**Characteristics of Neighbourhoods with High Incidence of Out-of-Hospital Cardiac Arrest and Low Bystander Cardiopulmonary Resuscitation Rates in England**

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**Key Messages**

1. High-risk neighbourhoods, with a high OHCA incidence and low BCPR rate, were characterised by higher population density and increased urbanisation; higher proportion of population in intermediate and routine occupations, lower proportion of people in managerial occupations; greater proportion of mixed race and non-white ethnic background, and lower proportion of white ethnic background; fewer people with higher educational qualifications; and a greater level of deprivation.
2. High-risk areas were seen across the country, and included city centres like Birmingham and London, parts of the north-east and Yorkshire; and some were on the coast in the south-east and east Yorkshire.
3. Knowing the characteristics and locations of high-risk areas could help focus future CPR training campaigns to where they are required most, and have the biggest impact on improving survival after cardiac arrest.

## Introduction

Data from the Out-of-Hospital Cardiac Arrest (OHCA) Outcomes (OHCAO) project for 2014 indicates that bystander cardiopulmonary resuscitation (BCPR) is undertaken, on average, in only 40% of OHCAs in England, the figure increases to about 55% in non-Emergency Medical Service (EMS) witnessed cases [1]. A low BCPR rate may, in part, explain why survival to hospital discharge (SHD) from OHCA in England is also low, 7.9%[1], as BCPR, a resuscitation attempt performed by a layperson who is not part of the organised emergency response system, more than doubles the chances of survival from an out-of-hospital cardiac arrest (OHCA)[2].

The community in which a person lives and works not only has an important influence on the likelihood that they have an OHCA, but also on the probability the event is witnessed and also that they will receive BCPR, and ultimately survive [3]. Previous research in the USA has shown BCPR incidence was lower in black/Latino/Hispanic neighbourhoods (compared to white neighbourhoods), regions of lower income (greater number living in poverty), areas of low levels of education, and areas with older population [3-8]. High-risk communities (where the incidence of OHCA is high and the prevalence of BCPR provision is low) are an important potential target for public health interventions to help reduce disparities in BCPR and to ultimately improve OHCA survival. Identification of areas of disparity could help direct strategies to areas be designed and implemented, moving from the notion of a one-size-fits-all approach to BCPR training, to one that is targeted where the need is the greatest.

The aim of this project was to examine the OHCA incidence and BCPR rates of bystander-witnessed OHCAs across England, using OHCAO registry data for 2013-2015 to identify neighbourhood characteristics associated with high frequency of OHCA and low uptake of BCPR.

## Methods

Analysis was based on OHCA events between 1st April 2013 and 31st December 2015. In the OHCAO registry OHCA patients of all ages where resuscitation was commenced or continued by EMS personnel are included. Patients who had a 'Do Not Attempt Cardiopulmonary Resuscitation' decision in place, or where a return of spontaneous circulation (ROSC) was achieved before arrival of EMS are excluded. The registry does not include cases that were bystander-witnessed, received BCPR, and achieved ROSC before ambulance arrival. This is because it is difficult to determine if such a case is actually a 'true' OHCA, which would only be possible if an automatic external defibrillator had been attached to the patient and given a shock, an event only observed in a small number of non-EMS witnessed cases (Hawkes et al., 2017). For this reason, when the OHCAO registry was set-up the ambulance services were instructed to not send details of such cases (Perkins and McDonnell, 2015). A patient was diagnosed dead on EMS arrival according to recognition of life extinct criteria [9], and were not included in the registry.

Age at date of OHCA was calculated from the patient's date of birth. If the calculated age was missing or out of a reasonable range (0-110 years), it was replaced by the EMS estimated age. According to the updated Utstein definition, unknown initial aetiology was recoded as a cardiac cause (presumed) [10]. The initial cardiac rhythm was defined into two different classifications. A shockable rhythm included ventricular fibrillation and pulseless ventricular tachycardia; and a non-shockable rhythm included asystole, pulseless electrical activity and bradycardia.

The incidence of OHCA was defined in two ways. Firstly, as the total number of OHCA events, over the 33 months, per 100,000 resident population served (residential population incidence); population data was taken as the average mid-year estimates for 2013-2015 published by the UK Office for National Statistics (ONS). Secondly, per 100,000 workday population bases on UK 2011 Census returns; with workday population, the usual residential population is re-distributed to their places of work (for those aged 16y and over), while those not in work are recorded at their usual residence. The BCPR rate was defined as the proportion of bystander-witnessed OHCAs receiving CPR by a layperson or bystander.

### Geocoding EMS Location

OHCA location information was geocoded using online software (https://www.doogal.co.uk). In cases where the software failed to give a valid postcode a manual process was undertaken to search for the address using the internet. A random sample of those locations that were automatically geocoded were checked manually. Postcode district (PCD), of which there are 2091 in England, was selected as the proxy unit of neighbourhood to ensure the number of OHCA cases was sufficient to not decrease the power of the analyses to detect any differences. An OHCA was categorised as 'Home' if the postcode from the geocoded EMS location was the same as the postcode of the patient's address (if provided), or if the EMS location was given as 'Home' or 'Place of Residence' and the patient's address was provided that allowed geocoding. If the geocoded EMS location and patient's address did not match, of the former was given as something else, e.g. 'Public Place' or 'Workplace', then the location was categorised as 'Other'. If neither of these criteria were met then the location was categorised as 'Unknown'.

Population Data

Neighbourhood characteristics were obtained from the UK 2011 Census (www.nomisweb.co.uk). Information on the proportion of the population in each PCD was obtained for the following:

- Ethnic Group: People classified themselves as whites, non-whites or mixed race;
- Long-Term Health Problem or Disability: People indicated they had a long-term physical health condition that limited their day-to-day activities or not at all;
- Highest Level of Qualification: The highest level of educational qualification achieved of people aged 16 and over, categorised as 'Yes' (levels 2, 3, 4 or apprentice) or 'No' (None, Level 1 or other);
- National Statistics Socio-economic Classification: People that indicated their occupation was (i) higher managerial, administrative and professional (Higher); (ii) Intermediate; or (iii) Routine and manual, never worked, or long-term unemployed (Routine).
- Age: Census age categorised as <65-years or ≥65-years.
- Country of Birth: Categorised as UK, other EU or other countries.
- Household deprivation: People with zero, 1, 2, 3 or 4 dimensions of deprivation; dimensions were based on four selected household characteristics (employment, education, health and disability, housing), categorised as 'Yes' (1,2,3 or 4 dimensions) or 'No' (zero).

In addition, the average of the following information for each PCD was obtained:

- Resident Population Density: Population per hectare (ha); continuous and categorised (<1, 1-<10, 10-<50, 50-<100, ≥100);
- Workday Population Density: An estimate of the population during the working day. It includes everybody who works in an area, wherever they usually live, and all respondents who live in the area but do not work. Continuous and categorised as for resident population density.
- Rural-Urban Classification: An official statistic used to distinguish rural and urban areas [11].

- Index of Multiple Deprivation (IMD): Measures relative levels of deprivation in small areas of neighbourhoods [12]; IMD is a non-linear measure of community socioeconomic status. For the analysis patients were categorised into quintiles of small-area deprivation, where the first quintile indicated the least deprived and the fifth quintile the most deprived group.

One PCD was excluded from the analysis because we could not obtain neighbourhood characteristics for it; this was the PCD for Heathrow Airport.

Choropleth Maps

Visual maps were created using ArcGIS 10.3 (Esri Inc.) to illustrate spatial patterns in OHCA incidence and BCPR rate.

Statistical Analysis

Descriptive statistics were used to analyse the difference in neighbourhood characteristics (t-test). Logistic regression analysis was undertaken to examine which neighbourhood characteristics might influence whether a PCD is defined as high-risk or not. Initially, single variable regression models were developed; any variable with a *p*-value ≤0.2 in the bivariate analysis was integrated into the final model. A backwards stepwise regression model was then developed, using a significance level of $p>0.1$ for removal from the model. Before running the model, the variables were tested for multi-collinearity using pair-wise correlation. Goodness-of-fit of the model was assessed by the Hosmer-Lemeshow test and area under the curve (AUC) was used to test the model's ability to correctly classify whether a PCD was high-risk or not. All statistical analyses were carried out using Stata version 15 (Statacorp, USA).

**Results**

This analysis was based on a total of 67,219 (88%) of the eligible 76,456 OHCA cases (*Table 1; see Supplementary Figure 1 for Utstein flowchart*). Approximately 42% of cases were witnessed by a bystander. The mean age (69.5y) of these cases was significantly greater than that of all cases (67.8y; $p<0.0001$). Over the three years the proportion presenting with a shockable rhythm averaged around 28%, and approximately 80% of cases were of cardiac aetiology. About 65% of the cases were ≥65y and 46% were confirmed to have occurred at home. The BCPR rate showed significant improvement from 50.2% in 2013 to 61.5% in 2015 ($p<0.05$).

Neighbourhood Characteristics

A total of 2050 PCDs were included in the analysis. There were no OHCAs in 40 PCDs, and we could not include PCD "TW6" which refers to Heathrow Airport, for which neighbourhood characteristics are not available (56 cases).

OHCA Incidence

There was significant variation in the OHCA incidence by a number of neighbourhood characteristics (*Supplementary Table 1*). In summary, the percentage of all OHCAs in the registry increased with increasing level of deprivation, population density, degree of urbanisation, proportion of population of mixed and non-white ethnicity, proportion in higher occupations or never worked, proportion born outside UK, and proportion aged >65y. OHCA incidence in each PCD varied considerably, averaging at 135.7/100,000 resident population (median: 127.6; range: 16.7-2649.0) (*Table 1*) Incidence was also calculated on the basis of workday population, and this averaged at 131.2/100,000 (median: 130.0; range: 2.03-768.0). This is the incidence for the whole study period (not the annual incidence) and will be used to identify high risk PCDs, it should not be used to compare with other population-based studies.

*Figure 1* shows the variation in OHCA incidence in England by PCD. The map indicates high OHCA incidence (>500/100,000) in areas of Westminster, Birmingham, Wolverhampton, East London, along the South-East and North-East coasts, and the Lake District. There are slight differences in the pattern between the two maps because some PCDs have a significantly higher, or lower, workday population that would influence the incidence. For example, the City of London PCD 'EC' has an average residential population of 2767 but an average workday population of 27919; the corresponding OHCA incidences are similarly different 590.3 and 30.3, respectively.

The characteristics of the PCDs with high OHCA incidence (i.e. >median) are given in *Table 2*. Mean residential population density was significantly higher in PCDs with a high OHCA incidence, whether the latter was calculated on the basis of residential population or workday population. In contrast the mean workday population density was significantly lower in these PCDs. PCDs with a greater than median OHCA incidence based on residential population (>127.6/100,000) or workday population (>130.0/100,000) were more urbanised (lower rural/urban index), had fewer people in managerial occupations and with educational qualifications, and fewer people with a white ethnic background. These PCDs also had more people in routine/manual occupations and with mixed/non-white ethnic background. There was also a greater degree in deprivation in these areas (lower IMD and higher household deprivation).

In contrast, high residential incidence PCDs had a lower proportion of people in intermediate occupations, people born in the UK and aged 65y and over, and an increased proportion of people born outside the UK. The opposite pattern was observed for high workday incidence PCDs for these variables.

Bystander CPR

Briefly, BCPR rates increased with decreasing levels of deprivation and population density; and increasing proportion of population of white ethnicity, proportion of people in higher and intermediate occupations, proportion aged <65y, and proportion born in the rest of the EU (*Supplementary Table 1*).

*Figure 2* shows the variation in BCPR rates in bystander-witnessed OHCAs in English PCDs. Low BCPR rates were observed in the North-East and Yorkshire, in parts of Milton Keynes, Cornwall, Somerset, Derbyshire, Wiltshire, Kent and Leicester.

Postcode district BCPR rates ranged from 0% to 100% with a mean of 56.8% (SD=26.0%). Ignoring those PCDs in which BCPR rate was 0 or 100 (n=333) had no effect on the mean (56.8%, SD=18.2%; range=4.8-94.4%). *Table 2* gives the characteristics of PCDs where the BCPR rate was less than or greater than 60%. The average workday population density in PCDs with a high BCPR rate was significantly higher than in PCDs with a low BCPR rate, although categorised density showed no difference between the two. Residential population density, on the other hand, was lower, 20.6/ha compared to 21.3/ha. The rural/urban index was significantly higher in PCDs with a low BCPR rate, indicating a greater level of rurality. Postcode districts with high BCPR rate had significantly more people in managerial and professional occupations, and significantly fewer in intermediate, routine and manual occupations compared to PCDs with low BCPR rates. These PCDs had significantly more people of white ethnic background, and significantly fewer of mixed or non-white ethnicity.

Deprivation (lower Index of Multiple Deprivation) was significantly greater in low-BCPR PCDs. There was no difference between the two groups in where people were born or the age composition.

### High-Risk Postcode Districts

High-risk PCDs were defined as those where the OHCA incidence was greater and the BCPR rate was below their respective medians (Residential incidence: 127.6/100,000; Workday incidence: 130.0/100,000; BCPR rate=60%). A total of 490 (23.9%) PCDs were judged to be residential and 498 (24.3%) workday high-risk (*Table 3)*, and their location is shown in *Figure 3*. 73 (14.9%) PCDs categorised as high-risk based on residential population incidence were not categorised as high-risk based on workday population incidence, whereas 81 (16.3%) that were not categorised as high-risk based on residential population incidence were categorised as high-risk based on workday population incidence. Very few are in the South-West or South-Central regions, but a large number are concentrated in the North-East, Yorkshire and in and around Birmingham. There are also pockets in and around London and on the South-East coast. Generally, in high-risk PCDs, irrespective of whether the incidence was based on the resident population or the workday population, there was a greater degree of urbanisation (lower rural/urban index), a greater proportion of people in routine occupations, of mixed/non-white background, and people whose activities were limited. There were fewer people in managerial and intermediate occupations, of white ethnic background and with educational qualifications. These areas were also more deprived (lower IMD and higher household deprivation). Country of birth did not appear to have a significant role.

### Regression Analysis

Bivariate logistic regression analysis of PCD risk (high or low) indicated significant associations with all the neighbourhood characteristics (*Supplementary Tables 3/4*). Backward stepwise regression of significant variables resulted in the final model in *Table 4*. The odds of a PCD being high-risk based on residential population incidence increased significantly with the proportion of people aged over 65y and where the proportion of people had no educational qualification, and decreased with increasing population density category and degree of rurality, and with the index of multiple deprivation. When high-risk was defined using OHCA incidence based on workday population, the odds increased with residential population density and proportion of people in managerial occupations. However, the OR decreased with workday population density, the proportion of people with educational qualifications and where their long-term health did not restrict activities, and also with increasing rurality. Both models showed good calibration (HL-Test $p>0.1$) and AUC was fair (0.7).

**Discussion**

We have identified a number of high-risk postcode districts in England where there was a high incidence of out-of-hospital cardiac arrest and a low rate of BCPR in bystander-witnessed OHCAs. These areas were characterised by a greater residential population density and lower workday population density; increased urbanisation; a greater proportion of people working in intermediate and routine occupations, and lower proportion in managerial occupations; greater proportion of mixed and non-white ethnic groups, and lower percentage of white ethnicity; lower proportion with high educational qualifications; and a greater level of deprivation (lower IMD). PCDs were in various parts of the country including the North-East, Midlands, East of England, London and South-East. This is the first such study in England, and the only one known that has examined the picture on a national basis.

Previous studies have observed an increase in population density to be associated with an increased OHCA incidence and a decreased likelihood of BCPR [13-17]. In multivariate regression analyses, population density was observed to be the primary non-clinical driver for disparity in BCPR provision [15, 16]. Related to population density, the degree of urbanisation/rurality has also been shown to impact on BCPR [18, 19].

The reasons why BCPR rates are higher in rural, less densely populated areas can be partly explained by lower deprivation in these areas. It has also been suggested that residents of these areas may think that because it would take the EMS time to arrive they should act urgently [16]. There is also less social anonymity in small towns and other less densely population areas, and the presence of factors that generate greater personal and social motivators to perform BCPR that are less likely in urban areas. For example, a survey in Arizona observed that over 80% of people would be willing to perform CPR on a family member compared to only 50% on a stranger [20]. Conversely, in more populated areas, bystanders may perceive help will arrive soon and consequently feel their action will add little benefit. There is also the so-called "bystander effect" where individuals are less likely to offer help to a victim when other people are present, because of ambiguity, a lack of cohesiveness and diffusion of responsibility [21].

Although BCPR rates are higher in less densely populated areas the outcomes are still poor, probably because of the increased EMS arrival time and subsequent delay in initiating advanced life support. However, in these areas survival is still higher if a patient does receive BCPR than when they do not, and is even better if an AED is also used by a bystander [17].

Previous studies have shown that large numbers of OHCAs occur in areas with a large population density, in Denmark [22], Japan [17], USA [6], and Australia [23]. Folke, Gislason [22] observed population density had the strongest association with OHCA occurrence, rate ratio for OHCA doubling with every quartile of population density. Nehme, Andrew [23] observed between 2003 and 2011, that as population density increased, age-adjusted incidence increased concomitantly, for both EMS attended and EMS treated OHCAs. We demonstrated in PCDs with a high residential OHCA incidence, the residential population density was about 50% higher compared to PCDs with a low incidence. In contrast, Straney, Bray [15] noted in Local Government Areas )LGA) of Victoria, Australia between 2011 and 2013 with the highest incidence the population density was significantly lower than in areas with the lowest incidence. Stromsoe, Svensson [13] also noted in Sweden the incidence was lower in areas with the highest population density but the association disappeared when incidence was adjusted for age and gender.

Studies have also shown that OHCA incidence is also increased in areas with significant population movement (e.g. railway stations, airports and shopping centres) explaining the heterogeneity of incidence between areas [24], and that this factor was a main driver in identifying "hot spots" for OHCA [24, 25]. We could not identify specific locations with a high population movement, but were able to look at workday population which gives an idea of commuting patterns and areas that attract employees. We observed that in PCDs with a high OHCA incidence the workday population density was 2.4 times greater than in PCDs with a low incidence, suggesting a significant influx of workers into these PCDs. Heathrow Airport, which has its own unique postcode, but could not be included in the overall analysis because we could not obtain neighbourhood characteristics for it, has a very large population movement and had a high number of OHCAs (67), and also a high BCPR rate (87%). The benefit of receiving BCPR, and defibrillation from an AED, in these areas has been highlighted in the UK, where the chances of achieving ROSC were almost doubled and survival to discharge trebled [26].

Although there was no difference in residential population density between PCDs with a high BCPR rate compared to low BCPR rate, the workday population density was significantly higher (about 40%) in the former. Previous studies have consistently shown an inverse relationship between BCPR rate and population density [13, 17, 23], and Straney, Bray [15] observed that population density explained 73% of the variation of receiving BCPR among LGAs.

Although some areas with a high population density and or workday population density had a high OHCA incidence they were not considered 'high risk', because they also had a high BCPR rate. An increased population density is not only predictive of OHCA incidence and BCPR rate, it is also significantly associated with the proportion of OHCAs of cardiac aetiology [17], cases with an initial rhythm of VF/VT [23], decreased ambulance response time [13, 17], and improved outcomes (transport with ROSC and survival to discharge) [13, 23].

High risk PCDs based on residential population, tended to have a greater population density (residential and workday) than low risk PCDs. Previously, Fosbol, Dupre [6] observed an odds of a census tract having a high rate of cardiac arrest and low rate of BCPR decreased with increasing population density, although this was not significant.

The degree of rurality, like population density, has a significant association with OHCA incidence and likelihood of BCPR. We observed PCDs with a low OHCA incidence and a high BCPR rate were more rural. Similarly, Uber, Sadler [16] observed OHCA clustering in more urban areas, but subjects with an OHCA in an urban area was less likely to receive BCPR. In Ireland, Masterson, Wright [27] observed a similar relationship, and also that more cases had defibrillation attempted before EMS arrival. However, they noted that these patients were less likely to arrive at hospital with a ROSC and to be discharged from hospital alive.

We showed that where there were larger proportions of people who indicated they were of mixed race or non-white ethnic background, a lower percentage from a white background, the PCDs were more likely to be high-risk. The ethnic make-up of a community has been widely recognised to impact on whether an OHCA in that community will receive BCPR or not. Many studies, mostly in the USA, have observed neighbourhoods that are largely made up of Black, Hispanics or Latinos have significantly lower BCPR rates, compared to mainly white neighbourhoods [3, 5-7, 16, 28-30]. In a similar study to ours, 'hot spot' census tracts in Ohio had a significantly higher proportion of African-Americans than 'cold spot' tracts [8], although census tracts cover a smaller population range (4,000-7,000) compared to English postcode districts (136-154233). A previous study in London observed that BCPR rates were significantly lower among South Asian OHCA patients compared to white OHCA patients [31]. A recent meta-analysis concluded that the odds that a Black patient would receive BCPR was significantly reduced (OR=0.63, 95% CI=0.53-0.76) compared to their white counterparts [32], and also less likely to survive to hospital admission and discharge. Akin to this a link between low BCPR rates and tracts with large numbers of people with limited English proficiency has also been observed [33, 34]. The exact reasons are unknown but could be cultural or related to deprivation, as the US studies have shown that the most deprived areas tend to have a large ethnic minority population.

Neighbourhoods with a low socioeconomic status (measured by various indices including household income, level of poverty, etc.) and high levels of deprivation are known to have a high OHCA incidence and low BCPR rate [5-8, 35-41]. We observed that high-risk areas were more likely to have fewer people in managerial and intermediate occupations and more in routine occupation, and were more deprived. There is consensus that OHCA incidence is significantly higher in deprived neighbourhoods compared to least deprived. Individuals in the most deprived areas of UK have been shown to have a reduced life expectancy and also spend a smaller proportion of their shorter lives in good health [42]. However, the opposite trend is seen with regards to the likelihood of receiving BCPR. In a previous study in North-East England BCPR incidence was observed to increase from 14.5% in the most deprived neighbourhoods to 23.3% in the least deprived [43], and the odds of receiving BCPR in the latter was 1.78 (95% CI=1.32-2.39) compared to former. In our analysis of the data for the whole country the odds, whilst a little lower had narrower confidence intervals (OR=1.14, 95% CI=1.05-1.23). The reasons why deprived areas are at high-risk are not clear but could be due to access to training, as it has been shown that people in UK in higher social grades, and full-time employment, are more likely to have received training in CPR (and AED use), and probably as a consequence show a greater willingness to perform CPR [44]. It could also be due to the stigma and fears around initiating BCPR [45].

Socioeconomic status is not only important predicting OHCA incidence and likelihood a case receives BCPR, it is also important for survival, in cases that have received BCPR the likelihood of survival increases with an increase in SES [46, 47].

Limitations

A limitation of the study was that we were not able to geocode approximately 12% of the OHCAs which may have biased the results. The majority of these were located in the South-West (81%). The main reason was that only the Utstein location could be provided, and is why the OHCA incidence is low in that region (Figure 1). We excluded these 12% because it is well known that witnessed arrests are strongly associated with BCPR [41], and rates of witnessed arrests fluctuate between the regions and over time.

We used PCD as the proxy for neighbourhood and assumed that its characteristics reflect the common characteristics shared by most of the individuals with OHCA there and the bystanders living in or moving through there. High-risk areas can change over time, therefore it is important to consider the fact in the development and testing of community-based interventions targeting these regions [48]. We assigned each OHCA to the PCD in which it occurred, this means that in PCDs where people commute to work or visit for holidays, or cities or town centres, may overestimate the incidence for that PCD. This was the case for a number of locations, where we also noted that BCPR rates were low and could be a focus for training and/or publicity. We could have used Lower or

Medium Super Output Areas as the proxy for neighbourhood but this would have reduced the number of OHCAs in each significantly that may have biased the results.

We did not separate OHCA events by public or private events, and it is possible that certain PCDs are high-risk because they have larger daytime populations [30]. However, a number of the high-risk PCDs were in residential areas, where it is known that the majority of OHCAs occur; an analysis of 2014 data from the OHCAO registry indicated that about 61% of known OHCAs occurred in the home [1], other studies have indicated about 80%. We were only able to confirm the location where a limited number of OHCAs occurred according to the Utstein criteria, e.g. home, public place, etc., the number confirmed as occurring in the home was below that observed elsewhere.

The categories chosen for the various neighbourhood characteristics were arbitrary and may not be generalisable across the country or in cross-nation comparisons. In addition, in the assessment of deprivation within a PCD we used the IMD which has been developed for use in the UK. If in the future we wish to compare between countries within the UK, adjustments will have to made because of the slightly different ways the IMD is calculated in each country [49].

Lastly, there may be other confounding factors that we did not consider that could impact on whether an individual receives BCPR or not, including the variation in neighbourhood cohesiveness or collective efficiency [5]. We also did not look at EMS variables here, some of which are known to impact on whether an individual is likely to receive BCPR or not. These include: arrest location, age & sex of patient, their ethnicity, and time/day at which event occurred.

## Conclusions

The study provides a key insight into the variation in OHCA incidence and BCPR rate across England. We have been able to identify the neighbourhood characteristics of high-risk areas that experience a high OHCA incidence and low BCPR rate that could be targeted for programmes of training in CPR, and AED use. These high risk areas could also be targets for public access defibrillator (PAD) placement strategies, however, further research is required and ongoing to identify the optimal location for PADs.

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**Contributors**

GDP designed the OHCAO study. TB, SB, CJ, RF, SB, HP, IG contributed to data collection. TB analysed the data and wrote the initial draft of the paper. TB, GDP and SB were involved in further drafting of the paper. All authors participated in interpreting the data, revising the paper for critically important intellectual content and gave final approval of the submitted version.

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**Competing Interests**

TB, SB, CJ, CH, GDP are employed by the University of Warwick, which receives grants from the British Heart Foundation and the Resuscitation Council (UK) for the conduct of the OHCAO project. JS is editor of Resuscitation journal for which he receives payment from publisher Elsevier.

**Ethics Approval**

Ethical approval for the OHCAO project was gained from the National Research Ethics Committee South Central, reference number 13/SC/0361. Confidential Advisory Group (CAG) approval was granted, reference number ECC 8.04(c)/2013, to collect identifiable patient information where it is not practical to obtain consent.

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