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Research article

Impact of socioeconomic status on cardiac arrest outcomes during COVID-19 pandemic

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ABSTRACT

Introduction: The coronavirus disease 19 (COVID-19) pandemic has affected healthcare services, potentially leading to inequitable outcomes based on patients' socioeconomic status (SES). This study aimed to evaluate the impact of COVID-19 on out-of-hospital cardiac arrest (OHCA) outcomes by examining disparities across SES levels.

Methods: The study analyzed non-traumatic OHCA cases registered in the Korean Out-of-Hospital Cardiac Arrest Registry from 2010 to 2021, encompassing 238,668 patients aged 18 years and older. SES was assessed at both the individual (Medicaid vs non-Medicaid) and area levels using a deprivation index. Outcomes included any return of spontaneous circulation, survival to admission, survival to discharge, and favorable neurological recovery. Logistic regression and generalized additive models (GAMs) were used for analysis.

Results: OHCA outcomes—including survival to admission, survival to discharge, and favorable neurological recovery—improved over the years, peaking in 2019 before subsequently declining. Logistic regression showed that the lowest SES area was associated with lower rates of ROSC (adjusted odds rations [aOR] 0.82, 95 % confidence interval [CI] 0.75–0.88) and survival to admission (aOR 0.56, 95%CI 0.49–0.64) and discharge (aOR 0.78, 95%CI 0.61–0.98) during the pandemic. GAM analysis revealed that lower SES groups (deprivation index levels 4 and 5) experienced higher-than-expected survival to admission and discharge rates, as well as favorable neurological recovery. Although outcomes in the deprivation index level 1 group (5.5 % in 2021) remained superior, indicating poor outcomes for the lowest SES area group (3.43 % in 2021), the disparity decreased following the pandemic.

Conclusion: Lower levels of SES are a significant risk factor for unfavorable neurological recovery in OHCA, independent of the COVID-19 pandemic. However, SES-related disparities in the outcomes decreased post-pandemic. Despite the overall negative impact of COVID-19, certain lower SES groups showed improved survival rates, likely due to differences in the EMS response and healthcare burden across regions.

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1. Introduction

Historically, infectious diseases have disproportionately affected individuals and communities with a lower socioeconomic status (SES) [1]. Previous pandemics, such as the 1918 H1N1 influenza and the more recent H1N1 in 2009, have demonstrated that the morbidity and mortality burden is heavier on those with limited access to healthcare resources, emphasizing the role of SES as a critical determinant of health disparities [2–4]. Lower SES has a negative impact even in cases of out-of-hospital cardiac arrest (OHCA). It is associated with a higher incidence of OHCA, lower rates of bystander cardiopulmonary resuscitation (CPR), and lower survival rates [5].

Recent studies have reported similar results during the coronavirus disease (COVID-19) pandemic. A lower SES was associated with increased cardiovascular disease–related mortality rates. The COVID-19 pandemic has negatively impacted people with a low SES and ethnic minority groups, with mortality rates among those in the most deprived areas being twice that of the least deprived areas [6]. Khanijahani et al. have confirmed that SES is a risk factor for COVID-19 incidence, death, and confirmed diagnosis [7]. This is attributed to access to healthcare, health behaviors, and exposure and vulnerability to diseases. This is interpreted as being influenced by accessibility to healthcare, the level of the community's emergency medical system, and personal factors such as exposure to disease, vulnerability, and health behavior.

Prognosis following an OHCA event involves a complex interplay between immediate medical intervention and post-resuscitation care. SES is often linked to health outcomes, which are influenced not only by personal factors such as the level of education, income, and employment status but also by social determinants such as housing circumstances and community support systems [8,9]. COVID-19 has significantly impacted individual health and the healthcare system as a whole [10].

Given that cardiac arrest treatment is influenced by both the level of the healthcare provider or hospital and the effectiveness of the broader overall emergency medical system, we hypothesized that the impact of COVID-19 on the healthcare system would result in variations in the outcomes of patients who experienced cardiac arrest depending on their SES.

This study aimed to determine whether there was a difference in outcomes between before and during the COVID-19 pandemic depending on the area-level SES of patients with OHCA.

2. Materials and methods

2.1. Study design and population

The data were obtained from the Korean Out-of-Hospital Cardiac Arrest Registry (KOHCAR) of the Korean Disease Control and Prevention Agency (KDCA) [11], a comprehensive nationwide registry established to monitor and enhance the quality of care for patients with OHCA in South Korea. The National Fire Agency integrates emergency medical services (EMS) records to identify target patients who experienced OHCA, confirm prehospital information, and forward this data to the KDCA. The KDCA then conducts medical record reviews to validate hospital treatments and survival outcomes. EMS records, including the EMS run sheet, in-depth OHCA registry, dispatcher CPR registry, and ambulance registry, were consolidated into a unified EMS-assessed OHCA database [12]. In the present study, patients with non-traumatic cardiac arrest who were aged 18 years or older and registered between 2010 and 2021 were eligible ($n = 252,903$). Cases where it was challenging to assess area-level SES because the patient's registered address was unknown ($n = 6291$) were excluded. Additionally, cases where administrative districts were reorganized during the study period and a time-series analysis was not possible ($n = 7944$) were excluded. Ultimately, 238,668 patients were included in the study (Fig. 1).

2.2. Variables

The analysis variables included patient and pre-hospital progress factors, such as age, sex, medical history, location of cardiac

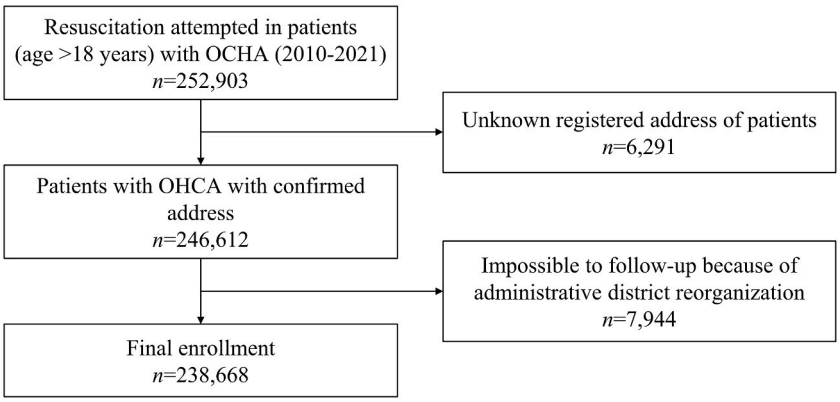


Fig. 1. Process for selecting the study population. OHCA, out-of-hospital cardiac arrest.

arrest, bystander CPR, witness status, level of urbanization (metropolitan vs. non-metropolitan) [13] and hospital treatment variables, such as percutaneous coronary intervention (PCI) and targeted temperature management (TTM). To evaluate SES at the individual level, the participants were categorized into Medicaid and non-Medicaid groups based on health insurance status. To classify area-level SES, we used the deprivation index (DI) developed by Park et al. [14], which sampled 10 % of the data from the 2010 Korean population census at the district level as recorded by the Korean National Statistics Office. Eleven components of the DI were selected (Table 1). Each component was Z-score standardized, and these values were subsequently combined to calculate the DI at the district level [15]. The indices were classified into five levels, ranging from districts with the lowest to the highest level of local deprivation. 'Pre-COVID period' refers to the period from 2010 to 2019, whereas 'COVID period' refers to the period from 2020 to 2021.

2.3. Outcomes

The primary outcome was survival with favorable neurological recovery (Cerebral Performance Category score of 1 or 2) at discharge. Secondary outcomes included return of spontaneous circulation (ROSC), survival to admission, and survival to discharge.

2.4. Statistical analyses

Demographic characteristics are described as percentages (%) for categorical variables or medians with interquartile ranges for continuous variables. Logistic regression modelling was used to examine the association between patient outcomes and SES during the pre-COVID and COVID periods. ROSC and survival to admission were adjusted for patient age, sex, comorbidities, witnessed cardiac arrest, bystander CPR, level of urbanization, and individual- and area-level SES status. Survival to discharge and favorable neurological recovery were adjusted for patient age, sex, comorbidities, witnessed cardiac arrest, bystander CPR, level of urbanization, individual- and area-level SES, PCI, and TTM.

Generalized additive models (GAMs) were used to estimate the association between COVID-19 and OHCA outcomes for area-level SES due to their ability to effectively captures non-linear relationships between variables such as age and patient outcomes, which are critical in our study. GAMs provide a balance between flexibility and interpretability, allowing us to clearly understand the influence of each variable. Moreover, they can be used for continuous and categorical data, making them suitable for our diverse dataset. Finally, they also mitigate the risk of overfitting, ensuring reliable predictions for 2020 and 2021. Clinically important variables were selected for building the models. Based on data from 2010 to 2019, ROSC and survival admission rates for 2020 and 2021 were predicted by adjusting for patient age, sex, comorbidities, witness status, bystander CPR, level of urbanization and SES. Additionally, rates of survival to admission and favorable neurological recovery were predicted by applying TTM to the existing variables, and the differences between the predicted and estimated values were compared. All analyses were performed using R version 4.3.1 (R Foundation for Statistical Computing, Vienna, Austria).

3. Results

3.1. Demographics and outcomes of patients with cardiac arrest

The analysis included the data of 238,668 patients with cardiac arrest between 2010 and 2021 (Table 2). Most of the patients were male (62.7 %). The median age slightly increased from 67 years in 2010 to 75 years in 2021. The DI, a marker of SES, showed a diverse distribution across different levels, with a notable proportion of patients categorized in levels 1 and 2, representing the less deprived segments of the population. The rate of bystander CPR showed a significant increase from 3.8 % in 2010 to 39.4 % in 2021.

OHCA outcomes such as survival to admission, survival to discharge, and favorable neurological recovery improved over the years, peaking in 2019. Subsequently, the outcomes declined.

Table 1
Definition of components of the deprivation index.

Components	Calculation formula
Single-person household	Single-person households/total households
Car ownership	Heads of households without a car/total heads of households
Inadequate housing conditions	Households with inadequate housing conditions/total households
Non-apartment living household	Households with residential type that is not apartment/total households
Female household	Female head of household/total heads of households
Low level of education	Individuals with less than high school education in population aged 30–64 years/total population aged 30–64 years
Old people	People over 65 years of age/total people
Low social status	Heads of households with low social status/total population aged 15–64 years
Marriage status	Divorced or bereaved people over the age of 15 years/total people over the age of 15 years
Male unemployment	Unemployed men aged 15–64 years/total economically active men aged 15–64 years
Homeownership	Self-housing owned household/total households

Table 2
Demographics and outcomes of patients with cardiac arrest.

Variable	Year												
	2010 (n = 15,993)	2011 (n = 16,424)	2012 (n = 17,824)	2013 (n = 18,814)	2014 (n = 19,835)	2015 (n = 20,562)	2016 (n = 19,921)	2017 (n = 20,005)	2018 (n = 21,025	2019 (n = 21,425)	2020 (n = 22,929)	2021 (n = 23,911)	Total (n = 238,668)
Sex, male	10,270 (64.2)	10,364 (63.1)	11,142 (62.5)	11,861 (63.0)	12,284 (61.9)	12,845 (62.5)	12,405 (62.3)	12,617 (63.1)	13,117 (62.4)	13,527 (63.1)	14,338 (62.5)	14,956 (62.5)	149,726 (62.7)
Age (years)	67 [51–77]	71 [57–79]	71 [57–80]	72 [58–80]	73 [59–81]	74 [60–82]	73 [59–81]	74 [60–82]	74 [61–82]	74 [61–82]	75 [61–82]	75 [62–83]	73 [59–81]
Comorbidities													
Hypertension	3806 (23.8)	5023 (30.6)	5650 (31.7)	6051 (32.2)	6109 (30.8)	6346 (30.9)	6465 (32.5)	6795 (34.0)	7603 (36.2)	7997 (37.3)	8302 (36.2)	9395 (39.3)	79,542 (33.3)
Diabetes mellitus	2429 (15.2)	3306 (20.1)	3722 (20.9)	3914 (20.8)	3954 (19.9)	4129 (20.1)	4194 (21.1)	4399 (22.0)	4961 (23.6)	5174 (24.1)	5637 (24.6)	6364 (26.6)	52,183 (21.9)
Heart disease	1373 (8.6)	1874 (11.4)	2151 (12.1)	2776 (14.8)	2844 (14.3)	3061 (14.9)	3040 (15.3)	3519 (17.6)	3851 (18.3)	4224 (19.7)	4352 (19.0)	4652 (19.5)	37,717 (15.8)
Chronic renal disease	411 (2.6)	540 (3.3)	572 (3.2)	907 (4.8)	1029 (5.2)	971 (4.7)	1083 (5.4)	1109 (5.5)	1271 (6.0)	1395 (6.5)	1522 (6.6)	1714 (7.2)	12,524 (5.2)
Chronic respiratory disease	647 (4.0)	818 (5.0)	919 (5.2)	1277 (6.8)	1186 (6.0)	1194 (5.8)	1201 (6.0)	1451 (7.3)	1566 (7.4)	1634 (7.6)	1643 (7.2)	1910 (8.0)	15,446 (6.5)
Stroke	1196 (7.5)	1596 (9.7)	1674 (9.4)	1809 (9.6)	1740 (8.8)	1783 (8.7)	1704 (8.6)	1915 (9.6)	2062 (9.8)	2109 (9.8)	2066 (9.0)	2292 (9.6)	21,946 (9.2)
Insurance													
Medicaid	1167 (8.4)	1475 (10.0)	1506 (9.5)	1609 (9.4)	1738 (9.4)	1744 (9.0)	1722 (9.2)	1853 (10.0)	2071 (10.5)	2255 (11.0)	2341 (10.6)	2538 (11.0)	22,019 (9.9)
Non-Medicaid	12,661 (91.6)	13,263 (90.0)	14,392 (90.5)	15,487 (90.6)	16,783 (90.6)	17,605 (91.0)	16,992 (90.8)	16,743 (90.0)	17,689 (89.5)	18,338 (89.0)	19,778 (89.4)	20,490 (89.0)	200,221 (90.1)
Deprivation index													
Level 1	3984 (24.9)	4032 (24.5)	4630 (26.0)	4628 (24.6)	5005 (25.2)	5214 (25.4)	5208 (26.1)	5077 (25.4)	5621 (26.7)	5756 (26.9)	6113 (26.7)	6528 (27.3)	61,796 (25.9)
Level 2	4317 (27.0)	4510 (27.5)	4667 (26.2)	5008 (26.6)	5218 (26.3)	5604 (27.3)	5382 (27.0)	5335 (26.7)	5467 (26.)	5708 (26.6)	6021 (26.3)	6610 (27.6)	63,847 (26.8)
Level 3	4035 (25.2)	3953 (24.1)	4283 (24.)	4621 (24.6)	4932 (24.9)	4950 (24.1)	4689 (23.5)	4806 (24.0)	5095 (24.2)	4963 (23.2)	5431 (23.7)	5530 (23.1)	57,288 (24.0)
Level 4	2241 (14.0)	2417 (14.7)	2581 (14.5)	2838 (15.1)	2824 (14.2)	2925 (14.2)	2813 (14.1)	2978 (14.9)	2972 (14.1)	3047 (14.2)	3246 (14.2)	3231 (13.5)	34,113 (14.3)
Level 5	1416 (8.9)	1512 (9.2)	1663 (9.3)	1719 (9.1)	1856 (9.4)	1869 (9.1)	1829 (9.2)	1809 (9.0)	1870 (8.9)	1951 (9.1)	2118 (9.2)	2012 (8.4)	21,624 (9.1)
Level of urbanization Metropolitan	6815 (42.6)	6746 (41.1)	7412 (41.6)	7997 (42.5)	8355 (42.1)	8609 (41.9)	8228 (41.3)	8282 (41.4)	8659 (41.2)	8632 (40.3)	9117 (39.8)	9615 (40.2)	98467 (41.3)
Location, public place	1962 (13.4)	2110 (14.5)	2168 (13.8)	2228 (13.7)	2440 (13.8)	2424 (13.4)	2522 (14.6)	2738 (16.2)	2733 (15.8)	2884 (18.0)	2765 (15.2)	2725 (14.6)	29,699 (14.7)
Witnessed	6056 (46.7)	7470 (52.0)	8013 (51.3)	7857 (49.3)	8746 (50.6)	9410 (52.9)	9963 (54.8)	10,737 (56.9)	10,991 (55.1)	10,712 (53.1)	12,334 (55.9)	13,061 (56.7)	115,350 (53.3)
Bystander CPR	613 (3.8)	861 (5.2)	1304 (7.3)	1787 (9.5)	2670 (13.5)	2964 (14.4)	4994 (25.1)	5968 (29.8)	6911 (32.9)	7324 (34.2)	8333 (36.3)	9428 (39.4)	53,157 (22.3)
PCI	115 (0.7)	263 (1.6)	364 (2.0)	392 (2.1)	420 (2.1)	490 (2.4)	1029 (5.2)	1440 (7.2)	1593 (7.6)	1625 (7.6)	1534 (6.7)	1676 (7.0)	10,941 (4.6)
TTM	214 (1.3)	380 (2.3)	552 (3.1)	574 (3.1)	497 (2.5)	449 (2.2)	469 (2.4)	651 (3.3)	780 (3.7)	743 (3.5)	786 (3.4)	835 (3.5)	6930 (2.9)
Outcomes													

(*continued on next page*)

Table 2 (*continued*)

Variable	Year												
	2010 (n = 15,993)	2011 (n = 16,424)	2012 (n = 17,824)	2013 (n = 18,814)	2014 (n = 19,835)	2015 (n = 20,562)	2016 (n = 19,921)	2017 (n = 20,005)	2018 (n = 21,025	2019 (n = 21,425)	2020 (n = 22,929)	2021 (n = 23,911)	Total (n = 238,668)
Any ROSC	4484 (28.0)	4879 (29.7)	5276 (29.6)	5669 (30.1)	6154 (31.)	6761 (32.9)	7135 (35.8)	7581 (37.9)	8116 (38.6)	8387 (39.1)	9030 (39.4)	9801 (41.0)	83,273 (34.9)
Survival to admission	1518 (9.5)	1795 (10.9)	2082 (11.7)	2409 (12.8)	2586 (13.0)	2717 (13.2)	2929 (14.7)	3068 (15.3)	3290 (15.6)	3473 (16.2)	3399 (14.8)	3590 (15.0)	32,856 (13.8)
Survival to discharge	564 (3.5)	745 (4.5)	907 (5.1)	1067 (5.7)	1146 (5.8)	1200 (5.8)	1360 (6.8)	1589 (7.9)	1613 (7.7)	1682 (7.9)	1595 (7.0)	1680 (7.0)	15,148 (6.3)
Favorable neurological recovery	156 (1.0)	306 (1.9)	413 (2.3)	538 (2.9)	694 (3.5)	774 (3.8)	834 (4.2)	1018 (5.1)	1068 (5.1)	1142 (5.3)	1187 (5.2)	1169 (4.9)	9299 (3.9)

Values are presented as n (%) or median (interquartile range).

CPR, cardiopulmonary resuscitation; PCI, percutaneous coronary intervention; TTM, targeted temperature management; ROSC, return of spontaneous circulation.

3.2. Logistic regression analysis of ROSC before and after COVID-19 pandemic

The low-SES (Medicaid) group at the individual level was associated with ROSC, with adjusted odds ratios (aOR) of 0.96 (95 % confidence interval [CI], 0.93–1.00) and 0.90 (95 % CI, 0.85–0.96) in the pre-COVID and COVID periods, respectively. The low-SES group, corresponding to DI level 5, showed a poor outcome, with an aOR of 0.80 (95 % CI, 0.76–0.83) and 0.82 (95 % CI, 0.75–0.88) before and after COVID-19, respectively (Table 3).

3.3. Logistic regression analysis of survival admission and discharge before and after COVID-19 pandemic

During the pre-COVID period, a low individual SES was not significantly associated with survival to admission ($P = 0.521$); however, a significant association was observed during the COVID period ($P < 0.001$). Compared with the group with DI level 1, the aOR for the group with DI level 5 indicated a lower survival to admission rate in the pre-COVID period (0.35, 95 % CI, 0.32–0.38) and during the COVID period (0.56, 95 % CI, 0.49, 0.64), although the disparity decreased (Table 4).

In both the pre-COVID and COVID periods, no significant association was observed between individual SES and survival to discharge. The aOR for the lowest area-level SES group was 0.50 (95 % CI, 0.43–0.58) and 0.78 (95 % CI, 0.61–0.98), respectively, indicating an association with survival discharge, but the difference diminished (Table 5).

3.4. Logistic regression analysis of favorable neurological recovery before and after COVID-19 pandemic

During the pre-COVID period, lower rates of favorable neurological recovery were associated with low individual- and area-level SES; however, regional disparities were not evident during the COVID period (Table 6).

Table 3
Logistic regression results of ROSC during the pre-COVID and COVID periods.

Variable	Pre-COVID period (2010–2019)				COVID period (2020–2021)			
	OR (95 % CI)	*P*-value	aOR (95 % CI)	*P*-value	OR (95 % CI)	*P*-value	aOR (95 % CI)	*P*-value
Sex, female	0.72 (0.70, 0.73)	<0.001	0.84 (0.82,0.85)	<0.001	0.75 (0.73, 0.78)	<0.001	0.87 (0.83, 0.91)	<0.001
Age	0.98 (0.98, 0.98)	<0.001	0.98 (0.98,0.98)	<0.001	0.98 (0.98, 0.98)	<0.001	0.98 (0.98, 0.98)	<0.001
Comorbidities								
Hypertension	1.06 (1.04,1.08)	<0.001	1.18 (1.16,1.21)	<0.001	1.14 (1.09, 1.19)	<0.001	1.14 (1.09, 1.19)	<0.001
Diabetes mellitus	0.95 (0.93,0.97)	<0.001	0.90 (0.87,0.92)	<0.001	0.96 (0.92, 1.01)	0.116	0.96 (0.92, 1.01)	0.116
Heart disease	1.26 (1.23,1.30)	<0.001	1.29 (1.26,1.33)	<0.001	1.20 (1.14, 1.26)	<0.001	1.20 (1.14, 1.26)	<0.001
Chronic renal disease	0.91 (0.87,0.96)	<0.001	0.80 (0.77,0.84)	<0.001	0.75 (0.69, 0.81)	<0.001	0.75 (0.69, 0.81)	<0.001
Chronic respiratory disease	0.70 (0.67,0.73)	<0.001	0.74 (0.71,0.77)	<0.001	0.86 (0.79, 0.92)	<0.001	0.86 (0.79, 0.92)	<0.001
Stroke	0.74 (0.71,0.76)	<0.001	0.79 (0.76,0.82)	<0.001	0.88 (0.82, 0.94)	<0.001	0.88 (0.82, 0.94)	<0.001
Witnessed	1.23 (1.20, 1.25)	<0.001	1.14 (1.11,1.16)	<0.001	1.00 (0.96, 1.04)	0.93	1.00 (0.96, 1.04)	0.930
Bystander CPR	1.74 (1.70, 1.79)	<0.001	1.50 (1.47,1.54)	<0.001	1.20 (1.15, 1.25)	<0.001	1.20 (1.15, 1.25)	<0.001
Insurance, Medicaid	0.92 (0.89, 0.95)	<0.001	0.96 (0.93, 1.00)	0.049	0.93 (0.87, 0.99)	0.015	0.90 (0.85, 0.96)	0.002
Deprivation index								
Level 1	1		1		1		1	
Level 2	0.96 (0.93, 0.98)	<0.001	0.94 (0.91, 0.97)	<0.001	0.94 (0.89, 0.99)	0.014	0.94 (0.89, 0.99)	0.014
Level 3	0.87 (0.85, 0.90)	<0.001	0.92 (0.89, 0.95)	<0.001	0.89 (0.85, 0.94)	<0.001	0.89 (0.85, 0.94)	<0.001
Level 4	0.69 (0.67, 0.72)	<0.001	0.81 (0.78, 0.84)	<0.001	0.79 (0.74, 0.85)	<0.001	0.79 (0.74, 0.85)	<0.001
Level 5	0.59 (0.57, 0.61)	<0.001	0.80 (0.76, 0.83)	<0.001	0.82 (0.75, 0.88)	<0.001	0.82 (0.75, 0.88)	<0.001
Level of urbanization Metropolitan	1.39 (1.36,1.42)	<0.001	1.23 (1.20, 1.25)	<0.001	1.26 (1.22, 1.31)	<0.001	1.18 (1.13, 1.23)	<0.001

ROSC, return of spontaneous circulation, COVID, coronavirus disease; OR, odds ratio; CI, confidence interval; aOR, adjusted odds ratio; CPR, cardiopulmonary resuscitation.

Table 4
— Logistic regression results of survival to admission during the pre-COVID and COVID periods.

Variable	Pre-COVID period (2010–2019)				COVID period (2020–2021)			
	OR (95 % CI)	P-value	aOR (95 % CI)	*P*-value	OR (95 % CI)	*P*-value	aOR (95 % CI)	*P*-value
Sex, female	0.71 (0.69, 0.73)	<0.001	0.93 (0.90, 0.96)	<0.001	0.67 (0.64, 0.71)	<0.001	0.87 (0.82, 0.92)	<0.001
Age	0.97 (0.97, 0.97)	<0.001	0.96 (0.96, 0.96)	<0.001	0.96 (0.96, 0.96)	<0.001	0.96 (0.95, 0.96)	<0.001
Comorbidities								
Hypertension	1.69 (1.64, 1.74)	<0.001	1.80 (1.74, 1.86)	<0.001	1.38 (1.31, 1.45)	<0.001	1.66 (1.56, 1.76)	<0.001
Diabetes mellitus	1.48 (1.44, 1.53)	<0.001	1.19 (1.15, 1.23)	<0.001	1.25 (1.18, 1.32)	<0.001	1.09 (1.02, 1.16)	0.016
Heart disease	1.66 (1.60, 1.71)	<0.001	1.51 (1.45, 1.57)	<0.001	1.50 (1.41, 1.59)	<0.001	1.53 (1.43, 1.64)	<0.001
Chronic renal disease	1.90 (1.81, 2.00)	<0.001	1.37 (1.29, 1.45)	<0.001	1.65 (1.51, 1.80)	<0.001	1.29 (1.17, 1.43)	<0.001
Chronic respiratory disease	1.30 (1.23, 1.36)	<0.001	1.61 (1.53, 1.71)	<0.001	1.19 (1.08, 1.30)	<0.001	1.5 (1.36, 1.65)	<0.001
Stroke	0.95 (0.91, 1.00)	0.045	1.00 (0.95, 1.06)	0.884	0.97 (0.89, 1.06)	0.554	1.09 (0.99, 1.20)	0.077
Witnessed	3.32 (3.22, 3.42)	<0.001	3.03 (2.93, 3.13)	<0.001	3.35 (3.15, 3.56)	<0.001	2.99 (2.81, 3.19)	<0.001
Bystander CPR	2.71 (2.64, 2.79)	<0.001	1.89 (1.83, 1.95)	<0.001	2.58 (2.45, 2.72)	<0.001	1.87 (1.77, 1.98)	<0.001
Insurance, Medicaid	0.97 (0.92, 1.01)	0.179	0.98 (0.93, 1.04)	0.521	0.91 (0.83, 0.99)	0.024	0.85 (0.78, 0.94)	<0.001
Deprivation index								
Level 1	1		1		1		1	
Level 2	0.89 (0.86, 0.93)	<0.001	0.89 (0.86, 0.93)	<0.001	0.93 (0.87, 1.00)	0.042	0.93 (0.87, 1.00)	0.059
Level 3	0.83 (0.80, 0.86)	<0.001	0.90 (0.86, 0.93)	<0.001	0.93 (0.87, 1.00)	0.048	0.97 (0.90, 1.05)	0.466
Level 4	0.46 (0.44, 0.48)	<0.001	0.59 (0.56, 0.63)	<0.001	0.62 (0.56, 0.67)	<0.001	0.73 (0.67, 0.81)	<0.001
Level 5	0.20 (0.19, 0.22)	<0.001	0.35 (0.32, 0.38)	<0.001	0.39 (0.34, 0.44)	<0.001	0.56 (0.49, 0.64)	<0.001
Level of urbanization Metropolitan	1.78 (1.73,1.82)	<0.001	1.37 (1.33, 1.41)	<0.001	1.55 (1.47, 1.63)	<0.001	1.32 (1.25, 1.40)	<0.001

COVID, coronavirus disease; OR, odds ratio; CI, confidence interval; aOR, adjusted odds ratio; CPR, cardiopulmonary resuscitation.

3.5. Difference between predicted outcomes and estimated outcomes after COVID-19 pandemic

For the GAMs, independent variables were tested for statistical significance. The significance of these predictors was determined by examining OR and p-values with strong significance. The ROSC rates observed in 2020 and 2021 were higher than the predicated values, considering patient age, sex, comorbidities, witness, and bystander CPR. Survival to admission and discharge rates during the COVID period were lower than predicted in the groups with DI levels 1, 2, and 3. In contrast, the survival to admission and discharge rates in the DI level 5 group were higher than predicted. The favorable neurological recovery rate was estimated to be lower than predicted in the groups with DI levels 2 in 2021. In the groups with DI levels 1, 2, and 3, the favorable neurological recovery rate decreased after COVID-19, whereas in the groups with DI levels 4 and 5, the actual value increased despite the predicted decrease (Fig. 2).

4. Discussion

This is the first study to investigate the impact of COVID-19 on cardiac arrest outcomes considering both individual- and area-level SES. Independent of the pandemic, a lower individual-level SES was identified as a risk factor for less favorable neurological recovery. However, the disparity based on SES diminished after the onset of COVID-19. Other cardiac arrest outcomes, such as ROSC, survival to admission, and survival to discharge, were lower among individuals and areas with SES levels.

The disparities in cardiac arrest outcomes related to older age and male sex are consistent with previous research findings [16]. These previous studies indicated that men are more likely to engage in health-risk behaviors than women are [16,17]. A lower SES was also associated with poor prognosis, a finding well supported by previous research. Not only was the incidence of OHCA higher in the lower-SES groups [16,18], but the outcomes of OHCA were also poorer in lower SES groups, aligning with the findings of other studies [19,20]. Individuals with a lower SES are more likely to have poor lifestyle habits, such as smoking and drinking, as well as risk factors for cardiovascular diseases, which could lead to poorer prognoses [21–23]. The EMS system in Korea is a government-based, single-tiered public service that provides equal benefits to everyone regardless of their SES level [24]. However, post-hospital arrival

Table 5
— Logistic regression results of survival to discharge during the pre-COVID and COVID periods.

Variable	Pre-COVID period (2010–2019)				COVID period (2020–2021)			
	OR (95 % CI)	*P*-value	aOR (95 % CI)	*P*-value	OR (95 % CI)	*P*-value	aOR (95 % CI)	*P*-value
Sex, female	0.49 (0.47, 0.51)	<0.001	0.88 (0.83, 0.93)	<0.001	0.46 (0.43, 0.51)	<0.001	1.04 (0.93, 1.16)	0.545
Age	0.96 (0.96, 0.96)	<0.001	0.96 (0.96, 0.96)	<0.001	0.95 (0.95, 0.95)	<0.001	0.96 (0.96, 0.96)	<0.001
Comorbidities								
Hypertension	1.53 (1.47, 1.59)	<0.001	1.60 (1.52, 1.69)	<0.001	1.23 (1.15, 1.33)	<0.001	1.38 (1.23, 1.54)	<0.001
Diabetes mellitus	1.11 (1.06, 1.16)	<0.001	0.87 (0.82, 0.93)	<0.001	0.99 (0.91, 1.08)	0.830	0.97 (0.86, 1.09)	0.582
Heart disease	1.90 (1.82, 1.99)	<0.001	1.60 (1.50, 1.69)	<0.001	1.66 (1.53, 1.80)	<0.001	1.56 (1.39, 1.75)	<0.001
Chronic renal disease	1.24 (1.14, 1.34)	<0.001	1.12 (1.01, 1.24)	0.027	1.07 (0.93, 1.22)	0.364	0.93 (0.77, 1.12)	0.452
Chronic respiratory disease	0.92 (0.85, 1.00)	0.049	1.42 (1.29, 1.56)	<0.001	0.70 (0.60, 0.81)	<0.001	1.14 (0.94, 1.39)	0.195
Stroke	0.79 (0.73,0.84)	<0.001	1.08 (0.99, 1.18)	0.087	0.68 (0.59,0.79)	<0.001	1.06 (0.88, 1.27)	0.555
Witnessed	4.97 (4.72, 5.22)	<0.001	3.32 (3.14,3.52)	<0.001	4.51 (4.1, 4.97)	<0.001	2.67 (2.37, 3.02)	<0.001
Bystander CPR	3.51 (3.38, 3.65)	<0.001	1.56 (1.48,1.64)	<0.001	3.20 (2.97, 3.44)	<0.001	1.90 (1.72, 2.10)	<0.001
Insurance, Medicaid	0.77 (0.72, 0.83)	<0.001	1.00 (0.92, 1.09)	0.995	0.71 (0.62, 0.81)	<0.001	0.98 (0.83, 1.15)	0.779
Deprivation index								
Level 1	1		1		1		1	
Level 2	0.89 (0.86, 0.93)	<0.001	0.93 (0.87, 0.99)	0.016	0.93 (0.87, 1)	0.042	0.93 (0.82,1.06)	0.278
Level 3	0.83 (0.8, 0.86)	<0.001	0.86 (0.8, 0.91)	<0.001	0.93 (0.87, 1)	0.048	1.01 (0.88,1.15)	0.924
Level 4	0.46 (0.44, 0.48)	<0.001	0.70 (0.64, 0.76)	<0.001	0.62 (0.56, 0.67)	<0.001	0.96 (0.81, 1.14)	0.66
Level 5	0.20 (0.19, 0.22)	<0.001	0.50 (0.43, 0.58)	<0.001	0.39 (0.34, 0.44)	<0.001	0.78 (0.61, 0.98)	0.033
Level of urbanization Metropolitan	1.80 (1.74,1.87)	<0.001	1.26 (1.20, 1.32)	<0.001	1.55 (1.45,1.67)	<0.001	1.11 (1.01, 1.23)	0.039
PCI	54.46 (51.63, 57.45)	<0.001	24.81 (23.34, 26.38)	<0.001	73.18 (66.62, 80.38)	<0.001	36.81 (33.16, 40.86)	<0.001
TTM	22.03 (20.79, 23.35)	<0.001	8.87 (8.24, 9.56)	<0.001	16.96 (15.26, 18.85)	<0.001	5.44 (4.67, 6.33)	<0.001

COVID, coronavirus disease; OR, odds ratio; CI, confidence interval; aOR, adjusted odds ratio; CPR, cardiopulmonary resuscitation; PCI, percutaneous coronary intervention; TTM, targeted temperature management.

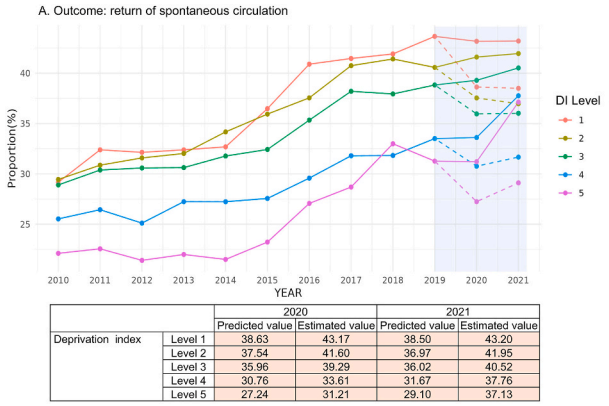
Table 6
— Logistic regression results of favorable neurological recovery during the pre-COVID and COVID periods.

Variable	Pre-COVID period (2010–2019)				COVID period (2020–2021)			
	OR (95 % CI)	*P*-value	aOR (95 % CI)	*P*-value	OR (95 % CI)	*P*-value	aOR (95 % CI)	*P*-value
Sex, female	0.37 (0.35, 0.40)	<0.001	0.79 (0.73, 0.85)	<0.001	0.35 (0.32, 0.39)	<0.001	0.84 (0.73,0.97)	0.014
Age	0.95 (0.95, 0.95)	<0.001	0.95 (0.95, 0.95)	<0.001	0.94 (0.94, 0.95)	<0.001	0.95 (0.94,0.95)	<0.001
Comorbidities								
Hypertension	1.52 (1.41, 1.63)	<0.001	1.52 (1.41, 1.63)	<0.001	1.09 (1.00, 1.18)	0.051	1.38 (1.21, 1.57)	<0.001
Diabetes mellitus	0.68 (0.62, 0.74)	<0.001	0.68 (0.62, 0.74)	<0.001	0.77 (0.70, 0.85)	<0.001	0.75 (0.65, 0.87)	<0.001
Heart disease	1.89 (1.75, 2.04)	<0.001	1.89 (1.75, 2.04)	<0.001	1.75 (1.60, 1.92)	<0.001	1.92 (1.68, 2.20)	<0.001
Chronic renal disease	0.85 (0.73, 1.00)	0.046	0.85 (0.73, 1.00)	0.046	0.67 (0.56, 0.82)	<0.001	0.63 (0.49, 0.81)	<0.001
Chronic respiratory disease	1.06 (0.91, 1.23)	0.452	1.06 (0.91, 1.23)	0.452	0.45 (0.36, 0.56)	<0.001	0.72 (0.55, 0.95)	0.019
Stroke	0.83 (0.72, 0.95)	0.005	0.83 (0.72, 0.95)	0.005	0.50 (0.41, 0.6)	<0.001	0.81 (0.64, 1.03)	0.082
Witnessed	6.91 (6.42, 7.44)	<0.001	3.99 (3.67, 4.34)	<0.001	5.29 (4.69, 5.96)	<0.001	2.78 (2.41, 3.21)	<0.001
Bystander CPR	4.71 (4.49, 4.94)	<0.001	2.01 (1.89, 2.14)	<0.001	3.47 (3.18, 3.79)	<0.001	1.96 (1.75, 2.20)	<0.001
Insurance, Medicaid	0.56 (0.50, 0.62)	<0.001	0.77 (0.68, 0.88)	<0.001	0.58 (0.49, 0.68)	<0.001	0.86 (0.70, 1.06)	0.160
Deprivation index								
Level 1	1		1		1		1	
Level 2	0.88 (0.83, 0.93)	<0.001	0.94 (0.87, 1.02)	0.114	0.89 (0.80, 0.99)	0.034	0.97 (0.84, 1.13)	0.719
Level 3	0.75 (0.70, 0.80)	<0.001	0.89 (0.82, 0.97)	0.009	0.87 (0.78, 0.97)	0.016	1.07 (0.91, 1.24)	0.425
Level 4	0.45 (0.41, 0.49)	<0.001	0.76 (0.68, 0.85)	<0.001	0.68 (0.59, 0.78)	<0.001	1.17 (0.96, 1.42)	0.119
Level 5	0.22 (0.19, 0.25)	<0.001	0.64 (0.53, 0.76)	<0.001	0.48 (0.39, 0.58)	<0.001	0.94 (0.72, 1.23)	0.656
Level of urbanization Metropolitan	1.68 (1.60,1.76)	<0.001	1.12 (1.05, 1.19)	<0.001	1.34 (1.23, 1.45)	<0.001	0.93 (0.83, 1.05)	0.249
PCI	70.99 (66.99, 75.22)	<0.001	30.23 (28.28, 32.32)	<0.001	85.60 (76.98, 95.19)	<0.001	47.45 (42.05, 53.55)	<0.001
TTM	12.61 (11.81, 13.47)	<0.001	2.56 (2.33, 2.80)	<0.001	8.06 (7.15, 9.08)	<0.001	1.00 (0.84, 1.18)	0.977

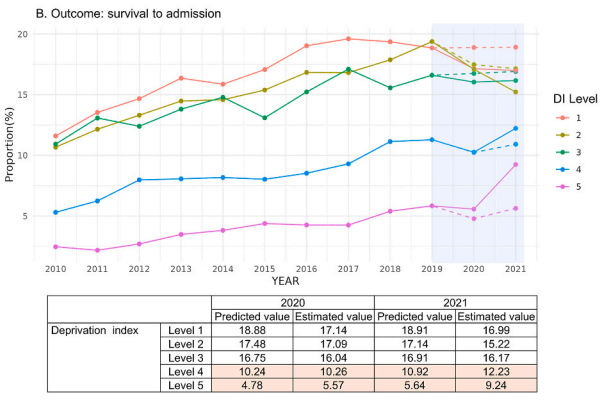
COVID, coronavirus disease; OR, odds ratio; CI, confidence interval; aOR, adjusted odds ratio; CPR, cardiopulmonary resuscitation; PCI, percutaneous coronary intervention; TTM, targeted temperature management.

interventions such as PCI and TTM may be selected differently based on an individual's economic status. This difference could be linked to poor outcomes [25,26].

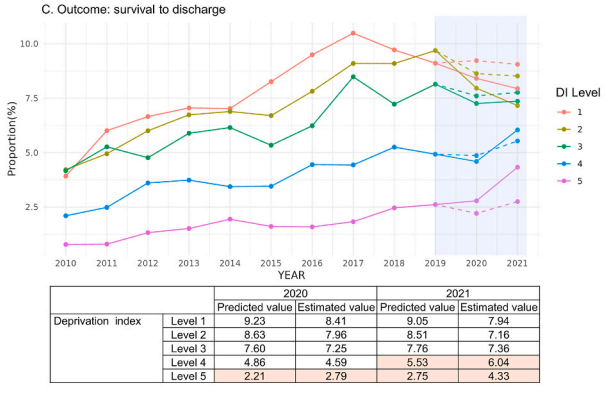
In this study, the groups with DI levels 4 and 5 showed worse outcomes for all metrics than the group with DI level 1. This result can



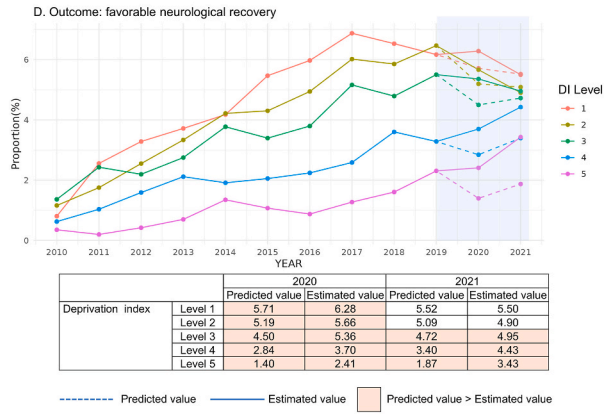
		2020		2021	
		Predicted value	Estimated value	Predicted value	Estimated value
Deprivation index	Level 1	38.63	43.17	38.50	43.20
	Level 2	37.54	41.60	36.97	41.95
	Level 3	35.96	39.29	36.02	40.52
	Level 4	30.76	33.61	31.67	37.76
	Level 5	27.24	31.21	29.10	37.13



		2020		2021	
		Predicted value	Estimated value	Predicted value	Estimated value
Deprivation index	Level 1	18.88	17.14	18.91	16.99
	Level 2	17.48	17.09	17.14	15.22
	Level 3	16.75	16.04	16.91	16.17
	Level 4	10.24	10.26	10.92	12.23
	Level 5	4.78	5.57	5.64	9.24



		2020		2021	
		Predicted value	Estimated value	Predicted value	Estimated value
Deprivation index	Level 1	9.23	8.41	9.05	7.94
	Level 2	8.63	7.96	8.51	7.16
	Level 3	7.60	7.25	7.76	7.36
	Level 4	4.86	4.59	5.53	6.04
	Level 5	2.21	2.79	2.75	4.33



		2020		2021	
		Predicted value	Estimated value	Predicted value	Estimated value
Deprivation index	Level 1	5.71	6.28	5.52	5.50
	Level 2	5.19	5.66	5.09	4.90
	Level 3	4.50	5.36	4.72	4.95
	Level 4	2.84	3.70	3.40	4.43
	Level 5	1.40	2.41	1.87	3.43

Fig. 2. Outcomes of OHCA in the pre-COVID and COVID periods: (A) return of spontaneous circulation, (B) survival to admission, (C) survival to discharge, and (D) favorable neurological recovery. OHCA, out-of-hospital cardiac arrest; COVID, coronavirus.

be attributed to the impact of lower SES areas on every link in the chain of survival. Areas with a lower SES often lack general knowledge about CPR, leading to delayed recognition of cardiac arrest and lower rates of bystander CPR [19,27–29]. Additionally, in lower SES areas, there is a lower installation rate of public access defibrillators and insufficient automated external defibrillator training, which reduces the utilization rate of defibrillation [5]. shows that the rate of bystander CPR before the COVID-19 pandemic was significantly lower in areas with lower SES than that of other areas.

Furthermore, for the chain of survival to progress swiftly to advanced resuscitation, a rapid EMS response is necessary. However, lower SES areas often experience delayed EMS responses [5], whereas communities with a higher SES benefit from shorter EMS response times [30,31]. The abundance of medical facilities, geographic accessibility, and favorable traffic conditions contribute positively to rapid EMS response times in areas with a higher SES [32].

The COVID-19 pandemic has significantly affected the management of patients with OHCA. Numerous studies have reported an increase in the incidence of OHCA following COVID-19 [33–35]. Conversely, survival outcomes decreased by 65 % [36]. Indeed, two studies based on the Korean EMS registry reported a deterioration across all outcome indicators [37,38]. As shown in Fig. 2, although indicators of OHCA outcomes had been improving until 2019, they began to decline during the COVID-19 period. However, after adjusting for patient factors, such as age, sex, bystander CPR, and witness variables, the actual rate of any ROSC exceeded the expected rate. This study excluded cases where pre-hospital resuscitation was initiated but not completed due to hospital transfer, indicating an increase in cases where hospital transfer was abandoned due to the low likelihood for resuscitation success at the scene.

In the analysis by area-level SES, the groups with DI levels 4 and 5 showed interesting results, including increased rates of survival to admission, survival to discharge, and favorable neurological recovery. This contrasts with reports that the spread of COVID-19 has negatively impacted tiers with lower SES. Generally, economic vulnerabilities are known to increase communication inequalities and health disparities [39] and decrease health care utilization [40]. Particularly, the restrictions on social activities due to the COVID-19 pandemic brought more significant economic contractions to low-income workers [41]. The conditions of patients with chronic diseases were exacerbated by restrictions on regular check-ups, an increased consumption of unhealthy foods, and restricted mobility, leading to undiagnosed or untreated metabolic syndrome [42]. These results, which are contradictory to those of previous studies, might be attributed to the different impacts of the EMS system owing to population density and urban structure differences. Historical outbreaks have reported more infections and higher mortality rates in highly urbanized areas [43]. One study has reported that areas

with high cluster cases experienced longer durations of the 2009 H1N1 viral infection [44], and Cave et al. mentioned that cities could become the epicenters of outbreaks [45]. Furthermore, higher-SES areas tend to have higher employment density and social connectivity [46], making them more vulnerable to epidemics because of their productive transient population. Consequently, the spread of COVID-19 pronounced in high-SES areas likely increased the burden on EMS and healthcare facilities relative to fixed healthcare facility resources.

Another factor that may mitigate disparities in outcomes is the public nature of EMS, which is thought to be due to its operation being centered on government initiatives. Although the government-operated EMS system has limitations, such as distribution based on population density, it is applied fairly regardless of a patient's SES [24].

In this study, the witnessed arrest rate in the DI level 5 group increased by 1.12 times after COVID-19 compared to before the pandemic, and bystander CPR increased by 2.5 times. These increases are higher than those observed in the DI level 1 group, indicating a potential reduction in EMS activation time. Furthermore, although this study did not calculate hospital response time, it is a key determinant in the decision to terminate resuscitation [47]. Therefore, we compared the rate of early termination of resuscitation within 20 min across different SES groups. We observed that the decrease in early termination of resuscitation was more pronounced in the lower SES groups compared to the higher SES groups.

Our study has some limitations. First, it focused on patients with OHCA who were transported to hospitals, thereby excluding cases in which resuscitation was abandoned in the pre-hospital phase. During the COVID period, the shortage of medical resources may have led to an increase in pre-hospital TOR [48], [49] potentially causing a selection bias where only patients with a higher likelihood of survival were transported to the hospital. Second, this study is a retrospective study, which precluded the selection of variables by the researchers. Consequently, we were unable to include variables commonly used as individual-level SES indicators, such as education level and occupation. Third, area-level SES were defined based on the first year of the study period (2010), but the SES of some regions has since changed. Finally, the DI was calculated based on the patients' registered residences. If a patient's cardiac arrest occurred outside their district of residence, the DI might have been affected by the EMS system of that particular area.

In conclusion, we identified that lower levels of SES remained a significant risk factor for less favorable neurological recovery, independent of the pandemic. However, the disparities in outcomes based on SES diminished after the onset of COVID-19. Interestingly, despite the overall negative impact of COVID-19 on cardiac arrest outcomes, certain lower SES groups showed improved survival rates, likely due to differences in EMS response and healthcare facility burdens across regions. These results underscore the complex interplay between SES, healthcare access, and emergency medical response, particularly in the context of a global pandemic. Future research should continue to explore these dynamics to improve equity in cardiac arrest care and outcomes. Additionally, research on patients with OHCA who are not transported to the hospital is necessary to assess the extent of underestimated inequalities.

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Data and code availability

The data used to support the findings of this study are available from the corresponding author upon request.

Ethics statement

This retrospective study was approved by the Institutional Review Board of Hallym University Dongtan Sacred Heart Hospital (IRB no. HDT 2024-03-004). Patients' personal information was not collected and informed consent was waived.

CRediT authorship contribution statement

Soonjoo Wang: Writing – review & editing, Writing – original draft, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Hang A. Park:** Writing – review & editing, Writing – original draft, Formal analysis. **Sangsoo Han:** Visualization, Formal analysis. **Ju Ok Park:** Writing – original draft. **Sola Kim:** Writing – original draft, Visualization, Methodology, Formal analysis. **Choung Ah Lee:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization.

Declaration of competing interest

We wish to confirm that there are no known conflicts of interest associated with this publication.

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

We confirm that we have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with respect to intellectual property. In so doing we confirm that we have followed the regulations of our institutions concerning intellectual property.

We understand that the Corresponding Author is the sole contact for the Editorial process (including Editorial Manager and direct communications with the office). He/she is responsible for communicating with the other authors about progress, submissions of

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Glossary

Abbreviations

SES	Socioeconomic Status
OHCA	Out-of-Hospital Cardiac Arrest
CPR	Cardiopulmonary Resuscitation
COVID-19	Coronavirus Disease 2019
KOHCAR	Korean Out-of-Hospital Cardiac Arrest Registry
KDCA	Korean Disease Control and Prevention Agency
EMS	Emergency Medical Services
PCI	Percutaneous Coronary Intervention
TTM	Targeted Temperature Management
DI	Deprivation Index
ROSC:	Return of Spontaneous Circulation
GAM	Generalized Additive Model
aOR	Adjusted Odds Ratio
CI	Confidence Interval

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