Available online at www.sciencedirect.com

Resuscitation Plus

journal homepage: www.elsevier.com/locate/resuscitation-plus

Clinical paper

Is there an association between 30-day mortality from out-of-hospital cardiac arrest (OHCA) and deprivation levels within Hampshire? A retrospective cohort study ☆

Peter Owen[a,b,d], Julian Hannah[a,b,d], Phillip King[e], Charles Deakin[b,c,d,e], James Plumb[a,b,c,d], Alexander I.R. Jackson[c,d,*]

Abstract

Introduction: People who live in population-dense areas, work in routine occupations, originate from a non-white background, have lower education attainment and experience a greater level of deprivation have an increased risk of suffering an OHCA and are less likely to receive bystander CPR. This study seeks to understand if these observed inequalities result in reduced survival by examining the relationship between deprivation and survival at 30 days at a UK single county level.

Methods: 30-day survival from non-traumatic OHCA in adults over 18 years of age in Hampshire from local ambulance service data (Jan 2019 – March 2023) was combined with indices of multiple deprivation (IMD) based on the home postcode. Multivariable logistic regression models were developed, through bidirectional stepwise regression, to evaluate the effect of deprivation on 30-day survival. Separate models were developed to consider non-linear relationships before a final model incorporated learning from previous iterations.

Results: Overall, 4184 patients were included in the final analysis, with 437 (10%) surviving to 30 days. Age of OHCA patients varied significantly between IMD deciles ($p < 0.01$), with a trend to younger patients in more deprived deciles. Univariable regression found no relationship between deprivation and survival. However, after controlling for age, sex, shockable rhythm and bystander CPR, increasing deprivation was associated with reduced survival (OR: 1.05, 95% CI 1.01–1.09). Other significant predictors were age, shockable rhythm and bystander CPR.

Conclusion: Increasing deprivation was associated with a reduced 30-day survival after accounting for other measured variables.

Keywords: Out of Hospital Cardiac Arrest, Deprivation, Socio-Economic Status, CPR, 30-day survival

Introduction

Out-of-hospital cardiac arrest is the sudden cessation of effective cardiovascular circulation in the prehospital setting[1]. The ambulance service in the England attends more than 84,000 OHCAs per year, with an incidence of around 53.0 OHCAs per 100,000 inhabitants.[2] Inequalities in the distribution of OHCA and the emergency service response have been identified previously within the UK and international populations[3]. Brown et al, noted cardiac arrests in the UK occur most frequently in high population density areas and areas which have a greater proportion of technical workers, from a non-white background, with lower education attainment[4]. These areas were also more deprived and OHCAs were less likely to receive bystander cardiopulmonary resuscitation (CPR). Similar findings can be seen in the USA,[5] Singapore[6] and New Zealand,[7] suggesting this a global issue rather than one driven solely by individual national factors.

Measuring deprivation can be challenging in clinical research as it is a complex and multifactorial construct. The Index of Multiple Deprivation (IMD) a nationally produced measure of deprivation based on England's Lower-Layer Super Output areas (LSOAS). LSOAs in England are defined areas made up of between 400 and 1,200 households and have a usually resident population between 1,000 and 3,000 persons. The Indices of Deprivation, which are based on seven individually weighted domains,[8] are used to rank each

☆ This article is part of a special issue entitled: 'Health inequalities' published in Resuscitation Plus.

* Corresponding author.
E-mail addresses: peter.owen@uhs.nhs.uk (P. Owen), alexander.jackson@soton.ac.uk (A.I.R. Jackson).

https://doi.org/10.1016/j.resplu.2025.100898

LSOA from 1 (most deprived) to 32,844 (least deprived). The most recent update the English IMD was conducted in 2019, using the LSOAs from the 2011 census, and is one of most recognised methods of evaluating deprivation in England.[9]

Deprivation is known to be an important factor in population health, and the understanding of its role in OHCA is growing. Recent studies, including a systematic review, identified trends between lower deprivation quintiles and survival to discharge from OHCA when appropriate confounders were adjusted.[10] Deprivation, education level and ethnicity have all been linked to disparities in both AED use and bystander CPR.[11] Understanding the reasons for this may be vital to improving outcomes, as both interventions greatly improve survival[12] and the observed differences are potentially reversible.[11] It has been suggested those educated to a higher level, (a construct included within the IMD), are more likely they are to be trained in CPR and then retain this knowledge enabling them to deliver it in an emergency.[13] It is also possible that the higher co-morbidity rates in areas with higher socioeconomic deprivation could worsen OHCA outcomes.[14] This is congruent with reports noting a social gradient in health outcomes across several measures, from maternal health to life expectancy, with higher deprivation groups demonstrating poorer outcomes in these areas.[15] However, at present the role of deprivation in outcome following OHCA has not been studied across much of the UK and it may be that regional differences in its effect exist. Establishing where the inequalities in OHCA outcome exist at a local level may allow more efficient targeting of resources to those most in need. For example, targeting community-level programmes such as improving access to CPR educational programmes. Doing this in a data-driven, proportionate manner may be a practical way of closing health inequalities where they exist, potentially improving OHCA outcomes.

This study aims to explore the effect of deprivation, defined by IMD, on 30-day survival following OHCA in Hampshire, UK.

Methods

Ethics

This study was granted Health Research Authority approval following a favourable review by South West Central Bristol Research Ethics Committee (REC). The study sponsor was University Hospitals Southampton NHS Foundation Trust and approval was further obtained from South Central Ambulance Service NHS Trust, who provided the data.

Study design

A retrospective cohort study examining the relationship between 30-day survival following OHCA and deprivation status measured by IMD in Hampshire, UK. Data for all ambulance responses to OHCA in adult (age $\geq$ 18**)** patients (age $\geq$ 18**)** within Hampshire with records held by South Central Ambulance Service (SCAS) from January 2019 to March 2023 were considered. Data including age, home and incident postcode, sex, ethnicity, presenting rhythm, bystander CPR, response time and whether the arrest was witnessed were all chosen as variables due to their importance in answering the research question and availability within the SCAS dataset. 30-day survival data were provided with this extract. Response time was calculated in minutes from the time of the ambulance call to the arrival of the first ambulance resource. Patients were excluded from the analysis if the cause of the arrest was traumatic; they were aged under 18 years of age, were pregnant, prisoners or part of the NHS National data opt-out. A pseudonymised version of the data were transferred to the University of Southampton prior to analysis.

Study setting

Hampshire is a semi-rural county in the South of England with a population of around 1.4 million. It is served by South Central Ambulance Service (SCAS), which also serves the populations of Berkshire, Buckinghamshire, and Oxfordshire. SCAS serve a population of over 7 million and answers over 500,000 urgent calls a year. Approximately 75% of Hampshire is classified as rural and these areas are home to 300,000 people, around 21.8% of the County's total population.[16] Hampshire ranks as the 16th least deprived Upper Tier Authority out of 151 in England. Among districts, Hart is the least deprived area nationwide. The most deprived areas in Hampshire are found in Rushmoor, Havant, Gosport, and Eastleigh, with smaller deprived areas in the New Forest (HCC, 2021).

Data quality and handling

Data handling and preparation were performed in Python (v3.12, Python Software Foundation, Available at https://www.python.org). 4284 patients were identified in the initial data extract. Patients with missing outcome data (30-day survival) were excluded (n = 100). Ethnicity was found to be missing in a high proportion of cases (83%) and was therefore excluded from analysis. Data on witnessed arrest status was explored, however, there were significant data quality issues. The witnessed data in the SCAS system is stored as a free text variable, this may be filled in with the name of the witness or left blank. The ambulance trust was not able to provide the raw text as this could breach confidentiality. They provided Boolean values (True if any string present, False if left blank). After initial exploration we queried possible data quality issues. This confirmed instance of the data field being completed with answers such as 'no witness' or 'unwitnessed', but SCAS were unable to quantify this or provide the raw field for further examination. Therefore, the presence of a string in the field did not reliably equate to the ground truth of a witnessed arrest. We therefore had to proceed without this data. Home postcode was found to be missing in 298 cases (6.95%) and was imputed with the incident postcode. Overlap between home and incident postcode was noted in 3118 cases (72.8%). Home postcode was felt to be more reflective of important socioeconomic and demographic factors (e.g. income, education, access to healthcare), which may influence OHCA outcome. Incident postcode was therefore not used in analyses and was used solely for imputation. All other variables demonstrated lower rates of missingness (0% $-$ 2.66%). The details of missingness and imputation for these can be found in supplementary materials section. Home postcodes were transformed to Office for National Statistics (ONS) 2011 Lower Layer Super Output Areas (LSOA11) before further transformation to Index of Deprivation 2019 deciles (IMD).[9] Of note this paper uses the standard expression of IMD deciles where 1 is the most deprived and 10 is the least deprived. Home postcode was also used to identify rural and urban locales as defined by ONS 2011 rural/urban classification.[17]

Statistical analysis

Final statistical modelling was performed in R (v4.3.1, R Core Team, Vienna, Austria 2023). Normally distributed data were expressed as mean ± standard deviation, while non-normally distributed data were expressed as median and interquartile range. Normality was evaluated visually with both distribution and Q-Q plots and using the

Shapiro-Wilk test in cases of uncertainty. Differences between survivors and non-survivors were evaluated using the Mann-Whitney U Test for non-normally distributed continuous variables, while the Chi-squared test was used for categorical variables. Differences between IMD deciles were evaluated using the Kruskal-Wallis test for non-normally distributed continuous variables and the Chi-squared test for categorical variables. The crude association between IMD decile and 30-day survival was assessed by univariable logistic regression. Multivariable modelling was performed with 30-day survival as the dependent variable and IMD decile as the independent variable. Possible control variables for multivariable modelling were selected based on data availability, quality and plausibility. Candidate control variables were as follows: age, sex, ambulance response time, presenting rhythm (shockable vs non-shockable), bystander CPR and rural vs urban home postcode. Prior to modelling continuous variables (age, response time and IMD decile) were evaluated for the presence of outliers and collinearity. Response time was log transformed and Winsorized at the 2nd and 98th percentiles to limit the effect of outliers, while preserving the majority of the distribution. Further details can be found in supplementary materials. No collinearity was observed with variance inflation factor testing. Three separate models were developed. First a parsimonious model assumed linearity of continuous variables with the log odds of survival. Control variables were evaluated by bidirectional stepwise logistic regression using Akaike's information criterion (AIC) to balance model fit and complexity. The assumption of linearity was tested using multivariable fractional polynomials. A model was developed where all continuous variables were evaluated with non-linear approaches. A final model was created modelling age in a non-linear fashion, while excluding response time (see results for further details). Where appropriate model results are presented as odds ratios and 95% Confidence Intervals (CI). For non-linear features visualisations are presented. All models are reported with survival as positive (i.e. the larger the odds ratio the greater chance of survival). Alongside AIC, the C-statistic, Brier score and a Pseudo-R2 (Nagelkerke's) were produced. All figures were produced in R using the ggplot2 Package (v3.5.1, ggplot2 Authors). Supplementary materials contain more detailed model outputs and code for their creation.

Results

Overall, 4184 patients were included in the analysis, with 437 (10%) surviving to 30 days (Table 1). The median age was 70 (IQR 57–80), with 2709 (65%) of these being male. Across all IMD groups, there was a similar distribution of survivors and initial presenting rhythm (Fig. 1) with no significant difference observed. There were significant differences in age between different IMD deciles ($p < 0.01$) which can be visualised in Fig. 2, with an overall trend of increasing age in less deprived deciles. A table comparing IMD deciles can be found in the supplemental materials. Survivors, on average, were significantly younger compared with non-survivors (62 years vs 71 years, (median), $p < 0.001$). Bystander CPR was undertaken in 2636 (63%) of all patients, with no significant difference between survivors and non-survivors ($p = 0.7$). The presenting rhythm was shockable in 939 (22%) of the total patients, with the proportion significantly higher in the survivors' group (70% vs 17%, $p < 0.001$). Median response duration was similar across both survivors and non-survivors (7.08 min vs 7.28 min, $p = 0.3$). There was no difference in the proportion of cases responded to within 7 min (Survivors – 47%, Non-Survivors – 49%, $p = 0.3$). Rurality was not significantly different between survivors vs non-survivors (16% vs 16%, $p = 0.8$). Crude analysis also demonstrated no difference in IMD decile between survivors and non-survivors (6 vs 6p = 0.5, median presented).

Logistic regression modelling

The univariable logistic regression model for IMD vs 30-day survival demonstrated a non-significant relationship (OR 1.01 95% CI 0.975–1.05). Following stepwise regression, the parsimonious multivariable model included age, response time, shockable rhythm, bystander CPR and sex. The remaining control variable (rurality) did not improve model performance and was therefore excluded. This model demonstrated that IMD decile was significantly associated with survival (OR 1.041 95% CI 1.001, 1.084) as was shockable rhythm (OR 11.76 95% CI 9.359–14.85), while age (OR 0.971 95% CI 0.964–0.978), and bystander CPR (OR 0.76 95% CI 0.610–0.967) were negatively associated with survival. The multivariable fractional polynomial modelling demonstrated a significant linear relationship for IMD decile (OR 1.577 95% CI 1.057–2.360) while suggesting non-linear relationships for both age and response time, these relationships can be visualised in Fig. 3. The complex relationship seen in this figure called into question the utility and validity of response time (see discussion) as a modelling variable and the final model excluded response duration, while modelling age in a non-linear fashion (age^3). Table 2 shows the final model odds ratios, all categorical and linear variables are presented, while Fig. 4 shows the relationship (non-linear) for age. This final model once again finds IMD decile to be positively associated with survival (OR 1.05, 95%

Table 1 – Table of case characteristics by 30-day survival.

Characteristic	Overall N = 4,184[1]	Non-Survivors N = 3,747[1]	Survivors N = 437[1]	p-value[2]
Age (years)	70 (57, 80)	71 (58, 80)	62 (51, 72)	<0.001
Sex (Male)	2,709 (65%)	2,376 (64%)	333 (77%)	<0.001
Bystander CPR	2,636 (63%)	2,364 (63%)	272 (62%)	0.7
IMD decile (home)	6 (4,9)	6 (4,9)	6 (4,9)	0.5
Rural location (home)	682 (16%)	613(16%)	69(1.6%)	0.8
Response duration (minutes)	7.10 (4.63,10.79)	7.08 (4.63,10.70)	7.28 (4.65,11.53)	0.3
Shockable rhythm	939 (22%)	632 (17%)	307 (70%)	<0.001

[1] Median (IQR) – continuous variables; n (%) – categorical variables.
[2] Wilcoxon rank sum test (continuous); Pearson's Chi-squared test (categorical).

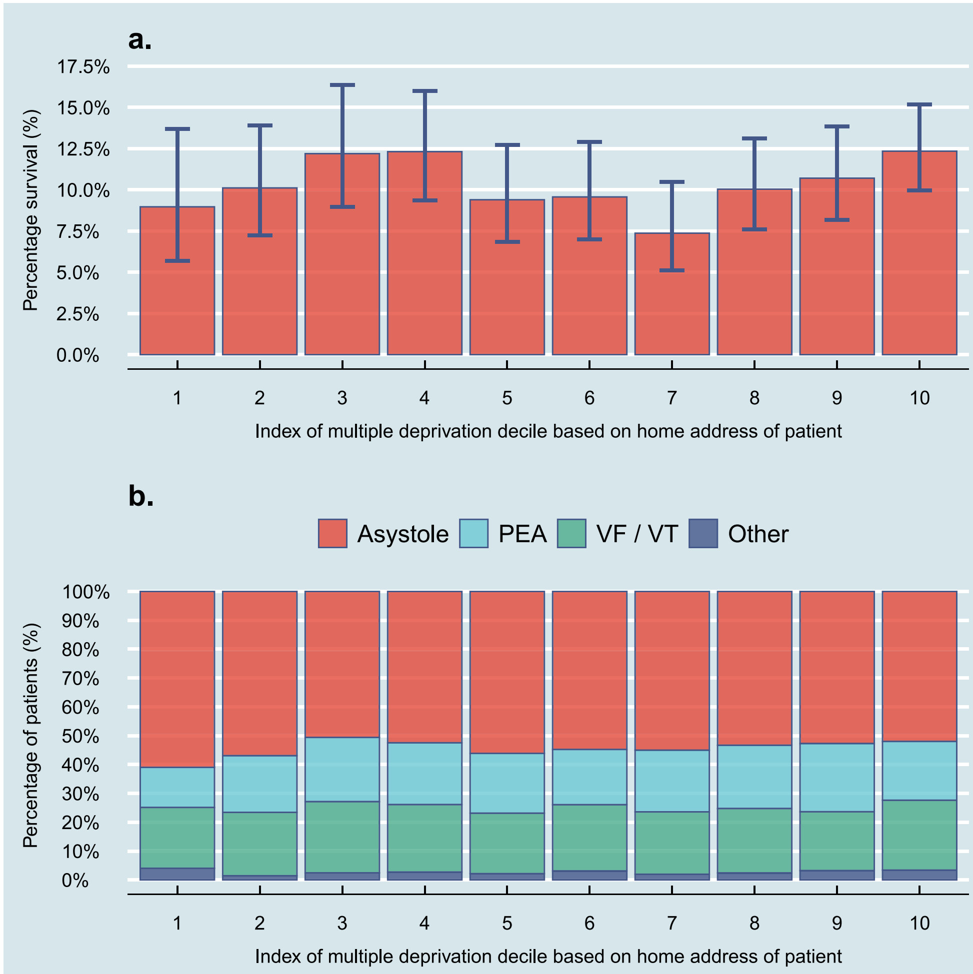

Fig. 1 – Plot of 30-day survival for each IMD (top) and percentage of presenting rhythm (bottom) based on IMD decile. Note for IMD 1 = most deprived, 10 = least deprived.

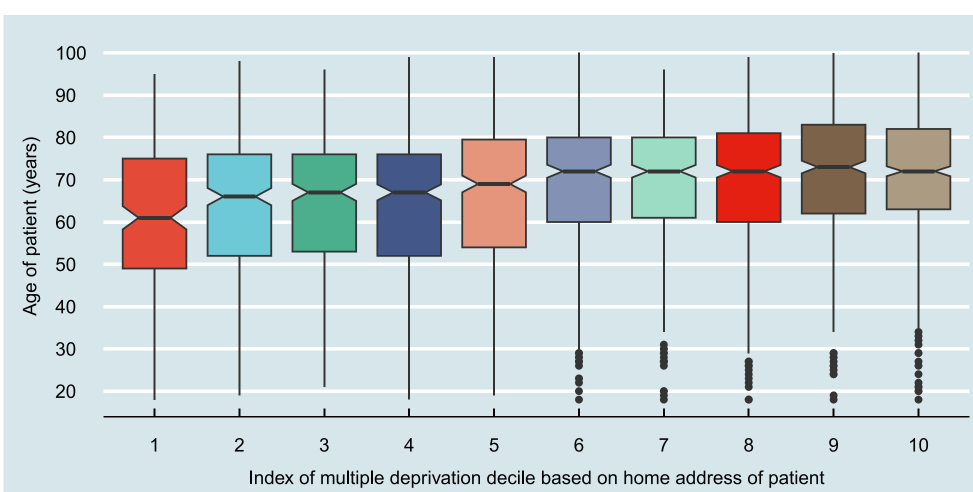

Fig. 2 – Boxplot showing distribution of age across index of multiple deprivation deciles. Note for IMD 1 = most deprived, 10 = least deprived.

CI 1.01–1.09) alongside shockable rhythm (OR 11.3 95% CI 9.00–14.3), while bystander CPR remains negatively associated (OR 0.75, 95% CI 0.75–0.95). Age was significantly negatively associated ($p < 0.001$) but due to the transformation the OR is not easily inter-

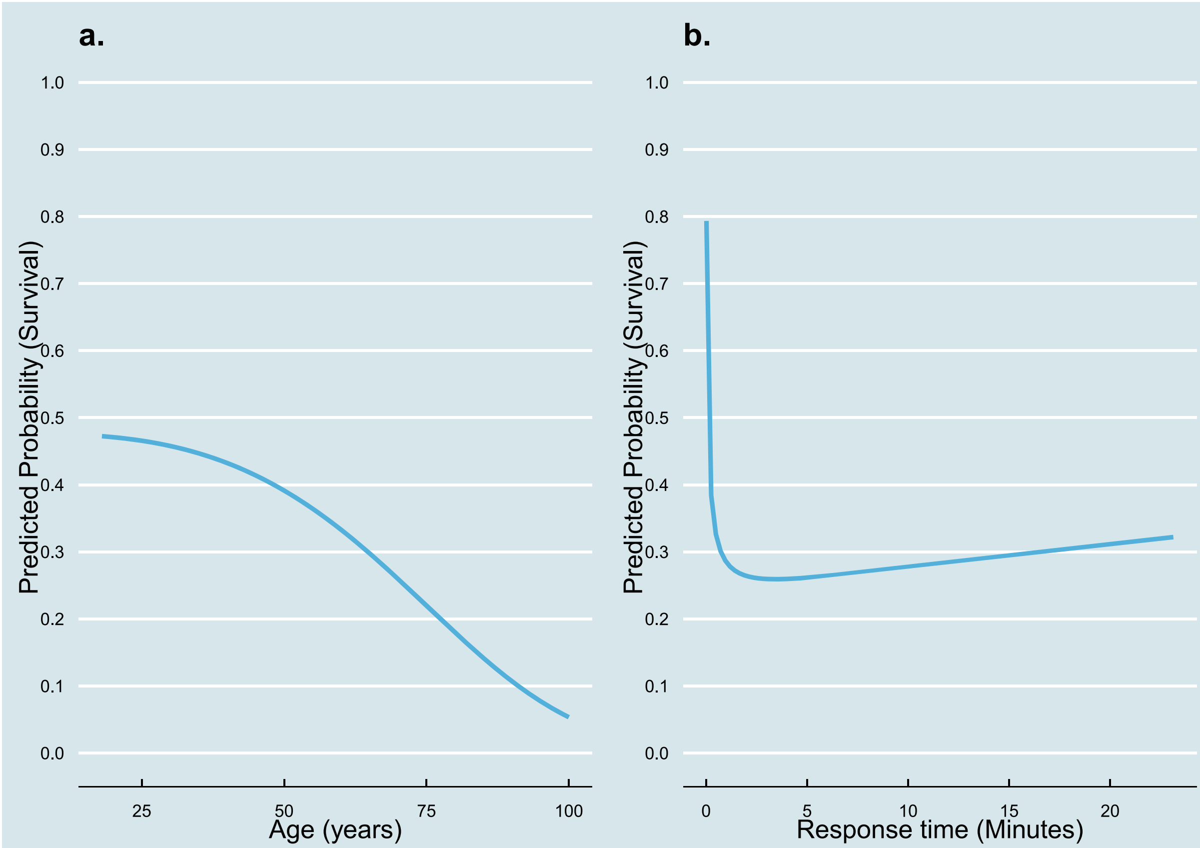

Fig. 3 – Relationship between age (panel a.), response time (panel b.) and probability of survival in the initial fractional polynomial model. Figure assumes all other variables constant (continuous variables held at mean, gender = male, shockable rhythm and bystander CPR true).

Table 2 – Final multivariable logistic regression model.

Characteristic	OR[1]	95% CI[1]	p-value
IMD decile (home)	1.05	1.01, 1.09	0.019
Shockable rhythm	11.3	9.00, 14.3	<0.001
Bystander CPR	0.75	0.60, 0.95	0.015
Sex (Male)	1.23	0.96, 1.60	0.11

[1] OR = Odds Ratio, CI = Confidence Interval.

pretable and Fig. 4 is the best illustration. The final model demonstrated a pseudo-R2 of 0.278, a c-statistic of 0.821 and a Brier score of 0.076.

Discussion

In our multivariable analysis a higher IMD decile, which represents decreasing levels of deprivation, is associated with improved 30-day survival. This is consistent with numerous studies that have demonstrated a link between deprivation and cardiac arrest survival.[10,18] Whilst our findings may not appear as pronounced as reported other papers from the UK,[19] several differences should be highlighted. The study by Bijman et al. was based in Scotland and used the Scottish IMD (SIMD) which is produced by a separate methodology, meaning the IMD's are not interchangeable. Furthermore, they opted to use quintiles, modelled as a categorical variable. Our approach used deciles modelled as a continuous variable. Both are valid but will produce different results, however the consistency of the findings across both studies lends credence to the overall validity to the association between increasing deprivation and decreased survival. Our multivariable analysis suggested increasing age has the most significant effect on 30-day survival after shockable rhythm, which with an OR of 11.76 was by some margin the most strongly associated factor with survival. Whilst age, in isolation, is a poor predictor of outcome in OHCA, our findings suggest it has a measurable effect on outcomes within our data.

We also note the key role age appears to have in the relationship between IMD and survival in our data. In univariable analysis IMD was not significantly associated with survival. During our stepwise parsimonious model development IMD only becomes a statistically significant predictor once age is controlled for. Given that age was

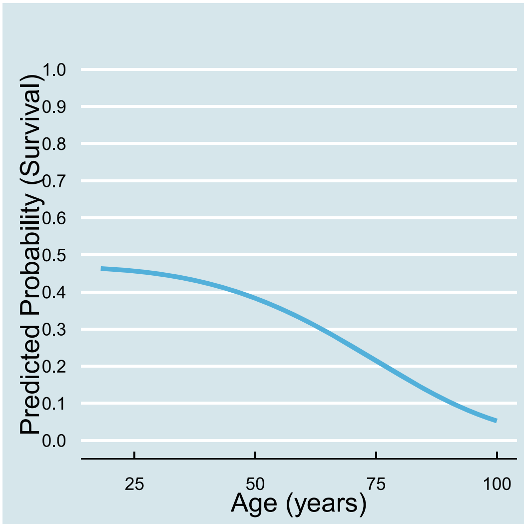

Fig. 4 – Relationship between age and probability of survival in the final logistic regression mode. Figure assumes all other variables constant (continuous variables held at mean, gender = male, shockable rhythm and bystander CPR true).

significantly different between IMD deciles it may be that this adjustment helps elucidate an underlying relationship. One hypothesis is that at higher levels of deprivation OHCA occurs in a younger cohort, as seen in our data, but this younger age may belie overall health status, which may be worse and account for the poorer outcome seen once age is adjusted for. This tallies with literature showing that increasing deprivation is frequently associated with increased multimorbidity,[20] and pre-arrest co-morbidity is commonly associated with unfavourable outcomes in OHCA.[21]

30-day survival for all OHCA (10%) and survival from initial shockable rhythm (32.6%) were similar to figures seen in contemporary literature throughout the UK for this period.[2] Interestingly, when bystander CPR was included in the analysis, this was associated with worse outcomes at 30 days. It is commonly assumed that early bystander CPR is associated with improved outcomes. However, several studies have demonstrated that it may not necessarily be the effect of bystander CPR but the fact the arrest has been witnessed expediating the access to defibrillation and other therapies.[22–23] Whilst we could not assess the effect of deprivation on public access defibrillation in our analysis it has been shown that within the UK, that defibrillator coverage tends to be higher in more affluent areas with lower population density.[24] In some instances, equitable access to public access defibrillators is more pronounced 'out of hours' for the more deprived communities.[25] It could also be that bystander CPR was particularly poor, and, as such, does not affect the outcomes as seen with other analyses.[26] We note the rate of bystander CPR in our data is lower than those reported by SCAS in the Out-of-Hospital Cardiac Arrest Outcomes (OHCAO) study over the same period.[2] Our data do not cover the entire SCAS service but rather only the county of Hampshire, it may be that there are regional differences within the area served by SCAS, as can be observed between ambulance services in the OHCAO study. Furthermore, whilst the bystander CPR rate is similar in both survivors and non-survivors in our study, what may be different is the proportion of bystander CPR cases that are witnessed, a known factor in survival. In SCAS, according to OHCAO, bystander CPR in unwitnessed OHCAs is around 67% compared to 81% in bystander witnessed. Therefore, the proportion of unwitnessed cases in Hampshire may be higher than other areas.[2] One final possible confounder is in cases where ambulance arrival was very prompt or arrest occurred after arrival there may have been no bystander CPR because ambulance administered CPR, which would be expected to be high quality, combined with other therapies, was available. Our initial data extract included a free-text field related to bystander CPR from which we hoped to gain more granular detail on the CPR given. However, the field was frequently incomplete, and the detail entered was highly variable and unstructured rendering quantitative analysis not feasible. We note that data quality issues, including missing data, are a frequent challenge in retrospective studies,[27] a problem which is likely to be exacerbated in resource constrained acute services, where frontline staff may prioritise patient care at the expense of detailed documentation and structured reporting. EHR data continue to offer valuable insights but their limitations must be considered.[27]

Rurality did not affect 30-day survival, and did not improve the fit of any of our multivariable models. One study found significantly lower odds of survival associated with rurality (OR 0.86, 95% CI: 0.79–0.93) and attributed this to longer response times compared with urban areas (7.5 vs 5.9 min, $p < 0.001$).[28–29] found a response time of longer than 20 min was associated with decreased survival in their adjusted analysis for deprivation and survival. It is possible Hampshire had a particularly good response in rural areas, or the county had a low rurality overall with shorter average drive times. Our findings around response time itself are more complex and nuanced. Our parsimonious model treated response time linearly and found no significant effect but the final OR was > 1, suggesting if anything a positive relationship, which would be difficult to rationalise. Our fractional polynomial model offers and insight into a possible non-linear relationship. Fig. 3 (b) shows the complex polynomial relationship used to model response time. An initial steep decline in survival is seen followed by a gradual increase in survival as time increases. A priori, we would expect that a prolonged response time would result in worse outcomes, delaying definitive professional care. Yet this was not seen here, we also note some response times exceed those which would be expected for OHCA in our region. We hypothesise that these cases may represent cardiac arrest after the initial ambulance call was placed, which would account for a less urgent, slower response. We do not believe this would be captured by the clinical system underlying this data. It may be that some of these outliers did not arrest until after an ambulance crew were onsite, which would explain the apparent increase in survival even as response time became longer. It is possible this relationship could be more fully understood with high quality data on witnessed status, ideally including if it was EMS witnessed. More broadly there are unmeasured variables within this study which may have a significant impact, as discussed in more detail in limitations below.

The study period included the period when COVID-19 was officially classified by the World Health Organisation as a pandemic on 11 March[30] with the UK going into to full lockdown on 23rd March 2020). Whilst some studies reported no increase in incidence of OHCA during the pandemic,[31–32] two UK studies both reported an increase incidence of OHCA during this period.[33–34] The London study found a decrease in public arrests and with a corresponding increase in incidence in private dwellings which was likely a consequence of the lockdown measures that had been put in place. A decrease in shockable rhythms may be reflective of increased response times seen during the study period.[34] Whilst it would be difficult to account for the true effect this had on our analysis it is possible that the pandemic influenced some variables in our study.

Strengths

Our data are drawn from a sizable geographic area with a reasonable cohort size. The nature of prehospital care in England means that this single provider database will have captured almost all cardiac arrests with attempted resuscitation, something not possible in more fragmented healthcare networks. The region is diverse, with rural, urban, affluent and deprived populations all within the county's borders. Our modelling approach tested non-linear approaches to the often-complex relationship between continuous variables and binary outcomes. In general, our findings were robust across differently configured models and the overall performance of the final model was reasonable considering the limitations (see below).

Limitations

By its very nature as a retrospective study, our analyses were limited by data availability and quality. Our modelling and findings are inherently limited by the data used. We were unable to acquire all the variables we would have hoped to use in sufficient quality, for example both ethnicity and witnessed arrest data were not suitable for inclusion. Despite this, our model demonstrated reasonable performance. A pseudo-R2 of 0.278 is not unreasonable given the considerable number of unmeasured variables which influence survival after OHCA. Our model does not account for pre-morbid state, underlying aetiology (other than shockable vs non-shockable rhythm) or any care processes following OHCA. It is therefore unlikely any modelling of these variables alone can explain all variation seen. However, the discrimination of the model was better with a c-statistic of 0.821, while a Brier score of 0.076 suggests good accuracy of the predictions.

Some data were missing both in outcome (30-day survival) and predictor variables (home postcode). However, the level was generally acceptable, with all but 2 variables having < 3% missing values. The two exceptions were ethnicity, which had to be excluded, and home postcode. The imputation strategy for home postcode is imperfect, however it has reasonable face validity and may introduce less bias than complete case analysis alone. Furthermore, the use of the more complete incident postcode as an alternative for all analyses was discussed but the authors felt it less likely to capture the broader context of an individual's health environment and identifying population-level risk factors. As mentioned, detailed data on patients' premorbid status was unavailable, as were details of hospital care or underlying aetiology. Therefore, we cannot explain with any great certainty what underlies the relationship seen between IMD and survival. However, the finding remained consistent through each stage of our modelling process and echoes finding in the OHCA literature as well as wider health inequalities research. The available data limits the ability of multivariable modelling to account for other confounding factors which may influence outcomes, such as witnessed status and quality of bystander CPR. These and other unmeasured confounders may be present where variables have not been measured or included in the analysis. Incomplete adjustment may be present where confounding variables may not be fully accounted for due to measurement error or categorisation issues. In addition, Assumptions made during the analysis may not reflect reality, leading to incomplete adjustment, despite efforts to model for differing assumptions. Furthermore, the Index of Multiple Deprivation represents an area and the average characteristics of those living there. It cannot fully represent any single person living within the area. Whilst 30–day survival is a recognised surrogate for the effectiveness of resuscitation efforts, its limitations are two-fold: firstly, results can be affected by downstream care or complications, and secondly, outcome metrics such as cerebral performance scores or the modified Rankin score may provide more meaningful interpretation of results.

Conclusion

Deprivation, as measured by IMD deciles, was associated with decreased survival in multivariable modelling. This may be due to higher pre-arrest co-morbidities, relative to age, in those living with higher levels of deprivation. While there is no panacea to these inequities for any health service, they highlight the complex and challenging relationship between deprivation and health at a population level, something which challenges most fields of medicine. In the setting of cardiac arrest, targeting CPR education initiatives and improving the availability of public access defibrillators in more deprived communities may help ameliorate lower survival in these groups. However, a deeper understanding of the relationship observed in this study, crucially with identification of possible causative pathways, is needed to target interventions at the root cause of the difference seen. It may be beneficial for health care providers across all stages of OHCA care to recognise the importance of accurate data capture and implement measures for this alongside data linkage with other datasets to allow a more complete evaluation in the future.

Key Learning points

What is already known:

- Deprivation has previously been associated with decreased survival following cardiac arrest
- Bystander CPR and community defibrillation rates are often lower more deprived populations.

What this study adds:

- Confirms existing literature, suggesting deprivation is associated with decreased survival following OHCA and is the first to model deprivation as a continuous variable.
- First study to demonstrate the relationship in this geographic setting, Hampshire, UK.
- Age and increasing deprivation status (measured by IMD) are associated with decreased 30-day survival after out-of-hospital cardiac arrest.

Conflict of interest

None declared.

Sources of funding

This study was completed as part of an internal data exploration project within the Hampshire and Isle of Wight Air Ambulance and no external funding was required.

JP has received financial support from Siemens Healthcare Limited for consumables and hardware for research into the measurement of haemoglobin mass (2015-2018). JP was given consumables from Intersurgical UK Ltd (2015-2018); has received honoraria for speaking and/or travel expenses from Siemens and Vifor Pharma and has received unrestricted grant funding from Pharmacosmos. JP was previously supported by the University of Southampton National Institute of Health Research Academic Clinical Fellowship Scheme. JP is unaware of any direct or indirect conflict of interest with the contents of this paper or its related fields

AIRJ is supported by an NIHR Doctoral Fellowship (NIHR302995) and was previously supported by the University of Southampton National Institute of Health Research Academic Clinical Fellowship Scheme. AIRJ acts as a paid consultant for Edwards LifeSciences (Now BD Advanced Patient Monitoring) and has accepted financial support from them to support clinical research, unrelated to this project. AIRJ is unaware of any direct or indirect conflict of interests relevant to this study.

CRediT authorship contribution statement

Peter Owen: Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Julian Hannah:** Writing – review & editing. **Phillip King:** Data curation. **Charles Deakin:** Conceptualization. **James Plumb:** Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Alexander I.R. Jackson:** Writing – review & editing, Software, Formal analysis.

Data availability

The data underlying this article will be shared on reasonable request to the corresponding author.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

The author is an Editorial Board Member/Editor-in-Chief/Associate Editor/Guest Editor for Resuscitation Plus and was not involved in the editorial review or the decision to publish this article.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.resplu.2025.100898.

Author details

[a]Hampshire and Isle of Wight Air Ambulance, United Kingdom [b]University Hospital Southampton NHS Foundation Trust, United Kingdom [c]Integrative Physiology and Critical Illness Group, Clinical and Experimental Sciences, Faculty of Medicine, University of Southampton, United Kingdom [d]Perioperative and Critical Care Theme, NIHR Southampton Biomedical Research Centre, Southampton NHS Foundation Trust, United Kingdom [e]South Central Ambulance Service NHS Foundation Trust, United Kingdom

REFERENCES

1. Myat A, Song KJ, Rea T. Out-of-hospital cardiac arrest: current concepts. *Lancet* 2018;391(10124):970–9.
2. Warwick Clinical Trial Unit. Annual Epidemiology and Outcomes. 2023. https://warwick.ac.uk/fac/sci/med/research/ctu/trials/ohcao/publications/epidemiologyreports/ohcao_epidemiological_report_2023_-_england_overview.pdf Accessed 5 November 2024.
3. Boulton AJ, Del Rios M, Perkins GD. Health inequities in out-of-hospital cardiac arrest. *Curr Opin Crit Care* 2022;28(3):229–36.
4. Brown TP, Booth S, Hawkes CA, et al. Characteristics of neighbourhoods with high incidence of out-of-hospital cardiac arrest and low bystander cardiopulmonary resuscitation rates in England. *Eur Heart J-Qual Care Clin Outc* 2019;5(1):51–62.
5. Raun LH, Jefferson LS, Persse D, Ensor KB. Geospatial analysis for targeting out-of-hospital cardiac arrest intervention. Am J Prev Med 2013;45(2):137–42.
6. Rakun A, Allen J, Shahidah N, et al. Ethnic and neighborhood socioeconomic differences in incidence and survival from out-of-hospital cardiac arrest in Singapore. Prehosp Emerg Care 2019;23(5):619–30.
7. Dicker B, Garrett N, Wong S, et al. Relationship between socioeconomic factors, distribution of public access defibrillators and incidence of out-of-hospital cardiac arrest. *Resuscitation* 2019;138:53–8.
8. Noble S, McLennan D, Noble M, et al. The English indices of deprivation 2019. CLG Ministry of Housing, Editor. London; 2019.
9. Office for National Statistics (ONS). 2021. *Census 2021 geographies*. Available at: https://www.ons.gov.uk/methodology/geography/ukgeographies/censusgeographies/ census2021geographies#lower-layer-super-output-areas-lsoas (Accessed: 16 September 2024).
10. van Nieuwenhuizen BP, Oving I, Kunst AE, et al. Socio-economic differences in incidence, bystander cardiopulmonary resuscitation and survival from out-of-hospital cardiac arrest: a systematic review. *Resuscitation* 2019;141:44–62.
11. Zahra SA, Choudhury RY, Naqvi R, et al. Health inequalities in cardiopulmonary resuscitation and use of automated electrical defibrillators in out-of-hospital cardiac arrest. *Curr Probl Cardiol* 2024;49(5)102484.
12. National Institute for Health and Care Excellence (NICE). 2023. Cardiac arrest - out of hospital care: what is the prognosis? Available at: https://cks.nice.org.uk/topics/cardiac-arrest-out-of-hospital-care/background-information/prognosis/ (Accessed: 23 December, 2024).
13. Ahn KO, Do Shin S, Hwang SS, et al. Association between deprivation status at community level and outcomes from out-of-hospital cardiac arrest: a nationwide observational study. *Resuscitation* 2011;82(3):270–6.
14. de Mestral C, Stringhini S. Socioeconomic status and cardiovascular disease: an update. *Curr Cardiol Rep* 2017;19:1–12.
15. Marmot M. Health equity in England: The Marmot review 10 years on. BMJ 2020;368.
16. Hampshire County Council. 2024. Rural Communities. [online] Available at: https://www.hants.gov.uk/community/rural-communities [Accessed 12 September 2024].
17. Office for National Statistics (ONS). 2024. LSOA (2001) to LSOA (2011) to LAD (December 2011) Best Fit Lookup in EW. Available at: https://www.data.gov.uk/dataset/4048a518-3eaf-457a-905c-9e04f4fffca8/lsoa-2001-to-lsoa-2011-to-lad-december-2011-best-fit-lookup-in-ew (Accessed: 9 October 2024).
18. Chamberlain RC, Barnetson C, Clegg GR, Halbesma N. Association of measures of socioeconomic position with survival following out-of-

hospital cardiac arrest: a systematic review. *Resuscitation* 2020;157:49–59.

19. Bijman LA, Chamberlain RC, Clegg G, Kent A. and Halbesma N. Association of socioeconomic status with 30-day survival following out-of-hospital cardiac arrest in Scotland, 2011–2020. European Heart Journal-Quality of Care and Clinical Outcomes. 2023: qcad053.
20. Pathirana TI, Jackson CA. Socioeconomic status and multimorbidity: a systematic review and meta-analysis. *Aust N Z J Public Health* 2018;42(2):186–94.
21. Majewski D, Ball S, Finn J. Systematic review of the relationship between comorbidity and out-of-hospital cardiac arrest outcomes. *BMJ Open* 2019;9(11)e031655.
22. Troiano P, Masaryk J, Stueven HA, Olson D, Barthell E, Waite EM. The effect of bystander CPR on neurologic outcome in survivors of prehospital cardiac arrests. Resuscitation 1989;17(1):91–8.
23. Vukmir RB. Witnessed arrest, but not delayed bystander cardiopulmonary resuscitation improves prehospital cardiac arrest survival. *Emerg Med J* 2004;21(3):370–3.
24. Brown TP, Perkins GD, Smith CM, Deakin CD, Fothergill R. Are there disparities in the location of automated external defibrillators in England?. *Resuscitation* 2022;170:28–35.
25. Burgoine T, Austin D, Wu J, et al. Automated external defibrillator location and socioeconomic deprivation in Great Britain. *Heart* 2024;110(3):188–94.
26. Wik L, Steen PA, Bircher NG. Quality of bystander cardiopulmonary resuscitation influences outcome after prehospital cardiac arrest. Resuscitation 1994;28(3):195–203.
27. Dziadkowiec O, Durbin J, Muralidharan VJ, Novak M, Cornett B. Improving the quality and design of retrospective clinical outcome studies that utilize electronic health records. *HCA Healthcare Journal of Medicine* 2020;1(3):131–8. Available from: https://doi.org/10.36518/2689-0216.1094.
28. Peters GA, Ordoobadi AJ, Panchal AR, Cash RE. Differences in out-of-hospital cardiac arrest management and outcomes across urban, suburban, and rural settings. Prehosp Emerg Care 2023;27(2):162–9.
29. Coppler PJ, Elmer J, Rittenberger JC, Callaway CW, Wallace DJ. Demographic, social, economic and geographic factors associated with long-term outcomes in a cohort of cardiac arrest survivors. *Resuscitation* 2018;128:31–6.
30. World Health Organization. 2022. WHO Director-General's opening remarks at the media briefing on COVID-19. January, 30.
31. Semeraro F, Gamberini L, Tartaglione M, et al. Out-of-hospital cardiac arrest during the COVID-19 era in Bologna: System response to preserve performances. Resuscitation 2020;157:1–2.
32. Elmer J, Okubo M, Guyette FX, Martin-Gill C. Indirect effects of COVID-19 on OHCA in a low prevalence region. Resuscitation 2020;156:282.
33. Charlton K, Limmer M, Moore H. Incidence of emergency calls and out-of-hospital cardiac arrest deaths during the COVID-19 pandemic: findings from a cross-sectional study in a UK ambulance service. Emerg Med J 2021;38(6):446–9.
34. Fothergill RT, Smith AL, Wrigley F, Perkins GD. Out-of-hospital cardiac arrest in London during the COVID-19 pandemic. Resuscitation plus 2021;5:100066.