BMJ Open

Are sociodemographic characteristics associated with spatial variation in the incidence of OHCA and bystander CPR rates? A population-based observational study in Victoria, Australia

Lahn D Straney,[1] Janet E Bray,[1,2,3] Ben Beck,[1] Stephen Bernard,[1,3,4] Marijana Lijovic,[1,4] Karen Smith[1,4,5]

For numbered affiliations see end of article.

Correspondence to
Dr Lahn D Straney; lahn. straney@monash.edu

ABSTRACT

Background: Rates of out-of-hospital cardiac arrest (OHCA) and bystander cardiopulmonary resuscitation (CPR) have been shown to vary considerably in Victoria. We examined the extent to which this variation could be explained by the sociodemographic and population health characteristics of the region.

Methods: Using the Victorian Ambulance Cardiac Arrest Registry, we extracted OHCA cases occurring between 2011 and 2013. We restricted the calculation of bystander CPR rates to those arrests that were witnessed by a bystander. To estimate the level of variation between Victorian local government areas (LGAs), we used a two-stage modelling approach using random-effects modelling.

Results: Between 2011 and 2013, there were 15 830 adult OHCA in Victoria. Incidence rates varied across the state between 41.9 to 104.0 cases/100 000 population. The proportion of the population over 65, socioeconomic status, smoking prevalence and education level were significant predictors of incidence in the multivariable model, explaining 93.9% of the variation in incidence among LGAs. Estimates of bystander CPR rates for bystander witnessed arrests varied from 62.7% to 73.2%. Only population density was a significant predictor of rates in a multivariable model, explaining 73% of the variation in the odds of receiving bystander CPR among LGAs.

Conclusions: Our results show that the regional characteristics which underlie the variation seen in rates of bystander CPR may be region specific and may require study in smaller areas. However, characteristics associated with high incidence and low bystander CPR rates can be identified and will help to target regions and inform local interventions to increase bystander CPR rates.

Strengths and limitations of this study

- This study demonstrates that the majority of statewide spatial variation in the incidence of out-of-hospital cardiac arrest can be explained by sociodemographic factors.
- Population density was shown to be inversely associated with the probability of receiving bystander cardiopulmonary resuscitation (CPR) among witnessed arrest. The mechanisms for this are not clear and will be the subject of future research.
- Understanding the underlying characteristics of 'high-risk' (low bystander CPR and high incidence) regions will help to inform interventions designed to boost bystander CPR participation rates.

variation have revealed that regional variation also exists in OHCA incidence and bystander cardiopulmonary resuscitation (CPR) rates,[4,5] which are seen across areas as small as neighbourhoods.

For example, we recently used the Victorian Ambulance Cardiac Arrest Registry (VACAR) to map OHCA cases to census tracks, known as local government areas (LGAs), within the Australian state of Victoria.[6] This work, which included metropolitan and rural LGAs, identified a threefold difference in the incidence rate and a 25.1% absolute difference in bystander CPR rates between the highest and lowest LGAs. We also saw wide variation between neighbouring LGAs for both rates. Understanding the underlying population-based factors that drive these variations is important in explaining the variation seen in OHCA survival, and may also provide information for targeting interventions to reduce OHCA incidence and improving rates of bystander CPR.

INTRODUCTION

Out-of-hospital cardiac arrest (OHCA) survival is poor and known to vary regionally.[1] This variation is seen across countries, states and cities.[2,3] Attempts to understand this

There are currently insufficient international data to know if there are common demographics that are seen in regions with high incidence, low bystander CPR or both.[7] Data until now, predominantly from urban areas of the USA, have identified that these 'high-risk' regions tend to have specific racial compositions and lower socioeconomic factors.[8–14] It is unknown if these characteristics are seen in high-risk areas of other countries,[7] and also if these characteristics apply to regions that include rural and remote areas. The extent to which local population health data contribute has also not yet been examined. Therefore, the aim of this study is to identify population-based demographic and health factors associated with (1) high incidence and (2) low bystander CPR, and to examine the contribution of these factors to the variation seen across our region—the Australian state of Victoria.

METHODS
Study design and setting
We conducted an observational study using prospectively collected population-based OHCA data from the state of Victoria in Australia. Victoria has a current population of 5.8 million, 75% of whom reside in the metropolitan region of Melbourne. Ambulance Victoria (AV) is the sole provider of emergency medical services (EMS) in the state. AV delivers a two-tiered EMS system; Advanced Life Support Paramedics and Intensive Care Ambulance Paramedics. Firefighters and volunteer Community Emergency Response Teams provide a first response in select areas of Victoria.

The Victorian Ambulance Cardiac Arrest Registry
AV maintains the Victorian Ambulance Cardiac Arrest Registry (VACAR), which registers and collects EMS clinical and outcome data for all OHCA attended by EMS in the state of Victoria.[15] Data collection is standardised using the Utstein definitions.[16] The Victorian Department of Health Human Research Ethics Committee (HREC) has approved VACAR (No. 08/02) data collection.

Local government areas
Australia has a federal system of government under which state governments preside in each of the eight states and territories. Beneath this are local governments, for which there are 79 LGAs in the state of Victoria. The location of the arrest was linked to Victorian LGAs using the ambulance dispatch coordinates for the event (longitude and latitude).

Census data
The 2011 Census data from the Australian Bureau of Statistics[17] were used to extract characteristics for each of the 79 Victorian LGAs. Characteristics included distributions of population age, country of birth, language spoken at home and highest level of education, as well as unemployment rate and estimates of personal income. Socioeconomic advantage and disadvantage were profiled using the 2011 Socio-Economic Indexes for Areas, 'SEIFA index', for each LGA.[18] A higher SEIFA score indicates relatively higher levels of advantage and lower levels of disadvantage. Modelled estimates of potential risk factors of cardiac arrest, including the prevalence of current smokers and alcohol consumption at levels considered to be a high risk to health and obesity, were extracted from the Public Health Information Development Unit (PHIDU)[19] for each LGA. High-risk alcohol consumption was defined as the daily consumption of seven or more standard drinks for males and five or more standard drinks for females, as per the 2001 National Health and Medical Research Council Guidelines.[20] Obesity was defined as a body mass index of 30 or greater. Further information on these census data is provided elsewhere.[21]

Inclusion and exclusion criteria
The VACAR was searched and data were extracted for OHCA cases occurring between January 2011 and December 2013. To match with available population data, cases were included if they were aged >20 years and the arrest was presumed to be of cardiac aetiology based on EMS documentation (ie, no other obvious cause was recorded such as trauma, hanging, drowning, etc).

We restricted the calculation of bystander CPR rates to those arrests that were witnessed by a bystander (not a paramedic). We coded cases in which the patient received bystander chest compressions, even if 'stated as inadequate or poor', as having received bystander CPR. We defined the absence of bystander CPR as those cases that received no bystander chest compressions, or those that received ventilation only. We excluded cases that were coded as 'unknown' or 'not stated' from estimates of bystander CPR rates (n=259, 4.1%).

The Melbourne central business area was excluded from these models as the residential LGA characteristics are unlikely to appropriately describe the typical population of this region (n=188, 3.0%).

Statistical analysis
We calculated the incidence of OHCA in Victorian LGAs using yearly population data from the Australian Bureau of Statistics, and bystander CPR rates for each LGA.

In the same manner as in a previous study, hierarchical (or mixed-effects) models were used to provide shrunken estimates of LGA-level variation in the incidence of OHCA and in the rates of bystander CPR.[6] This method provides more conservative estimates of the rates where data are sparse.

The effect of the LGA is modelled as a random intercept, which is assumed to be normally distributed with a mean of zero and with a variance that can be interpreted as the degree of heterogeneity among LGAs.

Random effects were estimated for each LGA for each outcome using separate models.

Cross-sectional health and sociodemographic data were reported across all LGAs, and separately for the highest and lowest 10 LGAs for bystander CPR and OHCA incidence. We used the non-parametric equality of medians test to compare the medians between groups.

Second stage hierarchical models were used to estimate a point estimate of the proportion of variance in outcomes across LGAs which could be explained by regional sociodemographic characteristics. The variance of the random effect provides an estimate of the variation in outcomes between LGAs. An intercept-only mixed-effects Poisson regression model was used to estimate the variation in the incidence of OHCA using the count of events as the outcome and the population as the offset. LGA characteristics were entered into the model and the proportion of variance explained was calculated by dividing the difference in the random-effect variance estimates by the variance of the random effect in the intercept-only model. In a similar manner, a mixed-effects logistic regression model was used to calculate the proportion of variation in bystander CPR rates explained by LGA characteristics. Backward stepwise regression was used to select multivariable models with an exit criterion of p>0.1.

The antilog of the random effect for the incidence model provides the ratio between the mean number of events expected and the number of events predicted for the LGA. In this way, the measure provides a value interpretable as an incidence rate ratio (IRR). Maps of the measure before and after controlling for sociodemographic characteristics were used to provide a visual representation of the extent to which LGA-level variation in the incidence persists after controlling for differences in population characteristics.
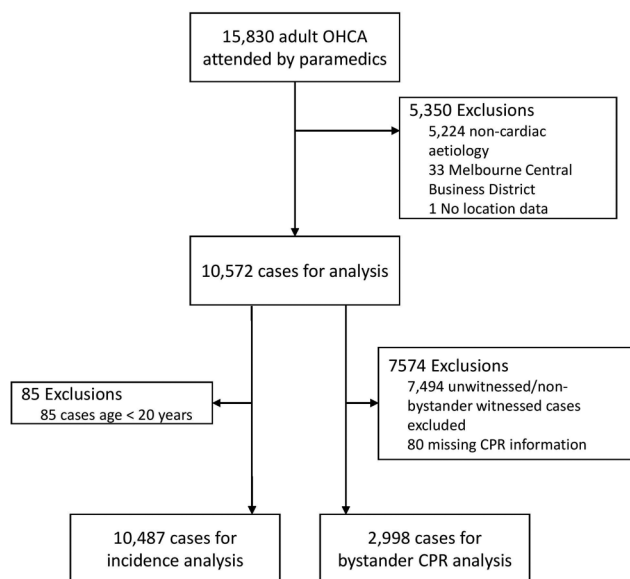

Figure 1 Patient flow chart. CPR, cardiopulmonary resuscitation; OHCA, out-of-hospital cardiac arrest.

Table 1 LGA characteristics stratified by all LGAs, and the highest 10 and lowest 10 LGAs for incidence and bystander CPR rates

LGA characteristic	All LGAs	Incidence			Bystander CPR		
		Highest 10 LGAs	Lowest 10 LGAs	p Value	Highest 10 LGAs	Lowest 10 LGAs	p Value
Population over 65 years (%)	16.4 (6.5–31.8)	22.7 (15.3–25.6)	10.6 (6.5–19.0)	<0.001	17.9 (6.8–21.3)	14.2 (9.6–17.1)	0.074
SEIFA*	980.5 (887.9–1114.3)	929.5 (887.9–959.8)	1016.6 (983.4–1114.3)	<0.001	979.0 (925.6–1046.8)	1019.4 (905.2–1073.8)	0.074
High school completion (%)	39.7 (24.3–76.1)	30.2 (27.0–35.5)	50.8 (37.7–76.1)	<0.001	38.1 (28.1–52.4)	58.2 (34.2–72.2)	<0.001
Bachelor's degree (%)	9.7 (5.1–30.4)	6.4 (5.1–8.5)	11.7 (8.9–30.3)	<0.001	8.8 (5.7–13.1)	18.4 (7.2–30.4)	0.007
Born overseas (%)	17.0 (9.7–61.9)	14.2 (11.0–20.8)	34.6 (14.4–40.0)	0.007	17.6 (11.4–38.9)	37.4 (19.4–61.9)	<0.001
Language other than English (%)	4.7 (1.5–61.2)	2.8 (1.8–6.9)	26.2 (3.2–42.7)	<0.001	4.5 (2.1–30.3)	29.4 (6.9–61.2)	<0.001
Current smokers (%)	15.4 (8.2–19.4)	17.7 (16.2–19.4)	13.3 (8.2–15.3)	<0.001	15.7 (12.5–18.6)	13.7 (9.9–18.9)	0.007
High-risk alcohol consumption (%)	2.3 (1.8–2.7)	2.6 (2.4–2.7)	2.1 (1.9–2.4)	<0.001	2.4 (2.0–2.7)	2.3 (2.0–2.5)	0.371
Obese (%)	17.6 (6.8–21.8)	20.3 (18.8–21.8)	15.3 (8.3–17.1)	<0.001	17.8 (13.2–21.2)	15.3 (9.5–19.4)	0.007
Population density (persons/km²)	25.7 (0.5–4824.5)	2.8 (0.8–51.9)	338.6 (7.2–3925.4)	<0.001	9.2 (2.1–331.0)	2214.1 (51.9–4124.9)	<0.001

Values represent median (range).
*Index of Socio-Economic Advantage and Disadvantage.
CPR, cardiopulmonary resuscitation; LGA, local government area.

Table 2 Univariable and multivariable Poisson regression models for out-of-hospital cardiac arrest incidence by LGAs in Victoria 2011–2013

	Univariable			Multivariable		
	IRR (95% CI)	p Value	Per cent of LGA variance explained	IRR (95% CI)	p Value	Per cent of LGA variance explained
Population aged over 65	1.53 (1.42 to 1.66)	<0.001	64.5	1.63 (1.54 to 1.73)	<0.001	93.9
SEIFA* (Z-score)	0.85 (0.82 to 0.90)	<0.001	41.1	0.91 (0.86 to 0.95)	<0.001	
Current smokers (per % increase)	1.86 (1.54 to 2.24)	<0.001	39.3	2.19 (1.71 to 2.80)	<0.001	
High school completion (per 10% increase)	0.91 (0.88 to 0.94)	<0.001	29.6	1.20 (1.15 to 1.24)	<0.001	
Bachelor's degree (per 10% increase)	0.87 (0.80 to 0.94)	0.001	15.3			
Born overseas (per 10% increase)	0.93 (0.89 to 0.97)	0.001	13.1			
High-risk alcohol consumption (per 1% increase)	2.57 (1.07 to 3.19)	<0.001	54.7			
Obese (per 5% increase)	1.27 (1.18 to 1.37)	<0.001	36.6			
Population density (ln(persons/km^2))	0.96 (0.94 to 0.97)	<0.001	25.5			

*Index of Socio-Economic Advantage and Disadvantage.
IRR, incident rate ratio; LGA, local government area.

RESULTS

Between 2011 and 2013, there were 15 830 adult OHCA attended by AV, of which 10 606 (67.0%) cases were of presumed cardiac aetiology. Figure 1 provides a patient flow chart. Case descriptions have been reported elsewhere.[15] The median number of OHCAs in each LGA during the study period was 259 (IQR 115–634). The LGA of Greater Geelong, South-west of Melbourne had the greatest number of OHCAs during the study period; 1308 attended cases of cardiac aetiology between 2011 and 2013.

Shrunken estimates of the (1) incidence rate among all cardiac cases and (2) rates of bystander CPR among non-paramedic witnessed arrests, have been previously reported by LGA.[6] Estimates of the incidence rate ranged from 41.9 to 104.0 cases per 100 000 population, with the highest incidence being reported in the Northern Grampians (a predominantly rural shire north-west of Melbourne) and the lowest incidence being reported in Nillumbik (a regional shire on the northern outskirts of Melbourne). The median estimated annual incidence rate among LGAs was 68.1 cases per 100 000 population (IQR 58.1–78.9).

Estimates of bystander CPR rates for non-paramedic witnessed arrests ranged from 62.7% in the inner city LGA of Yarra to 73.2% in the LGA of Wyndham (south-west of Melbourne). The median rate was 68.6% (IQR 67.4–70.0%).

Characteristics of LGAs

Table 1 details sociodemographic characteristics for Victorian LGAs. Across all Victorian LGAs, the median population density was 25.7 persons/km^2 (range 0.5–4824.5). The median proportion of the population: (1) aged over 65 was 16.4% (range 6.5–31.8%), (2) that held a bachelor's degree was 9.7% (range 5.1–30.4%), (3) that spoke a language other than English at home was 4.7% (range 1.5–61.2%; table 1).

When compared with LGAs with the lowest incidence of OHCA, LGAs with the highest incidence demonstrated greater levels of smoking, high-risk alcohol consumption, obesity and an older resident population (table 1). These LGAs also had lower socioeconomic levels (p≤0.001), lower levels of education (p≤0.001) and a lower proportion of the population born overseas (p=0.007). LGAs with the lowest rates of bystander CPR were those with greater population density, a larger proportion of the population who spoke a language other than English at home and higher high school completion levels (all p≤0.001).

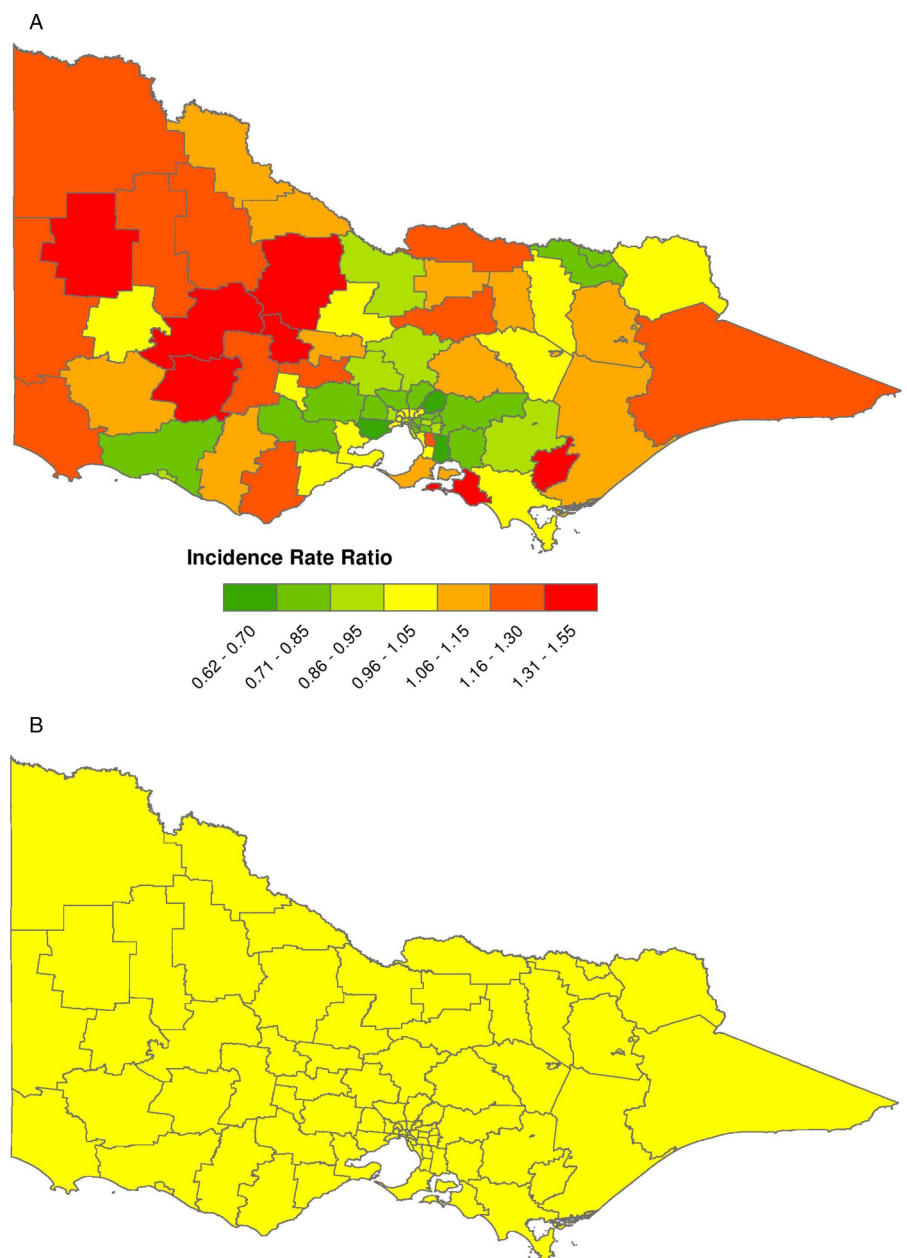### Risk and explanatory factors
Incidence of OHCA

Table 2 details the IRR for LGA characteristics on the incidence of OHCA. A higher prevalence of smoking, obesity, high alcohol consumption and an older resident population were associated with an increased incidence of OHCA in univariate models. Higher socioeconomic status, education, population density and proportion of overseas-born residents were associated with a decreased

incidence of OHCA in univariate models. The proportion of the population over 65, socioeconomic status, smoking prevalence and education remained significant predictors in the multivariable model. Collectively, these variables explained 93.9% of the variation in incidence among LGAs (figure 2). Higher levels of high school completion were protective in univariate testing but associated with an increased risk in the multivariable model. Figure 1 shows that after controlling for differences in the LGA characteristics, the variation in the incidence rate among LGAs is largely attenuated, with all LGAs reporting an IRR of between 0.95 and 1.05.

Bystander CPR

Table 3 provides the results of the logistic regression models for the relative odds of receiving bystander CPR.

Higher educational attainment, population density and the proportion of the population born overseas were significantly associated with decreased odds of receiving bystander CPR in univariate models. Obesity was associated with increased odds of receiving bystander CPR in the univariate model. Only population density remained a significant predictor when testing associations in a multivariable model. Population density explained 73% of the variation in the odds of receiving bystander CPR among LGAs (figure 3). We found that the proportion of arrests occurring in the home was not significantly associated with the odds of receiving bystander CPR.

DISCUSSION

Our results show that it is possible to identify high-risk regions for OHCA and to understand the regional

Figure 2 The estimated incidence rate ratio by Victorian local government areas for the incidence of out-of-hospital cardiac arrest 2011–2013 with (A) no adjustment for sociodemographic characteristics, and (B) adjusting for differences in age structure, prevalence of smoking, socioeconomic status and educational attainment.

Table 3 Univariable and multivariable logistic regression models for the relative odds of receiving bystander CPR following an out-of-hospital cardiac arrest in LGAs in Victoria 2011–2013

	Univariable			Multivariable		
	OR (95% CI)	p Value	Per cent of variance explained	OR (95% CI)	p Value	Per cent of variance explained
Population aged over 65	1.27 (0.99 to 1.63)	0.057				
SEIFA* (Z-score)	0.94 (0.86 to 1.04)	0.238				
Current smokers (per % increase)	1.45 (0.99 to 2.12)	0.059				
High school completion (per 10% increase)	0.87 (0.81 to 0.94)	<0.001	46.8			
Bachelor's degree (per 10% increase)	0.79 (0.69 to 0.91)	0.001	30.7			
Born overseas (per 10% increase)	0.88 (0.82 to 0.94)	<0.001	61.1			
High-risk alcohol consumption (per 1% increase)	1.30 (0.76 to 2.22)	0.333				
Obese (per 5% increase)	1.28 (1.08 to 1.51)	0.004	36.6			
Population density (ln(persons/km²))	0.91 (0.88 to 0.95)	<0.001	73.0	0.91 (0.88 to 0.95)	<0.001	73.0

*Index of Socio-Economic Advantage and Disadvantage.
CPR, cardiopulmonary resuscitation; LGA, local government area.

characteristics which underlie the variation seen in OHCA incidence and, but to a lesser extent, rates of bystander CPR.

Regional characteristics independently associated with a higher incidence of OHCA in our study were older age, lower socioeconomic status, smoking and high levels of education. Previous research has also reported a higher incidence in regions with older populations and lower socioeconomic factors, such as income,[8–14 22] but has only examined population demographics. Our study furthered this existing research by including population health data, which, when combined with the demographic data, explained almost all of the regional variation seen in OHCA incidence across our state. Not surprisingly, many of the underlying characteristics are also risk factors for cardiovascular disease, which, as a precipitating mechanism of OHCA, provides further evidence of a regional variation in risk of OHCA.[4]

We observed a complex relationship between population education levels and OHCA incidence. At the univariate level, higher education levels were associated with a decreased incidence. However, in the multivariable model, this effect was reversed. This is explained by correlations between explanatory variables, such that when we controlled for other risk factors in the multivariable model, higher education levels were associated with increased incidence of OHCA. This finding is contrary to an existing study that demonstrated no significant association between education level and OHCA incidence in univariate analyses.[23] In our region, a recent report found higher levels of education to be associated with longer times in deciding to seek medical attention following the onset of acute coronary symptoms,[24] a patient group that are most likely to experience OHCA. This factor is likely to increase the risk of experiencing an OHCA in this group and may explain some of the association between higher levels of education and increased OHCA incidence in our multivariable model.

Targeting interventions in regions with high incidence may be an effective means to reduce overall OHCA incidence, and may also improve survival as high-risk patients are likely to have worse OHCA prognosis.[4] Such regional interventions could target cardiovascular risk factors as well as elements in the chain of survival, such as automated external defibrillator placement and CPR training. Mass CPR training is no longer advocated.[25] CPR training focused on regions with low bystander CPR is considered more efficient, but may need to be tailored for each region.[7]

Higher population density was the only significant factor in the multivariable model associated with low bystander CPR in the witnessed OHCAs in our study, which included rural regions with low and very low population densities. Previous work conducted mostly in North American cities has only examined regions of moderate-to-very high population densities, and has excluded low-density regions.[11] Only two previous studies have found a similar association with population

Figure 3 The estimated relative odds of receiving bystander CPR by Victorian local government areas for bystander witnessed out-of-hospital cardiac arrests 2011–2013 with (A) no adjustment for sociodemographic characteristics, and (B) adjusting for population density. CPR, cardiopulmonary resuscitation.

A

Relative odds of receiving bystander CPR

0.77 - 0.86 | 0.87 - 0.94 | 0.95 - 0.99 | 1.00 - 1.02 | 1.03 - 1.07 | 1.08 - 1.15 | 1.16 - 1.26

B
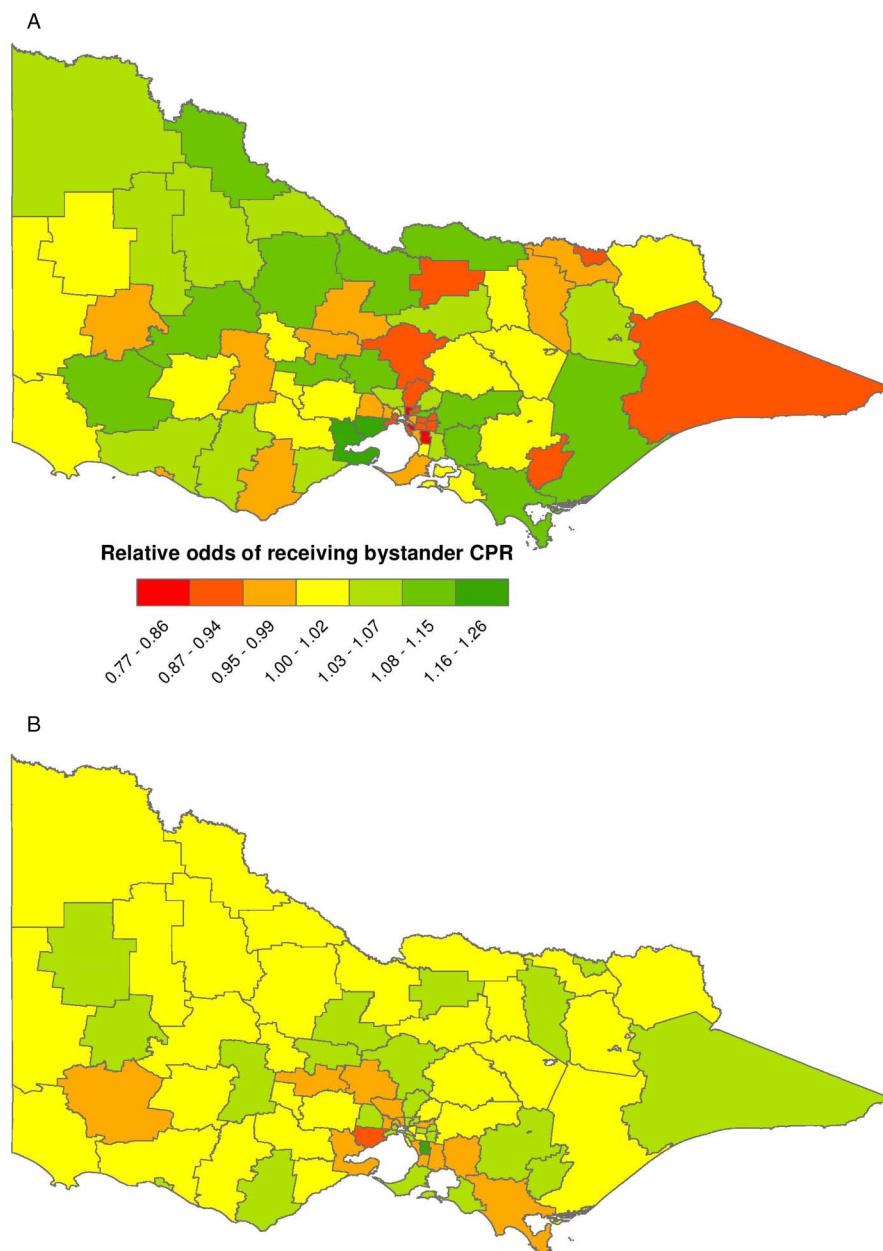
density.[12 26] These and other studies have typically found higher proportions of non-whites and low-income populations in regions with lower bystander CPR and higher OHCA incidence.[8–14] However, these previous studies also did not limit their analysis to witnessed OHCAs. We restricted our analysis of bystander CPR to bystander witnessed OHCAs to remove the confounding of regional variation in witnessed OHCAs,[12] a factor which is strongly associated with receiving bystander CPR.

Our association of lower bystander CPR and higher population density is difficult to explain, although it is consistent with a previous earlier report in our region.[3] Perhaps bystander CPR rates may need to be examined separately for metropolitan and rural regions to uncover common underlying population-based factors. However, other studies have also reported that bystander CPR variation is not completely explained by population factors.[10]

Although we observed differences in the proportion of arrests occurring in the home by population density, controlling for this did not influence our results. It is possible that high-density metropolitan regions could have lower rates of public witnessed OHCAs,[27] less social investment in their local society[28] or less CPR training.[29] It is also possible that the recognition of cardiac arrest during the call may vary regionally, as may the ability to effectively communicate in the emergency call due to language barriers. A higher proportion of people born overseas is seen in our high-density regions and this was associated with lower rates of bystander CPR at the univariate level. Listening to the emergency calls in regions with low bystander CPR rates may provide insight into the barriers in these regions and is the next planned phase of this research.

The primary limitation of this study is that the resident population may not accurately reflect the people at risk

in a given location, for example, those arresting while working or visiting a region. Although we excluded the central business area, other locations with large commercial areas may attract a sizeable working population, and thus the incidence rate may be exaggerated.

CONCLUSION

Regional characteristics associated with rates of OHCA incidence and bystander CPR participation can be identified. However, particularly for bystander CPR, these are likely to vary depending on the region covered and in some instances may be only relevant to specific communities. Education targeting regions with low bystander CPR may need to be designed and tailored for each region's characteristics and to first understand the local barriers to providing CPR.

Author affiliations
[1]Department of Epidemiology and Preventive Medicine, Monash University, Melbourne, Victoria, Australia
[2]Faculty of Health Science, Curtin University, Perth, Western Australia, Australia
[3]The Alfred Hospital Melbourne, Melbourne, Victoria, Australia
[4]Ambulance Victoria, Melbourne, Victoria, Australia
[5]Discipline—Emergency Medicine, University Western Australia, Perth, Western Australia, Australia

Twitter Follow Aus-ROC at @aus-roc

Contributors LDS prepared the analysis plan, undertook the statistical analysis, as well as drafted and revised the paper. JEB devised the study design, reviewed the analysis, as well as drafted and revised the paper. BB prepared and analysed the data, and revised the draft paper. SB reviewed the analysis and revised the draft paper. ML reviewed the analysis, and drafted and revised the paper. KS initiated the study, reviewed the analysis, as well as drafted and revised the paper.

Competing interests None declared.

Ethics approval Monash University Human Research Ethics Committee (CF12/3410–2 012001638).

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement These data were sourced from a third party as the data are maintained in an ongoing registry at Ambulance Victoria. The registry contains potentially identifiable information and thus data requests and extracts are performed with regard to the needs of individual projects to maintain confidentiality. The data used in this study are available on request to KS at Ambulance Victoria (karen.smith@ambulance.vic.gov.au).

REFERENCES

1. Berdowski J, Berg RA, Tijssen JG, *et al*. Global incidences of out-of-hospital cardiac arrest and survival rates: Systematic review of 67 prospective studies. *Resuscitation* 2010;81:1479–87.
2. Nichol G, Thomas E, Callaway CW, *et al*. Regional variation in out-of-hospital cardiac arrest incidence and outcome. *JAMA* 2008;300:1423–31.
3. Nehme Z, Andrew E, Cameron PA, *et al*. Population density predicts outcome from out-of-hospital cardiac arrest in Victoria, Australia. *Med J Aust* 2014;200:471–5.
4. Becker LB, Smith DW, Rhodes KV. Incidence of cardiac arrest: a neglected factor in evaluating survival rates. *Ann Emerg Med* 1993;22:86–91.
5. Sasson C, Keirns CC, Smith D, *et al*. Small area variations in out-of-hospital cardiac arrest: does the neighborhood matter? *Ann Intern Med* 2010;153:19–22.
6. Straney LD, Bray JE, Beck B, *et al*. Regions of high out-of-hospital cardiac arrest incidence and low bystander CPR rates in Victoria, Australia. *PLoS ONE* 2015;10:e0139776.
7. Sasson C, Meischke H, Abella BS, *et al*. Increasing cardiopulmonary resuscitation provision in communities with low bystander cardiopulmonary resuscitation rates: a science advisory from the American Heart Association for healthcare providers, policymakers, public health departments, and community leaders. *Circulation* 2013;127:1342–50.
8. Sasson C, Keirns CC, Smith DM, *et al*. Examining the contextual effects of neighborhood on out-of-hospital cardiac arrest and the provision of bystander cardiopulmonary resuscitation. *Resuscitation* 2011;82:674–9.
9. Sasson C, Magid DJ, Chan P, *et al*. Association of neighborhood characteristics with bystander-initiated CPR. *N Engl J Med* 2012;367:1607–15.
10. Root ED, Gonzales L, Persse DE, *et al*. A tale of two cities: the role of neighborhood socioeconomic status in spatial clustering of bystander CPR in Austin and Houston. *Resuscitation* 2013;84:752–9.
11. Raun LH, Jefferson LS, Persse D, *et al*. Geospatial analysis for targeting out-of-hospital cardiac arrest intervention. *Am J Prev Med* 2013;45:137–42.
12. Fosbol EL, Dupre ME, Strauss B, *et al*. Association of neighborhood characteristics with incidence of out-of-hospital cardiac arrest and rates of bystander-initiated CPR: implications for community-based education intervention. *Resuscitation* 2014;85:1512–17.
13. Semple HM, Cudnik MT, Sayre M, *et al*. Identification of high-risk communities for unattended out-of-hospital cardiac arrests using GIS. *J Community Health* 2013;38:277–84.
14. Nassel AF, Root ED, Haukoos JS, *et al*. Multiple cluster analysis for the identification of high-risk census tracts for out-of-hospital cardiac arrest (OHCA) in Denver, Colorado. *Resuscitation* 2014;85:1667–73.
15. Nehme Z, Bernard S, Cameron P, *et al*. Using a cardiac arrest registry to measure the quality of emergency medical service care: decade of findings from the Victorian Ambulance Cardiac Arrest Registry. *Circ Cardiovasc Qual Outcomes* 2015;8:56–66.
16. Perkins GD, Jacobs IG, Nadkarni VM, *et al*. Cardiac arrest and cardiopulmonary resuscitation outcome reports: update of the Utstein Resuscitation Registry templates for out-of-hospital cardiac arrest: a statement for healthcare professionals from a Task Force of the International Liaison Committee on Resuscitation (American Heart Association, European Resuscitation Council, Australian and New Zealand Council on Resuscitation, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Council of Southern Africa, Resuscitation Council of Asia); and the American Heart Association Emergency Cardiovascular Care Committee and the Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation. *Resuscitation* 2015;96:328–40.
17. Australian Bureau of Statistics. 2001.0—Census of Population and Housing: Basic Community Profile, 2011 Third Release. 2011 (cited 3 Apr 2015). http://www.abs.gov.au/AUSSTATS/abs@.nsf/productsbyCatalogue/B7AD1DB8CB27192ECA2570D90018BFB2?OpenDocument
18. Australian Bureau of Statistics. 2033.0.55.001—Census of Population and Housing: Socio-Economic Indexes for Areas (SEIFA), Australia, 2011. 2011 (cited 4 Apr 2015). http://www.abs.gov.au/ausstats/abs@.nsf/mf/2033.0.55.001
19. Public Health Information Development Unit (PHIDU). Social Health Atlas of Australia (cited 4 Jun 2015). http://www.adelaide.edu.au/phidu/maps-data/data/
20. National Health and Medical Research Council. Australian Alcohol Guidelines: Health Risks and Benefits. 2001 (cited 6 Apr 2015). https://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/ds9.pdf
21. Public Health Information Development Unit (PHIDU). Social Health Atlas of Australia: Notes on the Data. (cited 2015 Jn 4). http://www.adelaide.edu.au/phidu/current/data/sha-aust/notes/phidu_data_sources_notes.pdf

22. Warden C, Cudnik MT, Sasson C, *et al*. Poisson cluster analysis of cardiac arrest incidence in Columbus, Ohio. *Prehosp Emerg Care* 2012;16:338–46.
23. Ong ME, Earnest A, Shahidah N, *et al*. Spatial variation and geographic-demographic determinants of out-of-hospital cardiac arrests in the city-state of Singapore. *Ann Emerg Med* 2011;58:343–51.
24. Bray JE, Stub D, Ngu P, *et al*. Mass media campaigns' influence on prehospital behavior for acute coronary syndromes: an evaluation of the Australian Heart Foundation's warning signs campaign. *J Am Heart Assoc* 2015;4.
25. Vaillancourt C, Stiell IG, Wells GA. Understanding and improving low bystander CPR rates: a systematic review of the literature. *CJEM* 2008;10:51–65.
26. Ong ME, Wah W, Hsu LY, *et al*. Geographic factors are associated with increased risk for out-of hospital cardiac arrests and provision of bystander cardio-pulmonary resuscitation in Singapore. *Resuscitation* 2014;85:1153–60.
27. Jennings PA, Cameron P, Walker T, *et al*. Out-of-hospital cardiac arrest in Victoria: rural and urban outcomes. *Med J Aust* 2006;185:135–9.
28. Dixon J, Welch N. Researching the rural-metropolitan health differential using the 'social determinants of health'. *Aust J Rural Health* 2000;8:254–60.
29. Axelsson AB, Herlitz J, Holmberg S, *et al*. A nationwide survey of CPR training in Sweden: foreign born and unemployed are not reached by training programmes. *Resuscitation* 2006;70: 90–7.