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ORIGINAL RESEARCH

Socioeconomic status influences survival after out-of-hospital cardiac arrest outcomes

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Abstract

Background: Socioeconomic status may influence survival after out-of-hospital cardiac arrest (OHCA). This study is the first to assess the association between village-level income quartiles and survival to hospital discharge after OHCA in a mid-sized Asian city where EMS delivery is standardized and geographic variation in access is minimal. **Methods**: We conducted a retrospective analysis of 209 adult residential OHCA cases recorded in the Chiayi City EMS registry in 2024. Income quartiles (Q1–Q4) were defined by case-level distribution as ≤New Taiwan (NT)$823,000, NT$823,001–868,000, NT$868,001–931,000, and >NT$931,000. Three multivariable logistic regression models, each meeting the events-per-variable threshold of ≥10:1, were constructed: discharge (2 covariates: income, shockable rhythm), Return of spontaneous circulation (ROSC) >24 h (4 covariates), and ROSC >2 h (6 covariates). Crude and adjusted odds ratios (ORs) with 95% confidence intervals (CIs) were reported, along with model performance metrics (area under the receiver operating characteristic curve (AUC) and Hosmer-Lemeshow goodness-of-fit). **Results**: Survival to discharge increased from 3.8% in Q1 to 13.5% in Q4 ($p = 0.10$). ROSC >24 h ranged from 11.3% in Q1 to 26.9% in Q4 ($p = 0.09$). ROSC >2 h peaked in Q2 (40.4%) compared with 18.9% in Q1 ($p = 0.02$). Shockable rhythm was a strong predictor of survival (adjusted OR = 17.4, 95% CI 4.2–71.7, $p < 0.01$). EMS response time differed significantly by income quartile ($p = 0.03$), with Q2 showing the shortest times. Model AUCs ranged from 0.78 to 0.80. **Conclusions**: In small urban environments, socioeconomic status appears to influence OHCA outcomes in a non-linear manner, with moderate-income areas demonstrating higher early ROSC rates, potentially due to a greater prevalence of shockable rhythms and favorable community factors. These findings contrast with patterns observed in larger cities and suggest that targeted interventions may help reduce survival disparities.

Keywords

Out-of-hospital cardiac arrest; Socioeconomic factors; Survival to discharge; Return of spontaneous circulation; Emergency medical services

1. Introduction

Out-of-hospital cardiac arrest (OHCA) is a major global public health challenge. Despite improvements in emergency medical services (EMS) systems and advances in resuscitation technology, survival to hospital discharge remains below 10% in many high-income countries [1, 2]. OHCA-related outcomes are largely determined by the early phases of the chain of survival, including recognition of cardiac arrest, initiation of bystander cardiopulmonary resuscitation (CPR), and defibrillation before EMS arrival [3].

Socioeconomic status (SES) influences OHCA outcomes through disparities in CPR training, access to automated external defibrillators (AEDs), and community readiness [4–6]. While studies from Western countries have consistently demonstrated SES-related disparities [7–10], evidence from smaller Asian cities with standardized EMS and minimal geographic variation remains limited.

Taiwan provides a suitable setting for such research, with a universal healthcare system and nationally standardized EMS protocols that ensure equitable access to emergency care across socioeconomic groups [11]. Chiayi City, a mid-sized municipality in southern Taiwan with a population of approximately 270,000, follows these protocols with uniform training and response procedures, minimizing geographic inequality and allowing for focused assessment of village-level socioeconomic factors such as income. Although previous studies in Taiwan have shown the benefits of advanced life support units and mechanical CPR devices [11, 12], few have examined the effect of community income on early survival or public

readiness behaviors such as bystander CPR provision.

This study aimed to (1) evaluate the relationship between village-level income quartiles and survival to hospital discharge; (2) examine disparities in return of spontaneous circulation (ROSC) sustained for more than 24 h; (3) conduct a sensitivity analysis for ROSC sustained for more than 2 h; and (4) assess the potential mediating role of an initial shockable rhythm.

2. Materials and methods

2.1 Study design and setting

This retrospective cohort study analyzed OHCA cases in Chiayi City, Taiwan, during 2024. The city covers an area of 60 km^2 and comprises 84 administrative villages (45 in the east and 39 in the west), with populations of 144,501 and 116,677 residents, respectively. The EMS system, managed by the Chiayi City Fire Bureau, operates seven fire/ambulance stations, 14 ambulances, and 242 public automated external defibrillators (AEDs) located in train stations, schools, and other public facilities. AEDs and EMS resources are distributed uniformly across all 84 villages, ensuring equitable access regardless of income quartile, as confirmed by geospatial mapping, with no significant differences in proximity to EMS stations or AED locations. In this OHCA cohort, the mean EMS response time was 5.23 minutes (standard deviation (SD) 2.3), with variations by income quartile described in the results section. The primary outcome was survival to hospital discharge, and the secondary outcomes were return of spontaneous circulation (ROSC) sustained for more than 2 h and more than 24 h.

2.2 Data sources and linkage

Data were obtained from the Chiayi City EMS registry and comprised patient demographics, incident details, bystander interventions, EMS metrics, and outcomes. Village-level income data (2021, expressed in thousands of NT$) were retrieved from government statistics and linked to OHCA cases by geocoded incident location. Cases were assigned to income quartiles (Q1–Q4) based on case-level distribution: Q1 (≤NT$823,000; 53 cases), Q2 (823,001–868,000; 52 cases), Q3 (868,001–931,000; 52 cases), and Q4 (>NT$931,000; 52 cases). **Supplementary Tables 1**,**2** contains de-identified patient data and corresponding village income levels.

2.3 Study population

Eligible cases included adults (≥18 years) with non-traumatic OHCA occurring in 2024. Exclusion criteria were: (1) traumatic etiology, (2) age <18 years with distinct clinical etiologies and ethical considerations, and (3) incomplete EMS records. ROSC status was not an inclusion or exclusion criterion. Of the 243 OHCA cases recorded, 209 met the eligibility criteria (Fig. 1).

2.4 Data collection and variables

Collected variables included age, sex, incident location, witness status, bystander CPR (civilian, EMS, or none), public AED use (binary), number of AED shocks (categorized as 0, 1–2, or ≥3), initial cardiac rhythm (shockable: ventricular fibrillation/ventricular tachycardia; non-shockable: pulseless electrical activity/asystole), and outcomes (ROSC >2 h, ROSC >24 h, and survival to hospital discharge). All data were de-identified in compliance with Taiwan's Personal Data Protection Act.

2.5 Statistical analysis

The cohort characteristics are summarized using descriptive statistics. Continuous variables were tested for normality using the Shapiro-Wilk test, and normally distributed variables were compared across groups using one-way analysis of variance (ANOVA), and non-normally distributed variables using the Kruskal-Wallis test. When significant differences were detected, *post hoc* pairwise comparisons were performed using Tukey's Honestly Significant Difference (HSD) test for normal variables or Bonferroni-corrected Mann-Whitney U tests for non-normal variables. Linearity between continuous variables was evaluated using linear regression with the coefficient of determination (R^2).

Multivariable logistic regression models were constructed with variable selection based on clinical relevance and univariate significance ($p < 0.2$), while ensuring events-per-variable ratios ≥10 to avoid model instability. Three models were specified: (1) survival to hospital discharge (income quartile, shockable rhythm); (2) ROSC >24 h (income quartile, shockable rhythm, age, witnessed status); and (3) ROSC >2 h (income quartile, shockable rhythm, age, witnessed status, bystander CPR, incident location). Incident location was categorized as residence, clinic/nursing home, public settings (roadside, public building, educational facility, transit station, sports center, workplace), or other. The number of AED shocks was treated as a categorical variable (0, 1–2, ≥3). Multicollinearity was assessed using the variance inflation factor (VIF), with VIF >5 indicating concern; all variables had VIF <2. Crude and adjusted odds ratios (ORs) with 95% confidence intervals (CIs) were reported. Categorical variables were compared using Chi-square tests, with Fisher's exact test or Monte Carlo simulation (10,000 iterations) applied when >20% of cells had expected frequencies <5. Bonferroni correction was applied for *post hoc* comparisons. Data analyses were conducted using the statsmodels package (v0.14.0) in Python within a Jupyter Notebook environment. Propensity score matching was not performed due to the limited sample size and low event rates, which increased the risk of overfitting.

3. Results

3.1 Cohort characteristics

Of the 209 included OHCA cases, 60.3% were male, and the mean age was 71.8 years (SD 15.6). Cases were evenly distributed across income quartiles (Q1–Q4: 53, 52, 52, and 52 cases, respectively). Most incidents occurred in residences (72.7%). Bystander CPR was provided in 62.2% of cases (civilian: 46.9%, EMS: 15.3%), and public AED use was recorded in 2.9%. The mean number of AED shocks was 0.43 (SD 1.01). Age did not differ significantly across income quartiles ($p = 0.88$). EMS response time varied significantly

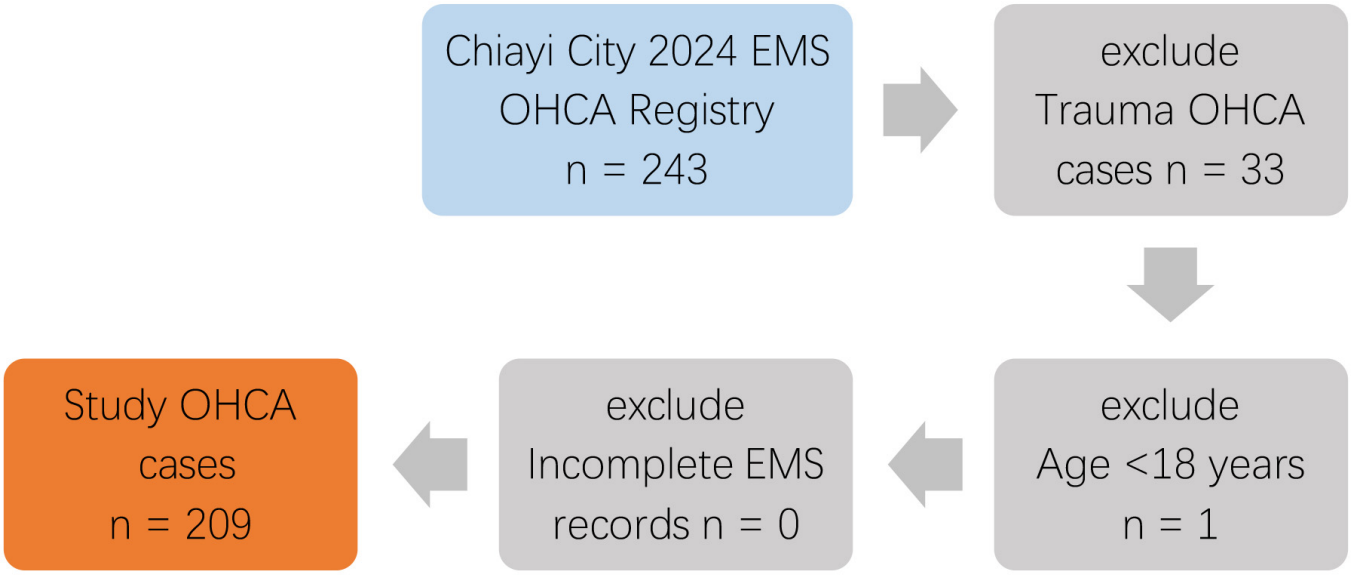

FIGURE 1. Study flowchart for selecting OHCA cases. OHCA, out-of-hospital cardiac arrest; EMS, emergency medical service.

($p = 0.03$), with Q2 recording faster times than Q4 (*post hoc* $p = 0.02$). There was no significant linear relationship between age and EMS response time ($p = 0.32$).

3.2 Incident location by income quartile

Incident locations varied significantly by income quartile (Table 1), with residential settings being predominant in lower quartiles, accounting for 84.9% of incidents in Q1, decreasing to 51.9% in Q4 ($p < 0.01$). In contrast, clinic/nursing home incidents were more frequent in Q4 (23.1%) than in Q1 (0.0%, $p < 0.01$). No significant differences were observed for public settings ($p = 0.55$) or other locations ($p = 0.42$). When location was included as a covariate in the multivariable model for ROSC >2 h, no independent association was found ($p = 0.12$).

3.3 ROSC distribution by income

A total of 68 patients (32.5%) achieved ROSC >2 h, 44 (21.1%) sustained ROSC >24 h, and 18 (8.6%) survived to hospital discharge (Table 1). Outcomes showed a non-linear distribution by income quartile. ROSC >2 h varied significantly (lowest in Q1 at 18.9%, peaking in Q2 at 40.4%; $p = 0.02$), with *post hoc* analysis confirming a difference between Q2 and Q1 ($p = 0.01$). ROSC >24 h demonstrated a borderline trend, ranging from 11.3% in Q1 to 26.9% in Q4 ($p = 0.09$). Survival to hospital discharge increased from 3.8% in Q1 to 13.5% in Q4 ($p = 0.10$), with *post hoc* analysis showing a significant difference between Q4 and Q1 ($p = 0.04$).

3.4 AED shocks and outcomes

AED shock categories (0, 1–2, ≥3) are presented in Table 2. Survival to hospital discharge was highest in patients receiving ≥3 shocks (28.6%), followed by those receiving 1–2 shocks (19.0%) and those with no shocks (5.0%) (adjusted odds ratio (aOR) 3.75, 95% CI 1.21–11.66, $p = 0.02$). However, higher shock counts (≥3) were associated with lower adjusted odds of survival in some cases, likely reflecting refractory arrhythmias (aOR 2.42, 95% CI 0.31–18.84, $p = 0.40$), as multiple shocks often indicate prolonged resuscitation rather than improved prognosis. In addition, there was no evidence of multicollinearity between public AED use and the number of shocks (VIF = 1.02).

There was no multicollinearity between the public AED usage and shock number (VIF = 1.02).

In summary, the higher income quartiles were associated with increased rates of ROSC >2 h and survival to hospital discharge; however, these associations were attenuated and no longer statistically significant after adjustment for confounders. No significant differences across income quartiles were observed for age, bystander CPR rates, or public AED use. EMS response time, however, differed significantly by income quartile.

3.5 Crude and adjusted associations

Crude and adjusted odds ratios for key outcomes by income quartile are shown in Table 3. For survival to hospital discharge, higher income quartiles had greater odds compared to Q1, but the associations did not reach statistical significance after adjustment (Q4 *vs.* Q1: aOR 2.06, 95% CI 0.76–5.64, $p = 0.10$). Shockable rhythm remained a strong independent predictor (aOR 17.4, 95% CI 4.2–71.7, $p < 0.01$). Similar non-significant patterns were observed for ROSC >24 h and >2 h after adjustment. Model performance was satisfactory, with AUC values ranging from 0.78 to 0.80, and no evidence of poor calibration (Hosmer-Lemeshow $p > 0.05$).

4. Discussion

This study examined the relationship between village-level SES and OHCA outcomes in Chiayi City, Taiwan, a small urban setting with a uniform EMS system. Analysis of 209 non-traumatic OHCA cases in 2024 revealed a non-linear

TABLE 1. Cohort characteristics, incident locations, and outcomes by income quartile.

Variable	Q1	Q2	Q3	Q4	Total (n = 209)	*p*-value*
Demographics						
Age, mean (SD)	71.4 (15.8)	72.1 (15.3)	71.9 (16.0)	71.8 (15.4)	71.8 (15.6)	0.877
Male, % (n)	60.4 (32)	59.6 (31)	61.5 (32)	59.6 (31)	60.3 (126)	0.716
Bystander CPR, % (n)	56.6 (30)	67.3 (35)	61.5 (32)	63.5 (33)	62.2 (130)	0.668
Public AED Use, % (n)	1.9 (1)	3.8 (2)	1.9 (1)	3.8 (2)	2.9 (6)	0.881
EMS Response Time, Mean (SD)	5.32 (2.01)	4.88 (1.84)	5.02 (2.15)	5.71 (2.33)	5.23 (2.09)	0.027
AED Shocks, Mean (SD)	0.38 (0.95)	0.46 (1.03)	0.44 (1.02)	0.44 (1.05)	0.43 (1.01)	0.086
Location (n, %)						
Residence	45 (84.9)	41 (78.8)	39 (75.0)	27 (51.9)	152 (72.7)	0.003
Clinic/Nursing Home	0 (0.0)	3 (5.8)	2 (3.8)	12 (23.1)	17 (8.1)	<0.001
Public Settings	1 (1.9)	3 (5.8)	4 (7.7)	3 (5.8)	11 (5.3)	0.552
Others	7 (13.2)	5 (9.6)	7 (13.5)	10 (19.2)	29 (13.9)	0.423
Outcomes, %						
ROSC >2 h	18.9	40.4	34.6	36.5	32.5	0.015
ROSC >24 h	11.3	21.2	25.0	26.9	21.1	0.094
Survival to discharge	3.8	7.7	9.6	13.5	8.6	0.102

**p-values from Kruskal-Wallis test for continuous variables; Chi-square/Fisher's for categorical.*
Q1 = The lowest income quartile; Q4 = The highest income quartile.
Percentages may not sum to 100% due to rounding.
CPR, cardiopulmonary resuscitation; AED, automated external defibrillator; EMS, emergency medical service; ROSC, Return of spontaneous circulation; SD, standard deviation.

TABLE 2. Outcomes by AED shock category.

Shock Category	Number of cases	%ROSC Outcomes		
		ROSC >2 h	ROSC >24 h	Survival to discharge
0	160	26.2	16.9	5.0
1–2	42	45.2	33.3	19.0
≥3	7	100.0	42.9	28.6

ROSC, Return of spontaneous circulation.

TABLE 3. Multivariable regression results.

Outcome	aOR (Q4 *vs.* Q1)	95% CI	*p*-value	AUC
ROSC >2 h	1.32	0.56–3.11	0.53	0.78
ROSC >24 h	2.12	0.70–6.45	0.18	0.79
Survival to Discharge	2.06	0.76–5.64	0.10	0.80

CI, confidence interval; AUC, area under the receiver operating characteristic curve; ROSC, Return of spontaneous circulation; aOR, adjusted odds ratio.

association between neighborhood income and outcomes. Moderate-income areas demonstrated advantages in early ROSC, possibly reflecting balanced resource access and community-level factors that promote prompt resuscitation, while higher-income areas showed a trend toward improved long-term survival. Overall, these findings provide novel insights into the influence of SES on OHCA outcomes in a non-Western, small-city context, addressing a gap in the literature, which has largely focused on large metropolitan or Western populations [13, 14].

4.1 Non-linear SES impact and Q2 peak

Moderate-income neighborhoods showed higher early ROSC rates, potentially attributable to both equitable access to resources and community characteristics that facilitate rapid intervention. This pattern suggests that mid-tier SES communities may exhibit stronger social cohesion, which could enhance

the likelihood of timely bystander CPR, consistent with prior observations in similar settings [11, 13]. The faster EMS response times observed in Q2 may have contributed to these results [12], although other factors such as the prevalence of initial shockable rhythms could also play a role. These findings indicate the importance of considering both clinical and community-level variables in urban EMS planning.

4.2 Shockable rhythm as a dominant predictor

An initial shockable rhythm was strongly associated with survival, aligning with extensive evidence supporting the effectiveness of rapid defibrillation in improving OHCA outcomes [14, 15]. Nevertheless, cases requiring multiple shocks may represent refractory arrhythmias or underlying cardiac pathology, which can limit prognosis despite prompt intervention [14]. The separate contributions of public AED use, and the number of shocks highlight opportunities for targeted community training to enhance early response in diverse SES contexts.

4.3 Incident location and SES

Incident location varied by SES, with wealthier areas having more arrests in institutional settings such as clinics and nursing homes. These environments may require specific response protocols and staff training to optimize early defibrillation and resuscitation efforts [16]. In contrast, lower SES areas showed a greater proportion of arrests in private residences, possibly reflecting reduced access to healthcare facilities. This contrasts with findings from larger cities, where high-SES areas more frequently experience arrests in public settings [17], and suggests that compact city design and uniform EMS coverage may reduce location-related disparities.

4.4 EMS response time and SES

Variation in EMS response times across quartiles may be attributable to subtle geographic or operational differences, such as accessibility in certain neighborhoods. Unlike patterns observed in larger cities, where low-SES areas often experience longer delays due to resource inequities [18], this small urban setting benefits from more consistent EMS coverage. Nonetheless, these differences emphasize the importance of optimizing station placement and community readiness to ensure equitable response times across all SES levels.

4.5 Implications and public health relevance

The patterns observed suggest that moderate-income neighborhoods could serve as models for enhancing bystander readiness through community-based strategies, given their relatively high bystander CPR rates. In high-income areas, the higher proportion of arrests occurring in clinics or nursing homes highlights the need for targeted staff training in early defibrillation. Interventions to improve AED availability and integration in lower SES areas may help reduce disparities. These findings support the development of localized strategies tailored to the social and spatial characteristics of small urban communities [19].

4.6 Comparison with broader literature

The non-linear SES associations observed in this study differ from the linear trends often reported in large metropolitan areas, where higher SES consistently correlates with better outcomes [20]. The importance of shockable rhythms aligns with international findings [15], yet the relatively low rate of public AED use suggests potential cultural, educational, or accessibility barriers compared to countries such as Japan, where public AED engagement is higher [21]. Further investigation incorporating individual-level SES data and detailed geospatial analyses could refine these urban-specific insights.

4.7 Strengths and limitations

This study's strengths include balanced income quartile definitions, use of multiple outcome measures, and conservative statistical modeling to avoid overfitting. Limitations include the modest sample size, the potential influence of unmeasured confounders such as comorbidities, and reliance on village-level income data from 2021. Propensity score matching was not used to preserve statistical power, but multivariable regression accounted for key covariates. Although the incident location was recorded, housing type (*e.g.*, apartment versus single-family home) was not specified, limiting the ability to assess housing-related influences on OHCA outcomes.

5. Conclusions

This study identified a non-linear relationship between neighborhood SES and OHCA outcomes in Chiayi City, with moderate-income areas potentially benefiting from enhanced community cohesion, greater bystander intervention, and efficient emergency responses that support early resuscitation, while higher SES areas may benefit from institutional settings that facilitate rapid access to care. Initial shockable rhythms were a key mediator, emphasizing the importance of timely defibrillation in improving survival across all SES groups. These patterns differ from the linear SES trends reported in larger urban centers, suggesting that uniform EMS systems in small cities can attenuate certain disparities. The findings highlight the need for localized strategies to strengthen bystander readiness and rhythm management without assuming that higher SES universally predicts better outcomes.

AVAILABILITY OF DATA AND MATERIALS

The data that support the findings of this study are included as **Supplementary material** (de-classified patient data and village income).

AUTHOR CONTRIBUTIONS

WTC—conceptualized the study, coordinated data collection from the Chiayi City Fire Bureau, managed the de-identification of the dataset, performed the statistical analysis and drafted the manuscript. CCC—assisted in the statistical analysis, including ROC curve and calibration plot development, and contributed to the interpretation of

results. CCT—assisted with data extraction and reviewed the manuscript for critical revisions. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study analyzed a government-maintained, de-identified database collected by the Chiayi City Fire Bureau for public health and emergency medical services purposes. Because the involved secondary use of legally public information consistent with its original purpose and constituted an evaluation of government-administered public policy effectiveness, the project qualified for exemption from formal Institutional Review Board (IRB) review under Taiwan's Human Subjects Research Act, Articles 5 (1) Categories 2 and 3, as announced by the Department of Health on 05 July 2012 (Wei-Shu-Yi-Tzu No. 1010265075). Consequently, the requirement for obtaining individual informed consent was waived. All procedures conformed to the principles of the Declaration of Helsinki.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at https://oss.signavitae.com/mre-signavitae/article/1978377419629707264/attachment/Supplementary%20material.xlsx.

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