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Relationship between socioeconomic factors, distribution of public access defibrillators and incidence of out-of-hospital cardiac arrest

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Abstract

Background: Survival from out-of-hospital cardiac arrest (OHCA) is improved when public access defibrillators are used. Areas of socioeconomic deprivation may have higher rates of OHCA and thus a greater demand for public access defibrillators. We aimed to determine if there was a relationship between socioeconomic factors, the geographic distribution of public access defibrillators (PADs) and incidence of OHCA.

Method: Socioeconomic deprivation data was obtained from the Census-based 2013 Index of Deprivation. Spatial information for PADs was obtained from a New Zealand PAD database (AED Locations) in 2016 and 2018. Location data for OHCA was obtained from the St John New Zealand OHCA registry for the period 1 October 2013 to 30 June 2016. Relationships between these variables were analysed using a Poisson regression analysis.

Results: Cardiac arrest incidence increased with increasing deprivation. The incidence in the most deprived areas of 156.5 events per 100,000 person years (135.4–180.9, 95% CI) is double the incidence in the least deprived areas at 78.0 events per 100,000 person years (66.4–91.7, 95% CI). Significant increases in the rates of OHCA were observed with every 1% increase in proportions of Māori (1.0%, 0.61–1.4%, 95% CI, $p = 0.001$), Pacific Peoples (0.6%, 0.21–0.9%, $p = 0.005$), >65 year olds (3.7%, 3.0–4.3%, $p < 0.001$), and males (3.7%, 1.8–5.6%, $p < 0.001$). In 2018, the decile 10 areas had the lowest coverage of PADs (65% of these areas contained a PAD) compared with less deprived areas (68–84%, median 81%).

Conclusions: The most socioeconomically deprived communities had the highest incidence of OHCA and the least availability of PADs. This provides impetus for targeted PAD placement in areas of higher deprivation.

Keywords: Automated external defibrillator (AED), Public access defibrillator (PAD), Out-of-hospital cardiac arrest (OHCA), Deprivation, Ethnicity, Resuscitation, Bystander, Defibrillation, Cardiopulmonary resuscitation

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Introduction

In New Zealand 5 people a day are treated for an out-of-hospital cardiac arrest (OHCA) with only 12% of these patients discharged from hospital and alive at thirty days.[1] Rates of survival can be much higher elsewhere, with 21% survival reported by King County in the USA in 2013.[2] These variations in survival from OHCA are not only noted internationally, but also regionally within countries.[3,4]

It is widely accepted that increased rates of bystander cardiopulmonary resuscitation (BCPR) and public access defibrillation are associated with significant increases in survival from OHCA.[5,6] There are also documented associations between geographic location, the incidence of OHCA, neighbourhood characteristics and BCPR rates.[4,7–9] Neighbourhoods with low-income have been associated not only with higher incidence of OHCA but also poorer rates of BCPR.[8–10] Once these factors or localities are identified these areas can then be targeted for programmes to increase rates of BCPR.[11]

Geospatial analyses and statistical modelling have been used to identify geographic areas for targeted placement of public access defibrillators (PADs).[12–16] However, there is a paucity of literature investigating relationships between socioeconomic factors and geospatial distribution of PADs and OHCA. In New Zealand we are uniquely placed to undertake this type of analysis: socioeconomic deprivation data are collected and measured through Census information for defined geographic localities,[17] spatial information for PADs is currently logged through the website AED Locations,[18] and geographic data on the location of OHCA incidents are collected by New Zealand's largest ambulance provider, St John, which serves 90% of the New Zealand population.[19] The objective of this study was to investigate if relationships exist between socioeconomic factors, geospatial distribution of PADs and incidence of OHCA within New Zealand.

Methods

Study design

This was a descriptive, cross-sectional, geospatial study of PAD location, OHCA incidence and population characteristics. The study was performed across the country of New Zealand, with the exclusion of the Wellington region. The Wellington region, which contains 10% of the New Zealand resident population, is excluded from this study as it is serviced by the Wellington Free Ambulance service and at the time of the study data were unavailable for this service.

The St John OHCA registry

The St John OHCA Registry contains data for all OHCA attended by New Zealand's largest emergency medical service, St John.[1] The registry covers incidents attended to within New Zealand with the exception of the Wellington region. Data collection was in accordance with the Utstein definitions.[20] Utstein variables collected in the New Zealand OHCA registry include whether an event was witnessed (EMS and/or bystander), use of a defibrillator, presenting rhythm, whether resuscitation was attempted (EMS and/or bystander) and whether return of spontaneous circulation was achieved. The geographic location of all OHCA attended by the St John ambulance service is determined via an automated vehicle location system on the locating ambulance, this system tracks the latitude and longitude location of a vehicle to the nearest 100metres. This geographic data is included within the registry.

Ethics

Ethical approval for this study was provided by the New Zealand Health and Disabilities Ethics Committee (No. HDEC 13/STH/192/AM02) and the Auckland University of Technology Ethics Committee (No. 13/367).

Census Area units

Data collected in the 2013 population Census is disseminated by Statistics New Zealand for a range of geographic areas. One of these geographic areas are termed Census Area Units (CAUs, n = 1826). These areas contain a median population of approximately 2000 people and are equivalent to a neighbourhood.[21] For the purposes of this study all data are compared at the CAU level.[17]

The NZDep2013 index of deprivation

The New Zealand 2013 Index of Deprivation (NZDep2013) is a summary score assigned to each CAU, derived from nine specific variables of the Census dataset: access to the internet, means tested benefit status, household income, number of unemployed (18–64 year olds), number of individuals with no qualifications (18–64 year olds), dwellings not owner occupied, single parent families, household occupancy and access to car.[17] The NZDep2013 index is represented as an ordinal decile scale that ranges from 1 to 10, with 1 representing the least deprived 10% of areas and 10 representing the 10% of areas that are the most deprived.[17] Area units were classified into NZDep2013 decile for analysis of OHCA events.

Population demographics

Population demographics of CAUs (ethnicity, age grouping and sex) were extracted from the 2013 New Zealand Census data. Ethnicities analysed were described as European, Māori (the indigenous population of New Zealand) and Pacific Peoples (people predominantly from South Pacific Islands including Samoan, Cook Islands Māori, Tongan and Niuean). In the New Zealand Census, individuals can identify as more than one ethnicity. In the 2013 New Zealand Census, 11.2% of respondents identified as more than one ethnicity.[22] Area units were classified by Statistics New Zealand as either main urban (population >30,000), secondary urban (10,000–29,999), minor urban (1000–9999), rural centre (300–999) or other rural area (all other units including islands and inlets).[23]

PAD locations

Locations of PADs are voluntarily registered with the AED Locations registry (https://aedlocations.co.nz/) either by the owners of the PAD or members of the public. Individual registration of a PAD is via an online portal or the GoodSAM smart phone application. The PAD locations register was established in 2010 for the purpose of communicating the locations of PADs to the public. The database is maintained by Abletech (Wellington, New Zealand).

Inclusion and exclusion criteria

Data from the St John New Zealand OHCA registry included 11537 OHCA events that were attended by St John during the period 1 October 2013 to 30 June 2016. All OHCA events were included regardless of whether or not a resuscitation attempt was made by St John, patient age, aetiology or occurrence in the presence of emergency medical services.

Data were obtained from Abletech for all registered PAD locations on 26 August 2016 to compare with OHCA locations. A further data search was performed in 15 January 2018 to observe trends in PAD placements. The New Zealand Census and NZDep2013 data are from the Statistics New Zealand 2013 datasets.[17,22] Data relating to 200 CAUs covered by the Wellington Free Ambulance service were excluded from the analyses.

Location data

Each OHCA event and PAD was mapped to a specific CAU using the ArcGIS 10.3.1 (ESRI Inc, Redlands, CA) geographic information system (GIS). The process of geocoding (obtaining geographic coordinates) was not required as this information was already held within the data (using a latitude and longitude coordinate system) and is considered accurate. Rather, the GIS allowed the point-level data (OHCA, PAD) to be combined with area-level information such as NZDep2013 score and sociodemographic information based on location. Only OHCA events that could be geographically mapped to an area unit were included in further analyses.

Statistical analysis

A Poisson regression model with a population offset was utilised to examine the effects of area unit level demographics and PAD availability on the incidence rates of OHCA events. All factors of interest (ethnicity, age, deprivation decile, sex, rurality and PAD availability) were statistically significant in the multiple variable model and as such are all adjusted for the other factors in the model to explain the differentials across area units.

Results

During the period of 1 October 2013 to 30 June 2016, St John attended 11537 OHCA events. Of these events 11248 (97.5%) mapped to a CAU. In August 2016, there were 5310 registered PADs that could be mapped to a CAU. In January 2018, there were 8372 registered PADs which could be mapped to a CAU. In each case this figure excludes PADs registered within the Wellington region, and PADs located external to the boundary of a CAU (for instance those which are marine-based).

OHCA incidence increases with deprivation

The incidence of OHCA events per 100,000 person years for each NZDep2013 decile is shown (Fig. 1). There is a statistically significant deprivation effect ($p < 0.001$) (Fig.1). Strikingly, the incidence in the most deprived CAUs (decile 10) of 156.5 events per 100,000 person years (135.4–180.9, 95% CI) is double the incidence in the least deprived (decile 1) CAUs at 78.0 events per 100,000 person years (66.4–91.7, 95% CI) (Fig. 1).

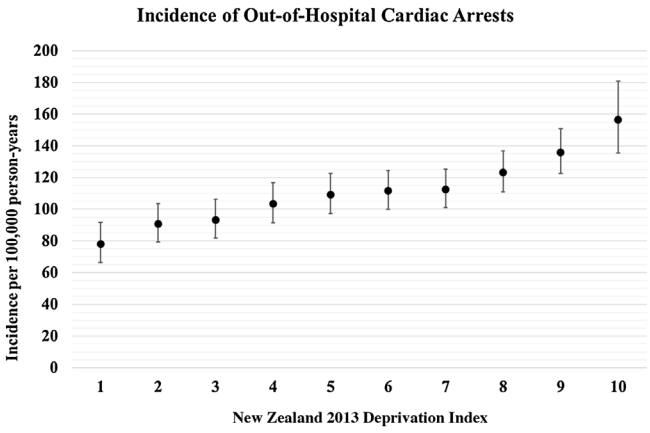

Fig. 1 – Deprivation (NZDep2013) decile-specific specific rates of OHCA per 100,000 person years. The error bars represent 95% confidence intervals.

Population demographics and incidence of OHCA

The 2013 Census data showed that the usually resident population across New Zealand consisted of 74% European, 15% Māori and 7% Pacific Peoples, whilst 14% of the population were aged over 65 years old and 49% of the population were male.[22] The results of the Poisson regression, adjusted for all other factors, was used to determine the relationship between sociodemographic characteristics (ethnicity, age and sex) and incidence of OHCA (Table 1).

The results indicated that for each 1% increase in the proportion of Māori within a CAU, there was an increased OHCA rate of 1.0% (0.6–1.4%, 95% CI, $p = 0.001$). For each 1% increase in the proportion of Pacific Peoples within a CAU, the OHCA rate increased by 0.6% (0.2–0.9%, $p = 0.005$). For each 1% increase in the proportion of individuals aged >65 years, the OHCA rate increased by 3.7% (3.0–4.3%, $p < 0.001$). For each 1% increase in

Table 1 – Relative rates of OHCA for increasing proportions of census area unit population by ethnicity, age and sex.

Population variable	OHCA relative rate[a]	95% Confidence interval	p-value
Proportion of Māori (per 1% Māori population increase)	1.01	1.01–1.01	<0.001*
Proportion of Pacific Peoples (per 1% Pacific Peoples population increase)	1.01	1.00–1.04	0.002*
Proportion of >65 year olds (per 1% >65-year-old population increase)	1.04	1.03–1.04	<0.001*
Proportion of males (per 1% male population increase)	1.04	1.02–1.06	<0.001*

[a] Adjusted for all other factors of interest.
* Statistically significant ($p < 0.05$).

the proportion of males in a CAU, the OHCA rate increased by 3.7% (1.8–5.6%, $p < 0.001$).

Area characteristics and incidence of OHCA

The degree of rurality of CAUs has been defined by Statistics New Zealand.[22] The proportion of the population residing within these areas according to rurality was 73% main urban, 6% secondary urban, 8% minor urban, 2% rural centre and 12% other rural area.[22] The results of the Poisson regression, adjusted for all other factors, was used to determine the relationship between area unit rurality and incidence of OHCA (Table 2). There was a statistically significant geography effect ($p = 0.003$). Compared to main urban areas, the OHCA rates in other rural areas were 21.8% higher (9.1–35.9%, $p = 0.001$) (Table 2).

Accessibility of PADs and OHCA

The mean number of PADs per area unit was calculated by NZDep2013 decile group using AED Locations data from August 2016 and January 2018 (Fig. 2). By January 2018, the decile 10 group still contained a low number of PADs (3.45 per area unit, 7.80 SD).

Table 2 – Relative rates of OHCA by area unit geography.

Area unit geography	Area unit count	OHCA relative rate[a]	95% confidence interval	p-value
Main urban	1061	1.00	–	–
Secondary urban	125	1.09	0.96–1.24	0.17
Minor urban	127	0.96	0.09–1.07	0.43
Rural centre	130	1.11	0.89–1.37	0.35
Other rural	383	1.22	1.09–1.36	<0.001*

[a] Adjusted for all other factors of interest.
* Statistically significant ($p < 0.05$).

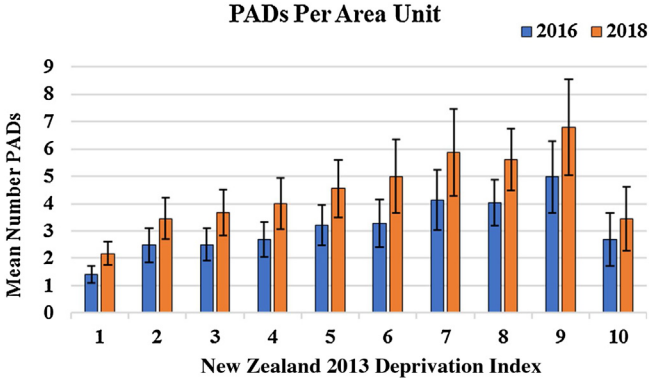

Fig. 2 – The number of registered PADs per deprivation (NZDep2013) decile in August 2016 (blue) and January 2018 (orange). The bars represent mean and error bars are 95% confidence intervals. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

Only the decile 1 areas had lower device availability at 2.17 PADs per area unit (2.59 SD).

The most deprived CAUs had the lowest coverage with registered PADs: 65% (112/173) contained a device – an increase of only 2% (4 CAUs) compared to devices registered in 2016 (Fig. 3). The highest PAD coverage was observed in the 2018 Decile 8 group (84%, 141/167). In total, 371/1667 (22%) CAUs covered by the St John ambulance service did not contain a registered PAD in January 2018.

The decile 10 area units without PADs contained a high proportion of Māori and/or Pacific Peoples compared to the general New Zealand population in 2013 (34% and 38% respectively) [22]. Three decile 10 CAUs without PADs also contained a high proportion of >65-year-olds. Only 3 decile 10 CAUs without PADs are geographically grouped as "other rural".

Discussion

Our study identified significantly increased OHCA rates in populations of Māori, Pacific People, those >65-years-old and males. In addition, enabled by geospatial mapping of 11248 OHCA events in New Zealand we identified an alarming increase in OHCA incidence with increasing levels of deprivation. The incidence of OHCA in the most deprived areas of New Zealand was double that of the least deprived areas. Furthermore, access to potentially life-saving PADs was lowest in the most deprived (decile 10) CAUs. Geographically there was a higher incidence of OHCA in more rural areas. The most highly deprived neighbourhoods of New Zealand have the poorest availability of public access defibrillators. A previous study has also reported that OHCA outcomes are worse in populations with high deprivation status.[24] However, an earlier New Zealand study documented no difference in OHCA outcomes with regards to socioeconomic status.[25] We did not investigate PAD use, patient outcomes, or rates of OHCA for those with a shockable presenting rhythm, all factors which are worthy of future investigation.

Our study was informed by the NZDep2013 Index of Deprivation, a robust measure of deprivation using nine weighted variables, rather than approximating based on income levels or residential land values.[26] Deprived areas of New Zealand have increased prevalence of coronary

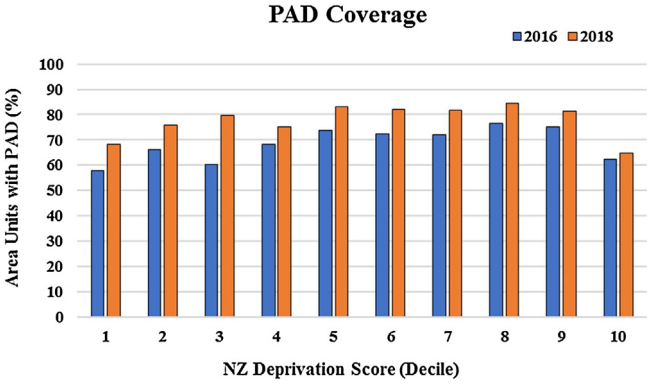

Fig. 3 – The percentage of CAUs within each deprivation (NZDep2013) decile that contain a PAD in August 2016 (blue) or January 2018 (orange) (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

heart disease and ischaemic heart disease.[27,28] Our findings are not unique to New Zealand, with several other countries reporting the incidence of OHCA is increased in areas of deprivation and in the older (>65 year-old) population.[4,9,10,29,30] Our results are consistent with known cardiovascular disease mortality in New Zealand, which is highest amongst those on the lowest income, of Māori or Pacific descent, males, and those >65 years-old.[31] Few other studies have investigated the incidence of OHCA by ethnicity at a similar area unit level: reduced risk was observed with an increasing Chinese population in Singapore and an increased risk was observed in neighbourhoods with an increased black population in North Carolina.[9,32]

Our study demonstrated that a large number of PADs are available in New Zealand but does raise questions about locality with populations at higher need having lowest access. Efforts to place PADs in areas of higher OHCA incidence has had some effect, with increasing numbers of PADs in deprived areas, except for, sadly, the most-deprived decile.

Despite availability of PADs the rate of PAD use in New Zealand is very low, with reports in 2017 indicating that only 9% of patients who had a cardiac arrest in public were defibrillated prior to ambulance arrival.[33] In our study data were unavailable regarding the time point at which PADs were placed into areas in relation to the time point at which an OHCA incident occurred, therefore it is possible that PADs were placed after an OHCA occurring. However, given the prevalence of PAD placement in general it is interesting that the rate of use of PADs is not higher. Factors contributing to low PAD use may include difficulty in locating PADs in times of emergency, as emergency call handlers are unable to provide such information, and a perceived requirement of specialist training to use a PAD.[34]

It may be cost-prohibitive for residents of the most deprived communities to attend certified first aid training courses which teach CPR and how to use an automated external defibrillator (AED). Therefore, in implementing strategies to target PAD placement in such communities, consideration needs to be made towards training which does not require a personal investment. In April 2018 the GoodSAM (Smartphone Activated Medics) smart phone application was launched in New Zealand. GoodSAM alerts bystanders to cardiac arrests occurring nearby and to the location of the closest PAD.[35] In New Zealand, all members of the public who know how to perform CPR or use an AED are able to register as GoodSAM responders regardless of whether they have learnt these skills via a free non-certified public awareness programme or via certified training.

One of the other challenges with PAD placement in New Zealand is the geographic distribution of the population. We showed that, whilst the overall number of events was low, there was a 21.8% higher rate of OHCA in the most rural areas of New Zealand. Geospatial analysis will be a useful tool in determining the best placement of PADs to service the rural population, particularly given that in the sparse rural population it is of little benefit to place PADs more than a 2-minute drive from likely locations of OHCA.

Finally, this study highlights that the most highly deprived (decile 10) areas are those which need attention, and the methods used here allow for periodic review of the success of new PAD placements. The next step will be correlation of these factors with OHCA outcomes, which is the subject of on-going work.

Limitations

The incidence rates in our study relate purely to the population usually resident within the area unit and do not account for transient populations such as those associated with population changes due to holiday destinations. As such some of these events will not accurately reflect the deprivation score of the patients domicile.

The PAD database that we used only includes PADs registered with AED Locations. It is possible there may be other devices in the community which were excluded from this study.

Conclusions

The poorest neighbourhoods in New Zealand had the highest incidence of out-of-hospital cardiac arrest and the least access to PADs. This provides impetus for targeted public access defibrillator placement in areas of deprivation.

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None

Competing interests

BD and VT are employees of St John.

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