assumed contribution of VCOR to reductions in CHD mortality over time was varied in the economic model to establish the minimum contribution required for VCOR to be cost-effective. This is justified based on current literature demonstrating that the registry data collection for the purposes of routine health systems benchmarking and feedback is, of itself, likely to contribute to reductions in mortality over time through improvements in clinical practice [10 12]. A similar approach whereby the benefits of the All New Zealand Quality Improvement (ANZACS-QI) Programme, a cardiac CQR, was assumed to contribute to temporal trends in patient mortality has been published elsewhere [12]. In brief, this evaluation assumed that the registry contributed to 15% of temporal trends in myocardial infarction (MI)-related mortality

and readmissions, based on improved adherence to medications indicated for the secondary prevention of ACS and reductions in time-to-treatment parameters [12].

Based on data from the ABS, the risk of CHD mortality in Victoria has decreased steadily over the period from 2014 to 2018 (Table 1). Notably, the clinical management of CHD has also evolved over time. This may in part be attributed to ongoing benchmarking and feedback through VCOR. First, in the period since VCOR was established, implementation of PCI via radial access (instead of femoral access) has improved considerably [6]. A Cochrane review of PCI via radial versus femoral access concluded that radial access was associated with reductions in major bleeding events, access site complications and mortality in the setting of ACS [23]. This is supported by data from cardiac registries in the US, UK and Australia; importantly, a propensity-score matched analysis of radial versus femoral access using VCOR data found that mortality benefits attributed to radial access were maintained over time and for patients with high-acuity (STEMI) and non-ACS indications for PCI [24-27]. Secondly, in addition to improved uptake of radial access PCI, hospital adherence to a door-to-balloon/device time (DBDT) has improved, with all PCI-capable hospitals across Victoria achieving a median DBDT of ≤ 90 minutes for STEMI patients [6]. As with improved uptake of radial access, improved hospital adherence to a DBDT ≤ 90 minutes is associated with considerable survival benefits for STEMI patients [28]. However, it is not possible to quantify the direct contribution of VCOR to the uptake of radial access PCI and improvements to DBDT, and the subsequent reduction in mortality trends downstream. As such, our model estimated the minimum contribution of VCOR to temporal trends in CHD mortality required for VCOR to be considered cost-effective. In brief, the assumed contribution of VCOR to the proportional change in CHD mortality was varied in increments of 0.025% until the incremental cost-effectiveness ratio (ICER) for VCOR versus No VCOR was cost-effective.

Cost inputs

Table 1 summarises the cost inputs used in the economic model. All costs were updated to 2021 values using the Australian Health Price Index and were expressed as AU$ [29].

Cost of VCOR

VCOR is funded through the Victorian Department of Health, Medibank Private and in-kind funding through Monash University [6]. Based on the VCOR annual report for 2018, the average annual cost borne by the Victorian Department of Health was $605,346 for the period from 2014 to 2018 (see Supplemental Table 3) [30]. We therefore assumed the annual cost of registry operation to be $600,000; this was varied in scenario analyses (see below).

Cost of mortality

There was an absence of relevant data pertaining to the costs of death. As per previous analyses [12 31 32], 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 4) [33]. This method has been used in similar economic evaluations [12 31 32]. 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 values [34].

Discounting

A discount rate of 5% per annum was applied to years of life lived and costs incurred beyond the first year [22].

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 No VCOR were aggregated to represent the clinical and cost impacts of VCOR over five years for the total Victorian population at risk of mortality from CHD.

The primary cost-benefit analysis estimated differences between the two groups regarding net societal costs. This was defined as the cost of VCOR operation, minus the cost savings attributed to reduced CHD mortality, added to the costs saved by prolonging years of life lived in the cohort. The primary outcome was the net cost attributed to VCOR operation. A key secondary outcome for our study was the ICER for VCOR compared with No VCOR in terms of cost per YoLS.

Statistical analyses

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

To explore changes in clinical practice over time, the population was stratified by sex and indication for PCI: non-ACS reasons, unstable angina, non-ST elevation myocardial infarction (NSTEMI) and ST elevation myocardial infarction (STEMI). Backward stepwise logistic regression with a P-value threshold of 0.10 was used to identify the following potential confounders of radial access, and DBDT ≤ 90 minutes: age (< 75 years and ≥ 75 years); in-hours hospital arrival (between 08:00 to 18:00 on a workday); cardiogenic shock or intubated out-of-hospital cardiac arrest (OHCA); left ventricular ejection fraction (LVEF); medicated diabetes mellitus; peripheral vascular disease; cerebrovascular disease; chronic oral anticoagulation therapy; prior coronary artery bypass grafting; previous PCI; use of glycoprotein IIb/IIIa inhibitors; use of thienopyridine or ticagrelor; estimated glomerular filtration rate (eGFR); required mechanical ventricular support; lesion complexity (American College of Cardiology/American Heart Association type A/B1 versus type B2/C lesions); unprotected left main PCI; chronic total occlusion PCI and in-stent restenosis PCI [35 36]. Multivariable logistic regression models with adjustment for key predictors identified in stepwise regression were used to explore annual trends in radial access and DBDT metrics. The results of these analyses were used to justify the assumption that VCOR is likely to contribute to small reductions in CHD mortality over time.

To explore trends in CHD mortality over time using mortality data from the ABS, simple linear regression modelling was performed with the year as the independent variable, and

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

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

Sensitivity analyses

A series of one-way sensitivity analyses were undertaken to determine the impact of uncertainty around key model parameters. Input parameters were varied individually in deterministic sensitivity analyses, while other variables were maintained at base case values to estimate the impact of parameters on cost-benefit/effectiveness. Key parameters assessed were the time horizon, the assumed contribution of VCOR to CHD mortality trends, costs assumed for CHD mortality, and the VoSLY. Additionally, a scenario analysis was performed, whereby the proportional contribution of VCOR to temporal trends in CHD mortality was assumed to be equivalent to the mortality benefit attributed to ANZACS-QI. Based on the assumed contribution of 15% to the observed temporal trend in MI-related mortality, ANZACS-QI prevented 36 MI-related deaths over a four-year period in the total New Zealand ACS population (N = 59,280) [12]. Upon extrapolation of this benefit to the wider population at risk of CHD mortality in Victoria (N = 4,017,397), the assumed contribution to the temporal reduction in CHD mortality was set to 0.5% for VCOR in this scenario analysis.

A probabilistic sensitivity analysis (PSA) was undertaken using 10,000 iterations to assess uncertainty in the model input parameters simultaneously. The input parameters, variations and corresponding distributions are presented in Table 1. As variance in mortality rates and costs were not available, methodology employed by Briggs *et al* was applied [19]. CHD mortality rates assumed uniform distributions (applying 20% variance from the input

variable), while gamma distributions were applied to costs (where the variance was equal to the mean/input value).

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 5 and 6).

The cohort was predominately male (77%), overweight or obese (76.2%) undergoing PCI for ACS (50.9%) in public hospitals (63.2%).

The results of multivariable modelling on changes in radial access and DBDT over time are presented in Supplemental Table 7.

The likelihood of patients managed through femoral access decreased annually across all non-ACS and ACS indications for PCI ($P<0.001$). 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 ($P<0.05$).

Economic analysis of the total Victorian population

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

The minimum proportional change in CHD mortality attributed to VCOR required for the registry to be considered cost-effective was 0.125% (see Figure 1). Table 2 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 at this level of registry contribution (0.125%) to CHD mortality trends.

Table 2: Results of the base case economic model, assuming that VCOR contributed to 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)		

CHD = coronary heart disease; CI = confidence interval; 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%

† Estimated from PSA

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

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

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

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

ANZACS-QI = All New Zealand Acute Coronary Syndrome Quality Improvement programme; 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 represented a positive ROI. The results of the additional PSA are presented in Figure 2 below.

Based on the results of the PSA, the majority (97.5%) of iterations fell below an ICER of $60,000 per YoLS.

Discussion

Our economic evaluation found that the minimum contribution to the proportional change in CHD mortality over time required for VCOR to be cost-effective was 0.125%. That is, for VCOR to be considered cost-effective from the perspective of the Australian health care system, the registry would need to prevent 23 CHD-related deaths between 2014 to 2018 (five years inclusive), through benchmarking and health systems quality improvement. In lieu of data pertaining to the direct impacts of VCOR operation on CHD mortality, our analyses suggest that VCOR is likely to be cost-effective on the basis of the comparatively small CHD mortality benefits (23 deaths over five years) required for the registry to fall within the widely-established willingness-to-pay threshold of $50,000 per YoLS [22]. Since the establishment of VCOR, there has been a considerable increase in hospital uptake of PCI via radial access [37 38]. Furthermore, the likelihood of STEMI patients being managed with timely reperfusion had increased annually throughout the period of 2014-2018 [37 38]. These trends in improved patient management are facilitated through VCOR benchmarking and health systems feedback, and are likely to contribute to the reduction in cardiac mortality observed across Victoria [6 24 39]. Lastly, data from VCOR has informed research exploring disparities in

the management of ACS to further drive improvements in cardiac care and subsequently, reduce CHD mortality across Victoria [40 41].

Our findings are in accordance with similar economic evaluations previously conducted in Australia and New Zealand [12 42]. The ROI estimated for five CQRs in Australia varied from 2.0 to 7.0 based on improvements in key performance indicators (KPIs) unique to each registry [42]. Similarly, a cost-effectiveness analysis of the ANZACS-QI program found a positive ROI (1.53) over one year of evaluation, which improved considerably after expanding the time horizon to five years (7.49) [12]. The collection of data by ANZACS-QI has been used for addressing sub-optimal adherence to guidelines in the management of ACS identified across New Zealand district health boards. In evaluating the cost-effectiveness and ROI attributed to ANZACS-QI, improvements in KPIs contributed to reductions in patient mortality and readmissions observed over the period of evaluation (2013 to 2016), and the registry was both cost-effective and represented a sound investment for the New Zealand health care system [12 43].

Additionally, there is considerable evidence of improved patient outcomes as a result of interventions attributed to cardiac CQR benchmarking and health systems feedback in the UK and Sweden [15 44 45]. Data collected by the British Cardiovascular Intervention Society (BCIS) was of considerable utility for informing clinical practice in the setting of PCI, allowing for the identification of variable uptake in radial access across hospitals, delays in PCI for NSTEMI patients, and a low rate of same-day discharge for patients undergoing elective PCI [44]. Changes to these parameters are likely to improve patient outcomes and efficiency in the delivery of health services for cardiac care [23 39 46]. Similarly, mortality from CHD in Sweden declined considerably between 1995 and 2014 due to changes in the evidence-based management of NSTEMI and STEMI based on data collected as part of the Swedish Web-system for Enhancement and Development of Evidence-based care in Heart disease

Evaluated According to Recommended Therapies (SWEDEHEART) CQR [15 45]. Such changes have been facilitated through ongoing quality improvement and benchmarking through SWEDEHEART and other, well-established CQRs [15 45].

In Australia alone, several cardiac CQRs have been established across a variety of settings. These include condition-specific registries, such as the Australian Resuscitation Outcomes Consortium (AUS-ROC) for out-of-hospital cardiac arrest, and the Australian and New Zealand Society of Cardiac and Thoracic Surgeons Database Program (ANZSCTS) as well as VCOR, a cardiac devices or procedures-focused registry [47]. The considerable VoSLY assumed in our methodology, coupled with the high mortality burden of cardiovascular diseases globally, is likely to offset the substantial costs attributed to establishing and maintaining cardiac CQRs. Our findings set precedence for similar evaluations to be performed internationally to support CQR uptake and investment, and emphasises the importance of registry development in consideration of KPIs which contribute to improved patient outcomes and ultimately, ROI [47].

Limitations

A key limitation to our analysis was the uncertainty around the clinical benefit conferred by VCOR with respect to the observed trend in mortality. Hence, we explored the minimum contribution to temporal reductions in CHD mortality required for VCOR to be cost-effective, based on the assumption that registry benchmarking and feedback contribute to a small proportion of temporal reductions in CHD mortality. Importantly, in scenario analyses whereby the benefit of VCOR was lowered from an already small value, the ICER increased slightly ($49,616 per YoLS to $62,521 per YoLS) and was still associated with positive ROI. Furthermore, 97.5% of iterated ICERs in the PSA fell below $60,000 per YoLS; while no

formally published value for cost-effectiveness has been established in Australia, the Choosing Interventions that are Cost-Effective (CHOICE) programme of the World Health Organisation (WHO) defines interventions with a cost per quality-adjusted life year (QALY) or YoLS less than one gross domestic product (GDP) per capita as 'very cost-effective' [48]. As the current GDP per capita in Australia is AU$89,743 (or US dollars (US$) 61,977 assuming 1 US$ = 1.45 AU$ in 2021), our analyses demonstrate that VCOR is likely to be very cost-effective [48-50]. Secondly, it was not possible to assess the impact of VCOR on readmissions for recurrent ACS, and on patient morbidity and quality-of-life through ABS data. Hence, our analyses were limited to capturing the mortality benefit attributed to VCOR. However, KPIs pertaining to patient morbidity, including major adverse cardiac and cerebrovascular events, hospital length-of-stay and in-hospital unplanned revascularisation, had remained stable and were relatively low throughout the period of evaluation [37 51]. Readmissions for ACS in Victoria had also remained stable over time [6 52]. Therefore, incorporating the potential cost and clinical impacts attributed to other trends in clinical practice or the reporting of KPIs outside of DBDT for STEMI patients by VCOR, would not have changed our findings in a substantial manner. Additionally, there is a lack of robust data pertaining to quality-of-life following ACS in Australia which limited analyses on the impact of VCOR on patient morbidity [53]. Thirdly, cost inputs for patient mortality were based on DRG estimates that were constant across age, sex, and ACS indications. This was in lieu of robust, bottom-up cost data [12 31 54]. However, sensitivity analyses found that the economic model was robust to the costs of hospitalisations.

Conclusion

VCOR represents a sound investment for the Victorian health care system. Based on the assumption that VCOR benchmarking and feedback contributed to a small proportion of the observed reduction in CHD mortality over time, the registry is associated with cost savings at the societal level. Additionally, VCOR is cost-effective from the perspective of the healthcare system.

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Author Contributions: PL and DL had full access to all of the data in this study and take responsibility for the integrity of the data and accuracy of the data analysis. PL, EZ and DL were responsible for the study concept and design, the acquisition, analysis and interpretation of data and drafting of the manuscript. PL, ALB, DS, DD, JL, CMR, EZ, and DL made significant contribution to drafting the work, or revising it critically for intellectual content. PL, ALB, DS, DD, JL, CMR, EZ, and DL provided final approval of the version to be published. PL is the guarantor of this paper.

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Ethics approval:

This study received ethical approval from Monash University Human Research Ethics Committee (13882).

Data availability statement:

All data are incorporated into the article and its online supplementary material.

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Figure Legends

Figure 1: Relative contribution of VCOR to CHD mortality trends versus VCOR cost-effectiveness

ICER = incremental cost-effectiveness ratio; YoLS = year of life saved

Figure 2: Results of the probabilistic sensitivity analysis

$AU = Australian dollars; YoLS = year of life saved

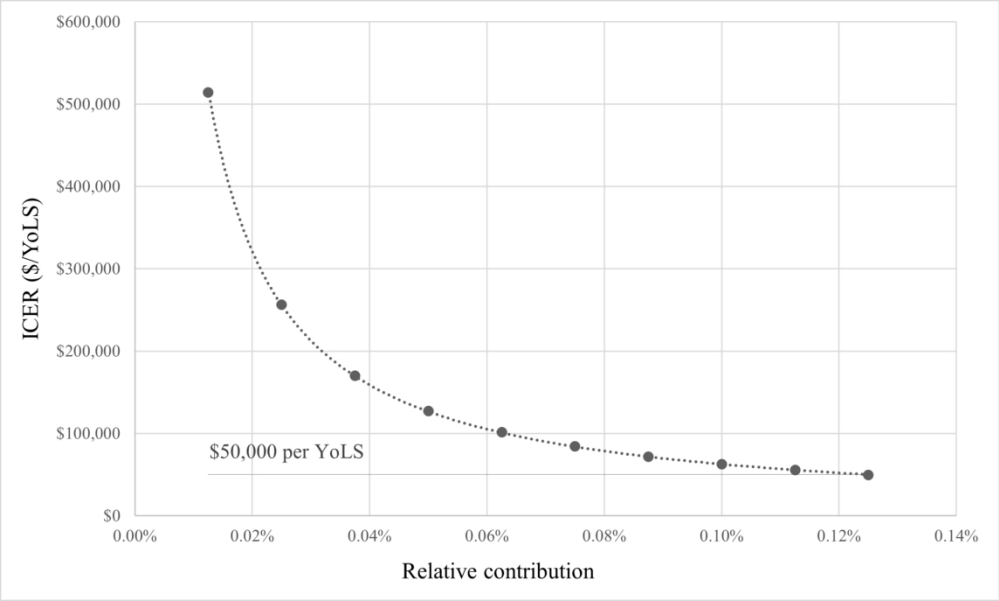

Figure 1: Relative contribution of VCOR to CHD mortality trends versus VCOR cost-effectiveness
ICER = incremental cost-effectiveness ratio; YoLS = year of life saved

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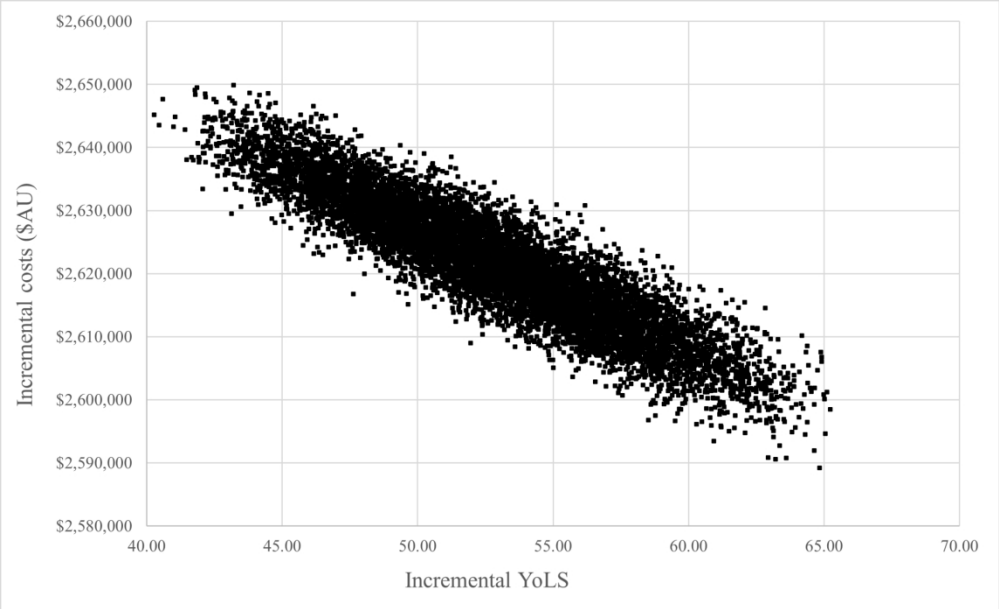


Figure 2: Results of the probabilistic sensitivity analysis
$AU = Australian dollars; YoLS = year of life saved

187x114mm (300 x 300 DPI)

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%	0.09%	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%
	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%	1.74%	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

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					
		2014	2015	2016	2017	2018	P-value*
	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 BYPSS+INV INVES, MAJC	602	$72,146
	F05B	CRNRY BYPSS+INV INVES, MINC	1,010	$51,816
	F06A	CRNRY BYPSS-INV INVES, MAJC	831	$62,580
	F06B	CRNRY BYPSS-INV INVES, INTC	1,683	$44,195
	F06C	CRNRY BYPSS-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

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

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/m2)	37 (0.5%)	40 (0.5%)	72 (0.9%)	59 (0.7%)	208 (0.7%)	
Normal (18.5 -24.9 kg/m2)	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/m2)	2,882 (41.1%)	3,014 (39.3%)	3,335 (39.6%)	3,596 (39.5%)	12,827 (39.8%)	
Obese (≥30 kg/m2)	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 Mean (SD)	91.85 (37.11)	92.21 (37.78)	91.80 (38.61)	90.42 (38.04)	91.53 (37.9)	0.011

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 (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%)	
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.

[a] P-value for year-to-year trend

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)	915 (13.1%)	853 (11.1%)	768 (9.1%)	737 (8.1%)	3,273 (10.2%)	<0.001
Glycoprotein IIb/IIIa inhibitor	5,843 (83.4%)	6,240 (81.5%)	6,729 (80.0%)	7,113 (78.1%)	25,925 (80.5%)	
Thienopyridine or Ticagrelor	5,751 (82.3%)	6,754 (88.5%)	7,707 (91.9%)	8,666 (95.3%)	28,878 (90.0%)	
Aspirin	6,057 (87.5%)	6,815 (90.3%)	7,452 (89.2%)	8,389 (92.2%)	28,713 (90.1 %)	
Antithrombin						
Lesion characteristics						

Multi-lesion disease, n (%N)	1,275 (18.2%)	1,557 (20.3%)	1,714 (20.4%)	2,001 (22.8%)	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 (89.3%)	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[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 (91.0%)	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
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

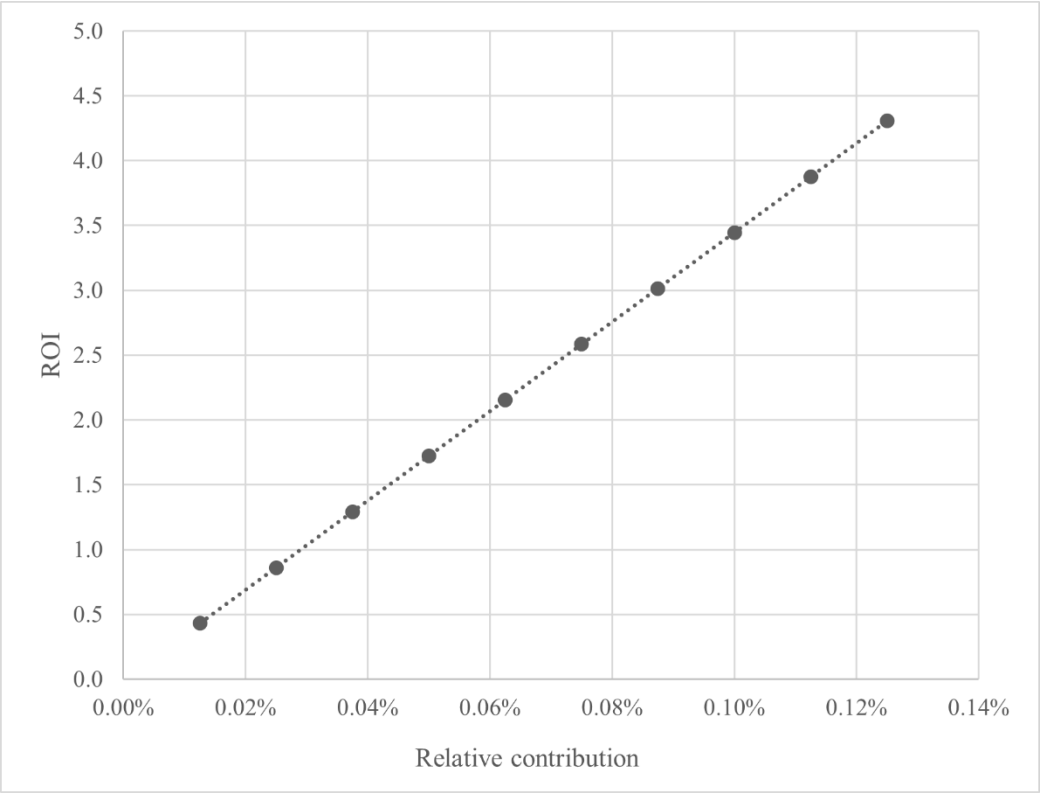
Parameter	OR (95% CI)*	P-value
Likelihood of Femoral Access		
STEMI		
Males	0.65 (0.62 0.69)	<0.001
Females	0.73 (0.66 0.82)	<0.001
NSTEMI		
Males	0.70 (0.66 0.74)	<0.001
Females	0.74 (0.67 0.81)	<0.001
UA		
Males	0.72 (0.65 0.80)	<0.001
Females	0.73 (0.63 0.85)	<0.001
Non-ACS		
Males	0.72 (0.70 0.75)	<0.001
Females	0.74 (0.70 0.80)	<0.001
Likelihood of DBDT ≤ 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

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

Running title: An economic evaluation of VCOR

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Abstract

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

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 a five-year period (2014 to 2018) were compared to deaths and costs arising from a hypothetical situation which assumed that VCOR did not exist. Data from the Australian Bureau of Statistics and published sources were used to construct a decision analytic life table model to simulate the follow-up of Victorians aged ≥25 years for five years, or until death. The assumed contribution of VCOR to the proportional change in CHD mortality trend observed over the study period was varied to quantify the minimum level of clinical benefits required for the registry to be cost-effective. 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 The minimum proportional change in CHD mortality attributed to VCOR required for the registry to be considered cost-effective was 0.125%. Assuming this clinical benefit, a net return of $4.30 for every dollar invested in VCOR was estimated (ROI ratio over five years: 4.3 (95% confidence interval (CI): 3.6 – 5.0). The ICER estimated for VCOR was $49,616 (95% CI: $42,228 – $59,608) per YoLS. Sensitivity analyses found that the model was sensitive to the time horizon assumed and the extent of registry contribution to CHD mortality trends.

Conclusions

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

Key words: Cost-effectiveness; acute coronary syndrome; cardiovascular disease; clinical quality registries; quality improvement.

Article summary

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 2020-2021, the prevalence of CHD in Australia was estimated to be 3% (571,000) of the adult population [1]. Although mortality from CHD has declined significantly since the 1960s, it remains the leading cause of death (approximately 10%) in Australia [1 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 2020-2021, 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, 48,034 PCIs were performed between 2020-2021[1]; in Victoria alone, 48% of all PCIs across Victoria in 2021 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 $2.35 billion Australian Dollars (AU$) in health expenditure in Australia, representing 2% of total health expenditure [7]. 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. In Victoria alone, the cost burden attributed to PCIs across public hospitals was estimated to be $72,179,656 in 2017 [9]. Importantly, increasing PCI case complexity and procedural volume over time warrants greater adherence to evidence-based

guidelines for the management of ACS to improve health systems efficiency and patient outcomes [9].

Clinical quality registries (CQRs) are increasingly utilised to improve health care processes and adherence to evidence-based guidelines and standards, and reduce the costs attributed to care delivery [10-13]. Through the collection of patient outcomes data for cardiovascular procedures, it is possible to benchmark a hospitals' performance to its peers and adherence to national standards of care and evidence-based guidelines [10]. Additionally, CQRs have significant utility in medical research [10-12]. Previous studies have demonstrated that major improvements to patient outcomes may be attributed to the existence of CQRs [10]. In the context of ACS, patient outcomes have improved considerably over time following the establishment of cardiac CQRs in Sweden, New Zealand, the US and the UK which have been attributed, in part, to registry operation [14-18]. However, although there are many studies utilising data from CQRs, few have assessed the clinical and cost impacts attributed to a CQR [11]. This is likely due to difficulties in distinguishing the extent of contribution of CQRs to improved patient outcomes over time versus secular trends in patient management, and in the nomination of an appropriate comparator arm to assess the true costs and benefits attributed to registry operation [11]. In this context, we explored the minimum level of contribution to improved patient outcomes required for the Victorian Cardiac Outcomes Registry (VCOR), a cardiac CQR, to be cost-effective and represent a sound investment for the health care system.

Methods

Model structure

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

The clinical and cost outputs for each model were totalled to determine the overall cost-effectiveness attributed to VCOR from the perspective of the Australian health care system, assuming a cost-effectiveness threshold of $50,000 per year of life saved (YoLS). The commonly used willingness-to-pay threshold of $50,000 per YoLS gained in determining cost-effectiveness [22] was used in lieu of an official willingness to pay threshold in Australia. We also explored the return-on-investment (ROI) attributed to the registry from a societal perspective.

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) [20 21]. 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 International Classification of Diseases version 10 (ICD-10) codes: 120 – I25), were sourced for each age and sex subgroup from the ABS [20 21] (Table 1 and Supplemental Tables 1 and 2).

Table 1: Input parameters used in the economic model, including trends in CHD mortality over time, costs and the assumed 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 (±20%)
25 - 34	0.00% – 0.00%	0.382	0.00% – 0.00%	0.257	
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 (α = 5,609; β =

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

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

* Based on simple linear regression analyses

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

The likelihood of all-cause or CHD mortality was estimated by dividing the number of deaths (all-cause or CHD-related) in each sex and age subgroup by the Victorian population for each subgroup [20 21]. The likelihood of non-CHD mortality was estimated by subtracting the likelihood of CHD mortality from the likelihood of all-cause mortality [20 21].

Effectiveness of VCOR

VCOR is a state-wide, ongoing population based CQR. It was established in 2012 to monitor the performance of cardiac services in hospitals across Victoria [13 23]. The key focus of VCOR currently is on patients undergoing PCI and cardiac implanted electronic devices [13 23]. The economic evaluation was based on estimating the downstream clinical and cost impacts of VCOR relative to a hypothetical scenario in which VCOR did not exist (No VCOR). That is, without VCOR contributing to reductions in CHD mortality over time, the extent to which CHD mortality declined over time would be less. In the absence of efficacy data, the assumed contribution of VCOR to reductions in CHD mortality over time was varied in the economic model to establish the minimum contribution required for VCOR to be cost-effective. This is justified based on current literature demonstrating that the registry data collection for the purposes of routine health systems benchmarking and feedback is, of itself, likely to contribute to reductions in mortality over time through improvements in clinical practice [10 12]. A similar approach whereby the benefits of the All New Zealand Quality Improvement (ANZACS-QI) Programme, a cardiac CQR, was assumed to contribute to temporal trends in patient mortality has been published elsewhere [12]. In brief, this evaluation assumed that the registry contributed to 15% of temporal trends in myocardial infarction (MI)-related mortality

and readmissions, based on improved adherence to medications indicated for the secondary prevention of ACS and reductions in time-to-treatment parameters [12].

Based on data from the ABS, the risk of CHD mortality in Victoria has decreased steadily over the period from 2014 to 2018 (Table 1). Notably, the clinical management of CHD has also evolved over time. This may in part be attributed to ongoing benchmarking and feedback through VCOR. First, in the period since VCOR was established, implementation of PCI via radial access (instead of femoral access) has improved considerably [23]. A Cochrane review of PCI via radial versus femoral access concluded that radial access was associated with reductions in major bleeding events, access site complications and mortality in the setting of ACS [24]. This is supported by data from cardiac registries in the US, UK and Australia; importantly, a propensity-score matched analysis of radial versus femoral access using VCOR data found that mortality benefits attributed to radial access were maintained over time and for patients with high-acuity (STEMI) and non-ACS indications for PCI [25-28]. Secondly, in addition to improved uptake of radial access PCI, hospital adherence to a door-to-balloon/device time (DBDT) has improved, with all PCI-capable hospitals across Victoria achieving a median DBDT of ≤ 90 minutes for STEMI patients [23]. As with improved uptake of radial access, improved hospital adherence to a DBDT ≤ 90 minutes is associated with considerable survival benefits for STEMI patients [29]. However, it is not possible to quantify the direct contribution of VCOR to the uptake of radial access PCI and improvements to DBDT, and the subsequent reduction in mortality trends downstream. As such, our model estimated the minimum contribution of VCOR to temporal trends in CHD mortality required for VCOR to be considered cost-effective. In brief, the assumed contribution of VCOR to the proportional change in CHD mortality was varied in increments of 0.025% until the incremental cost-effectiveness ratio (ICER) for VCOR versus No VCOR was cost-effective.

Cost inputs

Table 1 summarises the cost inputs used in the economic model. All costs were updated to 2021 values using the Australian Health Price Index and were expressed as AU$ [30].

Cost of VCOR

VCOR is funded through the Victorian Department of Health, Medibank Private and in-kind funding through Monash University [23]. Based on the VCOR annual report for 2018, the average annual cost borne by the Victorian Department of Health was $605,346 for the period from 2014 to 2018 (see Supplemental Table 3) [31]. We therefore assumed the annual cost of registry operation to be $600,000; this was varied in scenario analyses (see below).

Cost of mortality

There was an absence of relevant data pertaining to the costs of death. As per previous analyses [12 32 33], 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 4) [34]. This method has been used in similar economic evaluations [12 32 33]. 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 values [35].

Discounting

A discount rate of 5% per annum was applied to years of life lived and costs incurred beyond the first year [22].

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 No VCOR were aggregated to represent the clinical and cost impacts of VCOR over five years for the total Victorian population at risk of mortality from CHD.

The primary cost-benefit analysis estimated differences between the two groups regarding net societal costs. This was defined as the cost of VCOR operation, minus the cost savings attributed to reduced CHD mortality, added to the costs saved by prolonging years of life lived in the cohort. The primary outcome was the net cost attributed to VCOR operation. A key secondary outcome for our study was the ICER for VCOR compared with No VCOR in terms of cost per YoLS.

Statistical analyses

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

To explore changes in clinical practice over time, the population was stratified by sex and indication for PCI: non-ACS reasons, unstable angina, non-ST elevation myocardial infarction (NSTEMI) and ST elevation myocardial infarction (STEMI). Backward stepwise logistic regression with a P-value threshold of 0.10 was used to identify the following potential confounders of radial access, and DBDT ≤ 90 minutes: age (< 75 years and ≥ 75 years); in-hours hospital arrival (between 08:00 to 18:00 on a workday); cardiogenic shock or intubated out-of-hospital cardiac arrest (OHCA); left ventricular ejection fraction (LVEF); medicated diabetes mellitus; peripheral vascular disease; cerebrovascular disease; chronic oral anticoagulation therapy; prior coronary artery bypass grafting; previous PCI; use of glycoprotein IIb/IIIa inhibitors; use of thienopyridine or ticagrelor; estimated glomerular filtration rate (eGFR); required mechanical ventricular support; lesion complexity (American College of Cardiology/American Heart Association type A/B1 versus type B2/C lesions); unprotected left main PCI; chronic total occlusion PCI and in-stent restenosis PCI [36 37]. Multivariable logistic regression models with adjustment for key predictors identified in stepwise regression were used to explore annual trends in radial access and DBDT metrics. The results of these analyses were used to justify the assumption that VCOR is likely to contribute to small reductions in CHD mortality over time.

To explore trends in CHD mortality over time using mortality data from the ABS, simple linear regression modelling was performed with the year as the independent variable, and

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

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

Sensitivity analyses

A series of one-way sensitivity analyses were undertaken to determine the impact of uncertainty around key model parameters. Input parameters were varied individually in deterministic sensitivity analyses, while other variables were maintained at base case values to estimate the impact of parameters on cost-benefit/effectiveness. Key parameters assessed were the time horizon, the assumed contribution of VCOR to CHD mortality trends, costs assumed for CHD mortality, and the VoSLY. Additionally, a scenario analysis was performed, whereby the proportional contribution of VCOR to temporal trends in CHD mortality was assumed to be equivalent to the mortality benefit attributed to ANZACS-QI. Based on the assumed contribution of 15% to the observed temporal trend in MI-related mortality, ANZACS-QI prevented 36 MI-related deaths over a four-year period in the total New Zealand ACS population (N = 59,280) [12]. Upon extrapolation of this benefit to the wider population at risk of CHD mortality in Victoria (N = 4,017,397), the assumed contribution to the temporal reduction in CHD mortality was set to 0.5% for VCOR in this scenario analysis.

A probabilistic sensitivity analysis (PSA) was undertaken using 10,000 iterations to assess uncertainty in the model input parameters simultaneously. The input parameters, variations and corresponding distributions are presented in Table 1. As variance in mortality rates and costs were not available, methodology employed by Briggs *et al* was applied [19]. CHD mortality rates assumed uniform distributions (applying 20% variance from the input

variable), while gamma distributions were applied to costs (where the variance was equal to the mean/input value).

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 5 and 6).

The cohort was predominately male (77.0%), overweight or obese (76.2%) undergoing PCI for ACS (50.9%) in public hospitals (63.2%).

The results of multivariable modelling on changes in radial access and DBDT over time are presented in Supplemental Table 7.

The likelihood of patients managed through femoral access decreased annually across all non-ACS and ACS indications for PCI ($P<0.001$). 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 ($P<0.05$).

Economic analysis of the total Victorian population

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

The minimum proportional change in CHD mortality attributed to VCOR required for the registry to be considered cost-effective was 0.125% (see Figure 1). Table 2 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 at this level of registry contribution (0.125%) to CHD mortality trends.

Table 2: Results of the base case economic model, assuming that VCOR contributed to 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)		

CHD = coronary heart disease; CI = confidence interval; 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%

† Estimated from PSA

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

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

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

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

ANZACS-QI = All New Zealand Acute Coronary Syndrome Quality Improvement programme; 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 represented a positive ROI. The results of the additional PSA are presented in Figure 2 below.

Based on the results of the PSA, the majority (97.5%) of iterations fell below an ICER of $60,000 per YoLS.

Discussion

Our economic evaluation found that the minimum contribution to the proportional change in CHD mortality over time required for VCOR to be cost-effective was 0.125%. That is, for VCOR to be considered cost-effective from the perspective of the Australian health care system, the registry would need to prevent 23 CHD-related deaths between 2014 to 2018 (five years inclusive), through benchmarking and health systems quality improvement. In lieu of data pertaining to the direct impacts of VCOR operation on CHD mortality, our analyses suggest that VCOR is likely to be cost-effective on the basis of the comparatively small CHD mortality benefits (23 deaths over five years) required for the registry to fall within the widely-established willingness-to-pay threshold of $50,000 per YoLS [22]. Since the establishment of VCOR, there has been a considerable increase in hospital uptake of PCI via radial access [6 38]. Furthermore, the likelihood of STEMI patients being managed with timely reperfusion had increased annually throughout the period of 2014-2018 [6 38]. These trends in improved patient management are facilitated through VCOR benchmarking and health systems feedback and are likely to contribute to the reduction in cardiac mortality observed across Victoria [23 25 39]. Lastly, data from VCOR has informed research exploring disparities in

the management of ACS to further drive improvements in cardiac care and subsequently, reduce CHD mortality across Victoria [40 41].

Our findings are in accordance with similar economic evaluations previously conducted in Australia and New Zealand [12 42]. The ROI estimated for five CQRs in Australia varied from 2.0 to 7.0 based on improvements in key performance indicators (KPIs) unique to each registry [42]. Similarly, a cost-effectiveness analysis of the ANZACS-QI program found a positive ROI (1.53) over one year of evaluation, which improved considerably after expanding the time horizon to five years (7.49) [12]. The collection of data by ANZACS-QI has been used for addressing sub-optimal adherence to guidelines in the management of ACS identified across New Zealand district health boards. In evaluating the cost-effectiveness and ROI attributed to ANZACS-QI, improvements in KPIs contributed to reductions in patient mortality and readmissions observed over the period of evaluation (2013 to 2016), and the registry was both cost-effective and represented a sound investment for the New Zealand health care system [12 43].

Additionally, there is considerable evidence of improved patient outcomes as a result of interventions attributed to cardiac CQR benchmarking and health systems feedback in the UK and Sweden [15 44 45]. Data collected by the British Cardiovascular Intervention Society (BCIS) was of considerable utility for informing clinical practice in the setting of PCI, allowing for the identification of variable uptake in radial access across hospitals, delays in PCI for NSTEMI patients, and a low rate of same-day discharge for patients undergoing elective PCI [44]. Changes to these parameters are likely to improve patient outcomes and efficiency in the delivery of health services for cardiac care [24 39 46]. Similarly, mortality from CHD in Sweden declined considerably between 1995 and 2014 due to changes in the evidence-based management of NSTEMI and STEMI based on data collected as part of the Swedish Web-system for Enhancement and Development of Evidence-based care in Heart disease

Evaluated According to Recommended Therapies (SWEDEHEART) CQR [15 45]. Such changes have been facilitated through ongoing quality improvement and benchmarking through SWEDEHEART and other, well-established CQRs [15 45].

In Australia alone, several cardiac CQRs have been established across a variety of settings. These include condition-specific registries, such as the Australian Resuscitation Outcomes Consortium (AUS-ROC) for out-of-hospital cardiac arrest, and the Australian and New Zealand Society of Cardiac and Thoracic Surgeons Database Program (ANZSCTS) as well as VCOR, a cardiac devices or procedures-focused registry [47]. The considerable VoSLY assumed in our methodology, coupled with the high mortality burden of cardiovascular diseases globally, is likely to offset the substantial costs attributed to establishing and maintaining cardiac CQRs. Our findings set precedence for similar evaluations to be performed internationally to support CQR uptake and investment, and emphasises the importance of registry development in consideration of KPIs which contribute to improved patient outcomes and ultimately, ROI [47].

Limitations

A key limitation to our analysis was the uncertainty around the clinical benefit conferred by VCOR with respect to the observed trend in mortality. Hence, we explored the minimum contribution to temporal reductions in CHD mortality required for VCOR to be cost-effective, based on the assumption that registry benchmarking and feedback contribute to a small proportion of temporal reductions in CHD mortality. Importantly, in scenario analyses whereby the benefit of VCOR was lowered from an already small value, the ICER increased slightly ($49,616 per YoLS to $62,521 per YoLS) and was still associated with positive ROI. Furthermore, 97.5% of iterated ICERs in the PSA fell below $60,000 per YoLS; while no

formally published value for cost-effectiveness has been established in Australia, the Choosing Interventions that are Cost-Effective (CHOICE) programme of the World Health Organisation (WHO) defines interventions with a cost per quality-adjusted life year (QALY) or YoLS less than one gross domestic product (GDP) per capita as 'very cost-effective' [48]. As the current GDP per capita in Australia is AU$89,743 (or US dollars (US$) 61,977 assuming 1 US$ = 1.45 AU$ in 2021), our analyses demonstrate that VCOR is likely to be very cost-effective [48-50]. Secondly, it was not possible to assess the impact of VCOR on readmissions for recurrent ACS, and on patient morbidity and quality-of-life through ABS data. Hence, our analyses were limited to capturing the mortality benefit attributed to VCOR. However, KPIs pertaining to patient morbidity, including major adverse cardiac and cerebrovascular events, hospital length-of-stay and in-hospital unplanned revascularisation, had remained stable and were relatively low throughout the period of evaluation [38 51]. Readmissions for ACS in Victoria had also remained stable over time [23 52]. Therefore, incorporating the potential cost and clinical impacts attributed to other trends in clinical practice or the reporting of KPIs outside of DBDT for STEMI patients by VCOR, would not have changed our findings in a substantial manner. Additionally, there is a lack of robust data pertaining to quality-of-life following ACS in Australia which limited analyses on the impact of VCOR on patient morbidity [53]. Thirdly, cost inputs for patient mortality were based on DRG estimates that were constant across age, sex, and ACS indications. This was in lieu of robust, bottom-up cost data [12 32 54]. However, sensitivity analyses found that the economic model was robust to the costs of hospitalisations.

Conclusion

VCOR represents a sound investment for the Victorian health care system. Based on the assumption that VCOR benchmarking and feedback contributed to a small proportion of the observed reduction in CHD mortality over time, the registry is associated with cost savings at the societal level. Additionally, VCOR is cost-effective from the perspective of the healthcare system.

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Author Contributions: PL and DL had full access to all of the data in this study and take responsibility for the integrity of the data and accuracy of the data analysis. PL, EZ and DL were responsible for the study concept and design, the acquisition, analysis and interpretation of data and drafting of the manuscript. PL, ALB, DS, DD, JL, CMR, EZ, and DL made significant contribution to drafting the work, or revising it critically for intellectual content. PL, ALB, DS, DD, JL, CMR, EZ, and DL provided final approval of the version to be published. PL is the guarantor of this paper.

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Ethics approval:

This study received ethical approval from Monash University Human Research Ethics Committee (13882).

Data availability statement:

All data are incorporated into the article and its online supplementary material.

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Figure Legends

Figure 1: Relative contribution of VCOR to CHD mortality trends versus VCOR cost-effectiveness

ICER = incremental cost-effectiveness ratio; YoLS = year of life saved

Figure 2: Results of the probabilistic sensitivity analysis

$AU = Australian dollars; YoLS = year of life saved

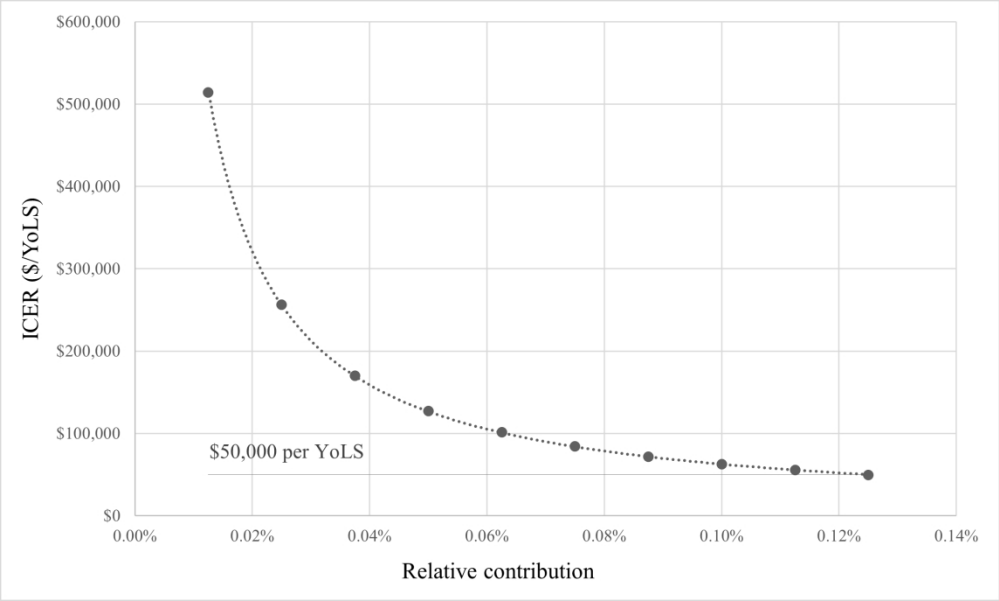


Figure 1: Relative contribution of VCOR to CHD mortality trends versus VCOR cost-effectiveness
ICER = incremental cost-effectiveness ratio; YoLS = year of life saved

185x111mm (330 x 330 DPI)

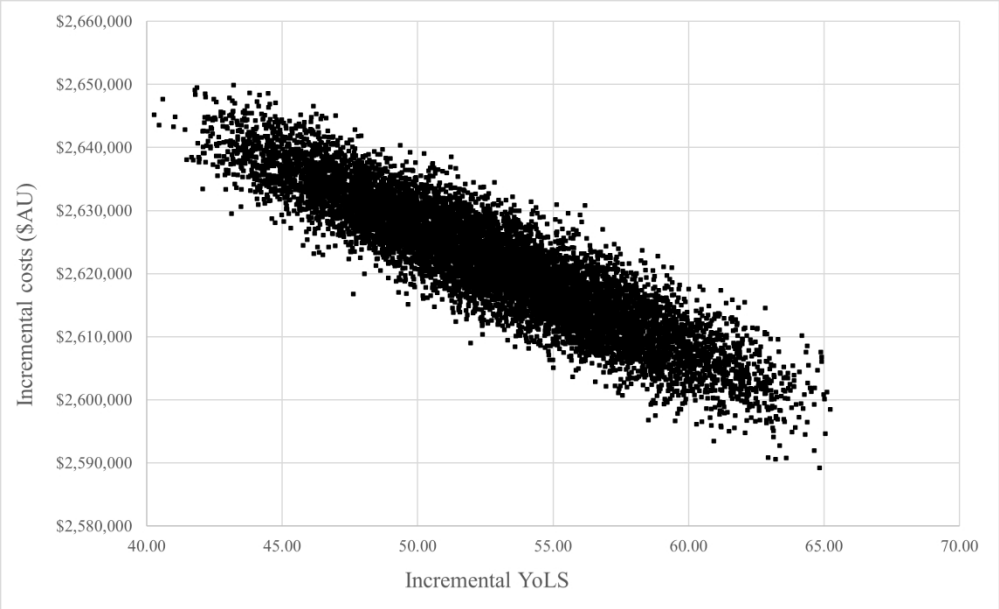


Figure 2: Results of the probabilistic sensitivity analysis
$AU = Australian dollars; YoLS = year of life saved

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%	0.08%	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%

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%	1.71%	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%
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%	0.21%	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%	1.19%	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%	0.34%	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%	2.72%	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					
		2014	2015	2016	2017	2018	P-value*
	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 BYPSS+INV INVES, MAJC	602	$72,146
	F05B	CRNRY BYPSS+INV INVES, MINC	1,010	$51,816
	F06A	CRNRY BYPSS-INV INVES, MAJC	831	$62,580
	F06B	CRNRY BYPSS-INV INVES, INTC	1,683	$44,195
	F06C	CRNRY BYPSS-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

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

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/m2)	37 (0.5%)	40 (0.5%)	72 (0.9%)	59 (0.7%)	208 (0.7%)	
Normal (18.5 -24.9 kg/m2)	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/m2)	2,882 (41.1%)	3,014 (39.3%)	3,335 (39.6%)	3,596 (39.5%)	12,827 (39.8%)	
Obese (≥30 kg/m2)	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 Mean (SD)	91.85 (37.11)	92.21 (37.78)	91.80 (38.61)	90.42 (38.04)	91.53 (37.9)	0.011

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 (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%)	
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 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 (78.1%)	25,925 (80.5%)	
Aspirin	5,751 (82.3%)	6,754 (88.5%)	7,707 (91.9%)	8,666 (95.1%)	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 (22.6%)	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 (89.3%)	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
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 (91.0%)	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
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

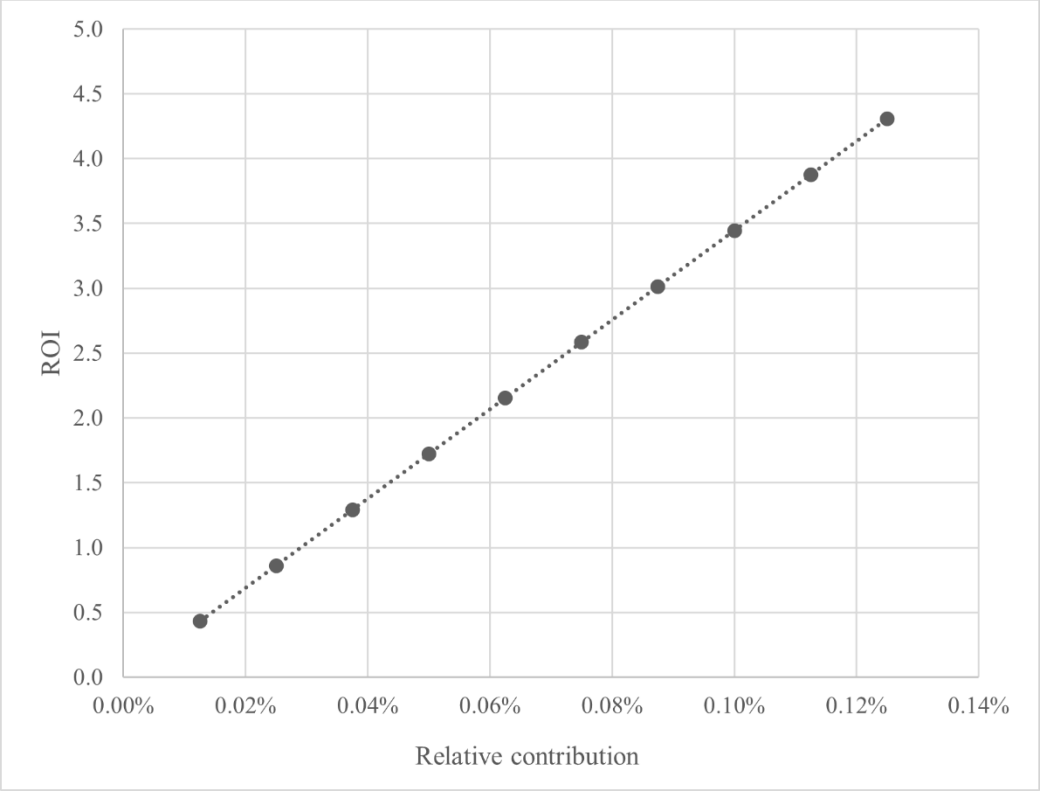
Parameter	OR (95% CI)*	P-value
Likelihood of Femoral Access		
STEMI		
Males	0.65 (0.62 0.69)	<0.001
Females	0.73 (0.66 0.82)	<0.001
NSTEMI		
Males	0.70 (0.66 0.74)	<0.001
Females	0.74 (0.67 0.81)	<0.001
UA		
Males	0.72 (0.65 0.80)	<0.001
Females	0.73 (0.63 0.85)	<0.001
Non-ACS		
Males	0.72 (0.70 0.75)	<0.001
Females	0.74 (0.70 0.80)	<0.001
Likelihood of DBDT ≤ 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

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