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ORIGINAL RESEARCH

Impact of population aging on survival outcome in out-of-hospital cardiac arrest: a retrospective observational cohort study

Song Yi Park[1], Sun Hyu Kim[2,*], Byungho Choi[2]

[1]Department of Emergency Medicine, Ulsan University Hospital, 44033 Ulsan, Republic of Korea
[2]Department of Emergency Medicine, Ulsan University Hospital, University of Ulsan College of Medicine, 44033 Ulsan, Republic of Korea

***Correspondence**
stachy1@uuh.ulsan.kr
(Sun Hyu Kim)

Abstract

Background: Population aging significantly affects the management and outcomes of out-of-hospital cardiac arrest (OHCA). This retrospective cohort study analyzed 2656 adult non-traumatic OHCA cases in Ulsan, South Korea, from January 2017 to December 2022, focusing on trends in survival and age-associated outcomes. **Methods**: The primary outcome was survival to hospital discharge and favorable neurological outcomes, with a secondary focus on age-related survival. Linear and multivariable regression models were employed. **Results**: The number of EMS (emergency medical service) assessed and treated OHCA increased by 16.1% annually, from 298 cases in 2017 to 588 in 2022 (EMS assessed; slope = 0.0008, intercept = −1.5807, r = 0.7187, p = 0.1076, standard error of the estimate (SE) = 0.0004, EMS treated; slope = 0.0004, intercept = −0.8493, r = 0.6731, p = 0.1429, SE = 0.0002). The median age increased from 65.0 years in 2017 to 73.5 years in 2022, with the proportion of individuals over 65 rising from 51.0% in 2017 to 70.0% in 2021 (slope = 0.0357, intercept = −69.7693, r = 0.9564, p = 0.0016, SE = 0.0075). Survival to hospital discharge decreased from 24.5% in 2017 to 13.1% in 2022 (slope = −0.0010, intercept = 2.0954, r = 0.0494, p = 0.6138, SE = 0.0023). However, favorable neurological outcomes improved slightly, from 10.1% in 2017 to 5.8% in 2022 (slope = 0.0040, intercept = −7.4546, r = 0.7539, p = 0.0421, SE = 0.0020). Increasing age was significantly associated with lower survival to hospital discharge (odd ratio = 0.970, $p < 0.001$) and worse neurological outcomes (odd ratio = 0.957, $p < 0.001$). The survival curve revealed a sharp decline around age 50, followed by a slower decline after age 80. **Conclusions**: The study highlights the impact of demographic shifts on OHCA outcomes and the need to optimize emergency medical services for older patients.

Keywords

Aging; Aged; Out-of-hospital cardiac arrest; Emergency medical services; Cardiopulmonary resuscitation

1. Introduction

Out-of-hospital cardiac arrest (OHCA) is a significant global public health challenge, with profound implications for patient survival and long-term outcomes. The reported incidence of OHCA treated by emergency medical services (EMS) personnel worldwide ranges from 30.0 to 97.1 cases per 100,000 person-years [1, 2]. Despite advancements in EMS systems, the survival to hospital discharge rate remains low, with approximately 8% of individuals surviving after OHCA [3, 4].

The global trend of population aging, driven by the increasing life expectancy and declining birth rates, is evident in many regions, including South Korea. South Korea officially became an aged society in 2017, with over 14% of its population aged over 65 years, achieving this status just 17 years after being recognized as an aging society in 2000 [5]. Projections indicate that by 2030, South Korea will boast the highest life expectancy at birth among 35 developed countries, for both males and females [6]. This demographic shift towards an aged society profoundly impacts healthcare systems, especially in managing and predicting outcomes of OHCA. A study in the Netherlands highlighted the importance of age in OHCA outcomes, emphasizing that resuscitation-related factors had a more pronounced impact on OHCA outcomes in elderly patients compared to comorbidity status [7].

While existing studies have explored age as a risk factor in OHCA survival, there is a scarcity of research focusing on the impact of rapid aging on survival outcomes. Understanding the association between the aging population and OHCA survival outcomes can provide critical insights into the interplay of demographic changes, healthcare systems and emergency response strategies. Therefore, this study aims to investigate the temporal trend of survival outcomes in OHCA and to identify the association between age and survival outcomes in rapidly aging communities.

2. Materials and methods

2.1 Study design and setting

This retrospective observational cohort study analyzed data concerning adult patients (age ≥18 years) who experienced nontraumatic OHCA in Ulsan, South Korea, spanning from January 2017 and December 2022.

Ulsan, situated on South Korea's east coast, covers an area of 1057.136 km^2 and had a population of over 1.1 million in 2022. Over the study period, the total population of Ulsan showed a progressive decline (1,157,077 in 2017; 1,150,116 in 2018; 1,143,692 in 2019; 1,135,423 in 2020; 1,120,753 in 2021 and 1,110,516 in 2022), while the proportion of individuals aged over 65 years steadily increased (9.9% in 2017; 10.6% in 2018; 11.4% in 2019; 12.4% in 2020; 13.5% in 2021 and 14.6% in 2022), indicating a shift towards an aged society by 2022 (Fig. 1) [8].

Ulsan's EMS system follows South Korea's National EMS systems, providing multiple dispatches, a basic-to intermediate-level service staffed by emergency medical technicians (EMTs). In 2022, Ulsan had 30 fire stations and a central dispatch center. EMS teams, typically comprising three highly trained personnel, are equipped to deliver immediate on-site cardiopulmonary resuscitation (CPR) and ensure continuous CPR during ambulance transport to the emergency department (ED). These personnel are certified registered nurses or possess qualifications of level 1 and 2 EMT, which correspond to EMT basic and intermediate levels in the United States [9]. EMS personnel confirm cardiac arrest based on the absence of signs of circulation, specifically absence of consciousness, breathing including abnormal breathing and pulse, or the presence of asystole or pulseless electrical activity on the electrocardiogram monitor. EMS personnel are authorized not to initiate or to cease CPR under specific criteria that are met, such as the return of spontaneous circulation, confirmation of death (livor mortis, rigor mortis or putrefaction) or the presence of a do-not-resuscitate (DNR) order. The decision not to initiate CPR initially is the resuscitation withhold, and to cease CPR upon identifying unmistakable signs of death after initiating CPR is the resuscitation withdrawal. The formal declaration of death is the responsibility of physicians within the hospital EDs. Ambulances are not staffed with physicians. EMS personnel conduct advanced life support procedures under the supervision of a medical director as required by law. Medical directors, mostly emergency medicine physicians, provide direct medical oversight in the dispatch center through communication via real-time video phone consultations with EMS teams at the scene, as well as indirect oversight in the fire station through feedback with post-activity reviews. These procedures encompass tasks such as airway management, establishing intravenous (IV) access, administering fluids or medications, and making informed decisions regarding resuscitation withholding or withdrawal [10].

2.2 Study population

All patients evaluated by EMS personnel as experiencing OHCA during the study period were considered for inclusion. Exclusion criteria comprised cases where resuscitation was withheld or withdrawn due to signs of death (livor mortis,

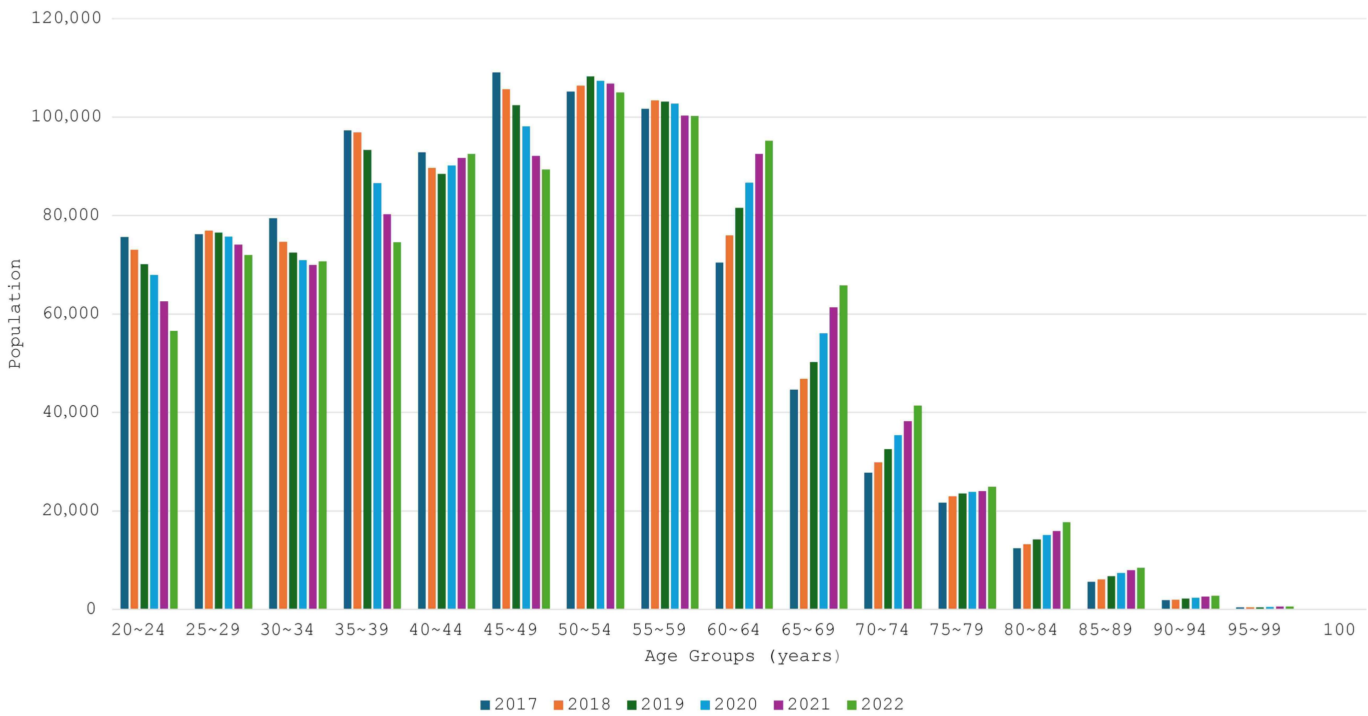

FIGURE 1. Changes in population distribution by age group during the study period, in Ulsan, South Korea.

rigor mortis or putrefaction) or a DNR order, suspected traumatic arrest (including trauma, intoxication or drowning) and individuals under 18 years of age.

2.3 Data source and collection

Data for this study were obtained from both prehospital and hospital stages. Prehospital data were sourced from the Ulsan Fire Agency headquarters, where information on factors influencing survival outcomes was electronically compiled from EMS dispatches and prehospital cardiac arrest patient care reports. Hospital data, encompassing survival outcomes, were collected from the EDs of the 17 receiving hospitals within the region.

Data collection adhered to the Utstein style reporting guidelines for OHCA, ensuring standardized reporting practices [11]. Cardiac arrest was confirmed based on the absence of signs of circulation. Patient variables included age, sex, witnessed arrest status, arrest location and comorbidities, such as hypertension, diabetes mellitus, cardiovascular disease, pulmonary disease, liver disease, renal failure and malignancy. Bystander-related variables included bystander CPR and the utilization of bystander automated external defibrillators (AEDs). EMS-related variables included initial rhythm, advanced airway management, mechanical compression device usage, IV access, epinephrine administration and EMS process times (response time, scene time and transport time). Response Time Interval (RTI) was defined as the time from EMS dispatch to EMS arrival at the scene. Scene Time Interval (STI) was defined as the time from EMS arrival at the scene to EMS departure from the scene. Transport Time Interval (TTI) was defined as the time from EMS departure from the scene to EMS arrival at the ED. Hospital variables included survival to hospital discharge and favorable neurological outcomes. All patients, including those transferred to other hospitals, were monitored until discharge. Neurological outcomes were evaluated using the Cerebral Performance Categories (CPC) scale in discharge records, with CPC scores 1 and 2 considered favorable outcomes [12].

2.4 Outcome measures

The primary outcome was the annual trends of survival to hospital discharge and favorable neurological outcomes rate. The secondary outcome was the association between age and survival outcomes.

2.5 Statistical analysis

Descriptive statistics were used to summarize the characteristics of the study population across each year from 2017 to 2022. Categorical variables were presented as frequencies and percentages, while continuous variables were described using the median and interquartile range (IQR), based on non-normal distributions indicated by the Kolmogorov-Smirnov and Shapiro-Wilk tests.

In trend analysis, a chi-square test was utilized to assess the variability in the proportion across years. Linear regression analysis was employed to investigate temporal trends in these rates, evaluating for consistent patterns of increase or decrease and assessing the statistical significance of observed trends.

Multivariable logistic regression models were constructed to identify the independent associations between predictor variables (age) and the primary outcomes (survival to hospital discharge and favorable neurological outcomes) across all years. Adjusted odds ratios (OR) with 95% confidence intervals (CI) were calculated to quantify the strength and direction of these associations while controlling for potential confounding variables.

Cubic spline models were employed to explore the association between age and survival outcomes. Cubic splines are a specific type of spline curve model that offers a flexible approach to capture complex, non-linear patterns in the data, thus providing a more comprehensive understanding compared to traditional linear models. By considering the entire age range of this study, we thought that the associations may not be discernible through the traditional linear modeling technique. Knots, representing points of flexibility in the cubic spline curve, were strategically placed based on cumulative percentiles of the study population at the 5th, 25th, 50th, 75th and 95th percentiles, ensuring optimal capture of underlying data patterns [13]. Statistical analyses were conducted using SAS software (version 9.4; SAS Institute Inc., Cary, NC, USA); p-value < 0.05 was considered indicative of statistical significance.

3. Results

In Ulsan, there were 280,483 EMS calls during the study period. Of these, EMS personnel assessed 7106 as OHCA. EMS withheld resuscitation for 3314 due to death signs or DNR orders, while initiating resuscitation for 3792. Additionally, resuscitation was withdrawn in 110 cases due to confirmed death during resuscitation. A total of 3682 were transferred to EDs, with 1028 excluded for traumatic arrest, age below 18 or missing data. Finally, 2656 patients were included in the study population (Fig. 2).

3.1 Annual trends of the study population and the survival outcomes

The total EMS calls increased from 44,937 in 2017 to 54,296 in 2022. For the EMS assessed OHCA cases, a linear regression analysis was performed to assess the trend observed over the years. The analysis revealed a slope of 0.0008 and an intercept of −1.5807. The correlation coefficient (r) was calculated as 0.7187, a p-value of 0.1076 with a standard error of the estimate of 0.0004, indicating a moderate positive relationship between the variables. It suggests an increasing trend that did not reach statistical significance. The number of EMS treated OHCA cases shows a similar trend. A linear regression analysis was a slope of 0.0004 and an intercept of −0.8493. The correlation coefficient (r) was calculated as 0.6731, a p-value of 0.1429 with a standard error of the estimate of 0.0002, suggesting an increasing trend but statistically insignificant. However, adult nontraumatic OHCA cases treated and transported by EMS personnel (study population) exhibited a significant increase annually with a slope of 0.0029, an intercept of −5.4574, a correlation coefficient (r) of 0.8849, p-value of

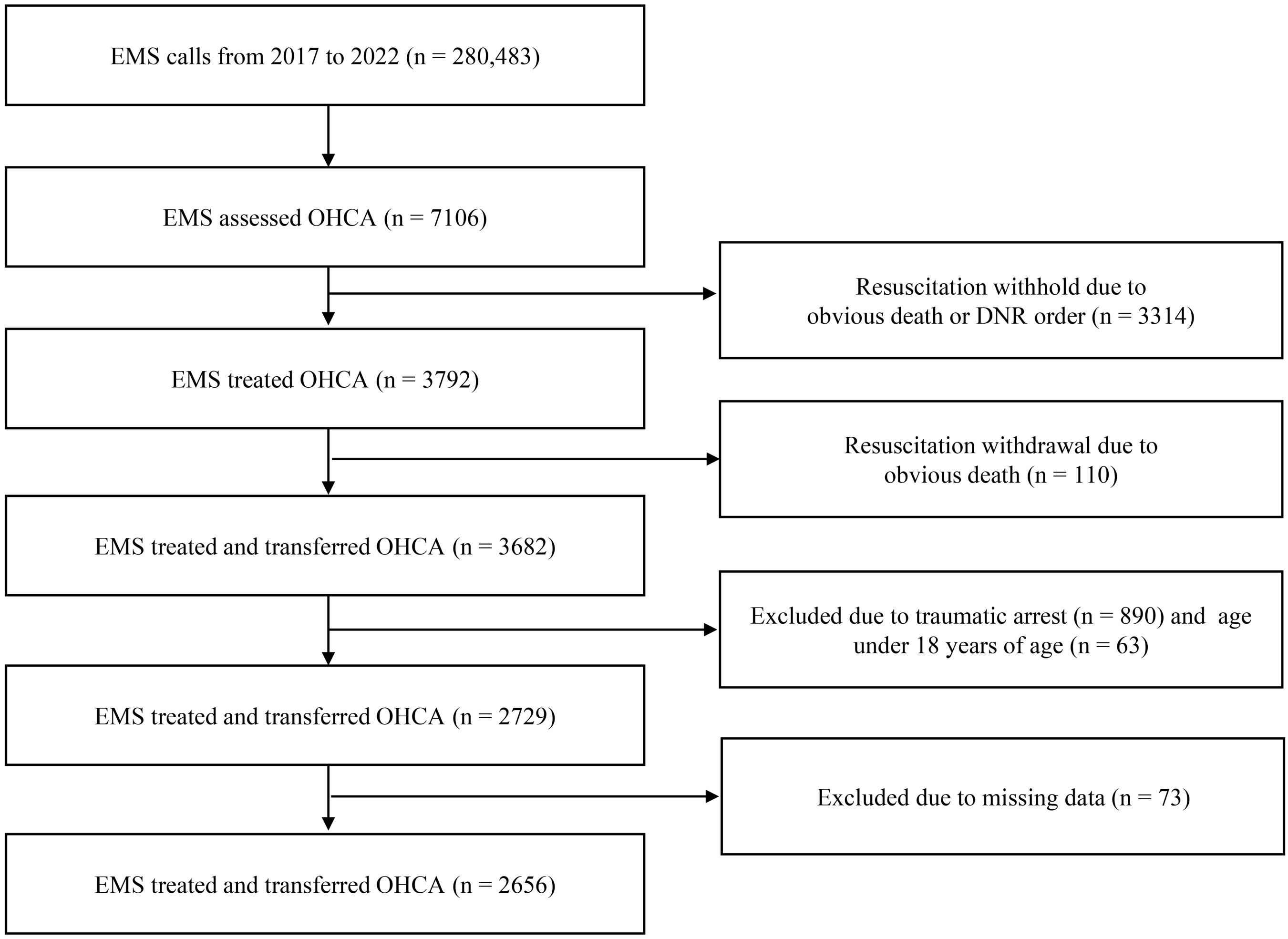

FIGURE 2. Study population inclusion and exclusion process. EMS: emergency medical services; OHCA: out-of-hospital cardiac arrest; DNR: do not resuscitate. Resuscitation withhold denotes the decision not to initiate CPR initially due to obvious death signs such as livor mortis, rigor mortis or putrefaction. Resuscitation withdrawal involves initiating CPR but subsequently ceasing efforts upon identifying unmistakable signs of death.

0.0250 and a standard error of the estimate of 0.0010 (Table 1).

The median age of study population showed a gradual rise, ranging from 65.0 years in 2017 to 73.5 years in 2022. The proportion of patients aged over 65 years increased from 51.0% in 2017 to 70.0% in 2021. A linear regression analysis reveals a slope of 0.0357 and an intercept of −69.7693. The correlation coefficient (r) was calculated as 0.9564, a p-value of 0.0016 with a standard error of the estimate of 0.0075. It indicates that the proportion of patients aged over 65 shows a statistically significant increasing trend over time (Table 2, Fig. 3).

Survival to hospital discharge rate declined consistently from 24.5% in 2017 to 17.5% in 2018, 14.9% in 2019 and 12.3% in 2021, with a slight increase to 13.1% in 2022. The trend analysis was a slope of −0.0010 and an intercept of 2.0954, a correlation coefficient (r) of 0.0494, and a p-value of 0.6138 with a standard error of the estimate of 0.0023, suggesting a slightly decreasing trend over time, but statistically not significant. Favorable neurological outcomes decreased from 10.1% in 2017, 5.4% in 2018, 7.1% in 2019, 6.6% in 2020, 3.4% in 2021, with a subsequent rise to 5.8% in 2022. A linear regression analysis was a slope of 0.0040 and an intercept of −7.4546. The correlation coefficient (r) was calculated as 0.7539, p-value of 0.0421 with a standard error of the estimate of 0.0020. It indicates a favorable neurological outcomes rate shows an increasing trend over time (Table 2).

3.2 Factors impacting survival outcomes

Age showed a significant association with survival to hospital discharge (OR = 0.970, 95% CI: 0.961–0.978, p-value < 0.001). Patients experiencing OHCA in non-public arrest locations (OR = 0.640, 95% CI: 0.473–0.867, p-value = 0.004), those with unwitnessed OHCA events (OR = 0.532, 95% CI: 0.403–0.702, p-value < 0.001), and those with non-shockable rhythm (OR = 0.273, 95% CI: 0.203–0.366, p-value < 0.001) exhibited lower odds of survive to hospital discharge compared to those sustaining OHCA in public locations, witnessed OHCA, and shockable rhythm (Table 3).

Increasing age was significantly associated with unfavorable neurological outcomes (OR = 0.957, 95% CI: 0.941–0.973, p-value < 0.001). Unwitnessed OHCA events (OR = 0.442, 95% CI: 0.256–0.762, p-value = 0.003) and non-shockable rhythm (OR = 0.055, 95% CI: 0.031–0.096, p-value < 0.001) were associated with decreased odds of favorable neurological outcomes (Table 4).

TABLE 1. Annual trend of the study population.

Variables	Total	2017	2018	2019	2020	2021	2022
Total EMS call	280,483	44,937	44,218	44,822	43,194	49,016	54,296
EMS assessed OHCA	7106 (2.5%)	972 (2.2%)$^{1)}$	1100 (2.5%)	1143 (2.6%)	1205 (2.8%)	1267 (2.6%)	1419 (2.6%)
Resuscitation withholds	3314 (46.6%)	459 (47.2%)$^{2)}$	516 (46.9%)	524 (45.8%)	556 (46.1%)	588 (46.4%)	671 (47.3%)
EMS treated OHCA	3792 (1.4%)	513 (1.1%)$^{1)}$	584 (1.3%)	619 (1.4%)	649 (1.5%)	679 (1.4%)	748 (1.4%)
Resuscitation withdrawal	110 (2.9%)	29 (5.7%)$^{3)}$	25 (4.3%)	17 (2.7%)	19 (2.9%)	8 (1.2%)	12 (1.6%)
EMS transported OHCA	3682 (1.3%)	484 (1.1%)$^{1)}$	559 (1.3%)	602 (1.3%)	630 (1.5%)	671 (1.4%)	736 (1.4%)
Traumatic OHCA	890 (12.5%)	139 (14.3%)$^{4)}$	158 (14.4%)	156 (13.6%)	148 (12.3%)	155 (12.2%)	134 (9.4%)
OHCA under 18 years	63 (0.9%)	20 (2.1%)$^{4)}$	11 (1.0%)	11 (1.0%)	5 (0.4%)	7 (0.6%)	9 (0.6%)
Missing data	73 (1.0%)	27 (2.8%)$^{4)}$	17 (1.5%)	11 (1.0%)	7 (0.6%)	6 (0.5%)	5 (0.4%)
Study population	2656 (0.9%)	298 (0.7%)$^{1)}$	373 (0.8%)	424 (0.9%)	470 (1.1%)	503 (1.0%)	588 (1.1%)

EMS: emergency medical services; OHCA: out-of-hospital cardiac arrest; $^{1)}$: The ratio of EMS assessed OHCA cases to the total EMS calls; $^{2)}$: the ratio of resuscitation withholds to the EMS assessed OHCA; $^{3)}$: the ratio of resuscitation withdrawal to the EMS treated to the EMS treated OHCA; $^{4)}$: the ratio of traumatic OHCA, OHCA under 18 years and missing data to the EMS assessed OHCA.

TABLE 2. Demographic and clinical characteristics of the study population.

Variables	Total	2017	2018	2019	2020	2021	2022
Number of patients	n = 2656	n = 298	n = 373	n = 424	n = 470	n = 503	n = 588
Patient variables							
Age (median, IQR)	71.0 (58.0–81.0)	65.0 (54.0–79.0)	68.0 (56.0–79.0)	72.0 (57.0–81.0)	70.0 (57.0–80.0)	73.0 (62.0–82.0)	73.5 (61.0–83.0)
Age >65 yr	1665 (62.7)	152 (51.0)	217 (58.2)	263 (62.0)	286 (60.9)	352 (70.0)	395 (67.2)
Sex (male)	1643 (61.9)	197 (66.1)	252 (67.6)	274 (64.6)	280 (59.6)	314 (62.4)	326 (55.4)
Comorbidities	n = 2402	n = 182	n = 320	n = 348	n = 435	n = 507	n = 610
Hypertension	681 (28.4)	50 (27.5)	95 (29.7)	96 (27.6)	113 (26.0)	153 (30.2)	174 (28.5)
Diabetes mellitus	527 (21.9)	33 (18.1)	64 (20.0)	74 (21.3)	103 (23.7)	110 (21.7)	143 (23.4)
Cerebrovascular disease	169 (7.0)	12 (6.6)	27 (8.4)	31 (8.9)	22 (5.1)	33 (6.5)	44 (7.2)
Cardiovascular disease	398 (16.6)	35 (19.2)	62 (19.4)	58 (16.7)	73 (16.8)	75 (14.8)	95 (15.6)
Pulmonary disease	169 (7.0)	16 (8.8)	24 (7.5)	24 (6.9)	29 (6.7)	34 (6.7)	42 (6.9)
Liver disease	51 (2.1)	3 (1.6)	7 (2.2)	3 (0.9)	14 (3.2)	13 (2.6)	11 (1.8)
Renal failure	103 (4.3)	8 (4.4)	9 (2.8)	15 (4.3)	20 (4.6)	23 (4.5)	28 (4.6)
Malignancy	304 (12.7)	25 (13.7)	32 (10.0)	47 (13.5)	61 (14.0)	66 (13.0)	73 (12.0)
Arrest location							
Public	462 (17.4)	72 (24.2)	79 (21.2)	74 (17.5)	75 (16.0)	83 (16.5)	79 (13.4)
Non-public	2029 (76.4)	208 (69.8)	273 (73.2)	321 (75.7)	364 (77.4)	390 (77.5)	473 (80.4)
Ambulance	165 (6.2)	18 (6.0)	21 (5.6)	29 (6.8)	31 (6.6)	30 (6.0)	36 (6.1)

TABLE 2. Continued.

Variables	Total	2017	2018	2019	2020	2021	2022
Number of patients	n = 2656	n = 298	n = 373	n = 424	n = 470	n = 503	n = 588
Witnessed status							
EMS witnessed	206 (7.8)	15 (5.0)	22 (5.9)	34 (8.0)	47 (10.0)	40 (8.0)	48 (8.2)
Bystander witnessed	1039 (39.0)	147 (44.3)	182 (42.9)	189 (36.6)	234 (39.8)	242 (40.1)	251 (34.5)
Unwitnessed	1189 (44.8)	93 (31.2)	139 (37.3)	209 (49.3)	222 (47.2)	233 (46.3)	293 (49.8)
Unknown	222 (8.4)	58 (19.5)	52 (13.9)	26 (6.1)	14 (3.0)	28 (5.6)	44 (7.5)
Bystander variables							
Bystander AED							
Applied	119 (4.5)	54 (18.1)	37 (9.9)	28 (6.6)	0 (0.0)	0 (0.0)	0 (0.0)
Not applied	2537 (95.5)	244 (81.9)	336 (90.1)	396 (93.4)	470 (100.0)	503 (100.0)	588 (100.0)
Bystander CPR							
Performed	1616 (60.8)	202 (67.8)	250 (67.0)	265 (62.5)	283 (60.2)	300 (59.6)	316 (53.7)
Unperformed	983 (37.0)	84 (28.2)	111 (29.8)	149 (35.1)	179 (38.1)	194 (38.6)	266 (45.2)
Unknown	57 (2.1)	12 (4.0)	12 (3.2)	10 (2.4)	8 (1.7)	9 (1.8)	6 (1.0)
EMS variables							
Initial rhythm at the scene							
Shockable	445 (16.8)	78 (26.2)	84 (22.5)	63 (14.9)	78 (16.6)	67 (13.3)	75 (12.8)
Non-shockable	2211 (83.2)	220 (73.8)	289 (77.5)	361 (85.1)	392 (83.4)	436 (86.7)	513 (87.2)
EMS process time (min)							
RTI	7 (5.0–9.0)	6.5 (5.0–9.0)	6 (5.0–8.0)	6 (5.0–9.0)	7 (5.0–9.0)	7 (6.0–9.0)	8 (6.0–10.0)
STI	14 (11.0–17.0)	12 (8.0–16.0)	13 (10.0–15.0)	13 (10.0–16.5)	14 (11.0–18.0)	14 (12.0–18.0)	15 (11.0–18.0)
TTI	5 (3.0–8.0)	4 (3.0–7.0)	4 (3.0–8.0)	5 (3.0–8.0)	5 (3.0–8.0)	5 (3.0–9.0)	5 (3.0–9.0)
Advanced airway							
No advanced airway	410 (15.4)	115 (38.6)	80 (21.4)	59 (13.9)	26 (5.5)	42 (8.3)	88 (15.0)
Tracheal intubation	291 (11.0)	83 (27.9)	83 (22.3)	45 (10.6)	31 (6.6)	29 (5.8)	20 (3.4)
I-gel/Supraglottic	1955 (73.6)	100 (33.6)	210 (56.3)	320 (75.5)	413 (87.9)	432 (85.9)	480 (81.6)
Mechanical compression							
Applied	1258 (47.4)	12 (4.0)	53 (14.2)	130 (30.7)	257 (54.7)	374 (74.4)	432 (73.5)
Not applied	1398 (52.6)	286 (96.0)	320 (85.8)	294 (69.3)	213 (45.3)	129 (25.6)	156 (26.5)
IV access							
Present	1438 (54.1)	142 (47.7)	209 (56.0)	221 (52.1)	281 (59.8)	324 (64.4)	261 (44.4)
Not present	1218 (45.9)	156 (52.3)	164 (44.0)	203 (47.9)	189 (40.2)	179 (35.6)	327 (55.6)
Epinephrine use							
Administered	371 (14.0)	33 (11.1)	36 (9.7)	21 (5.0)	76 (16.2)	113 (22.5)	92 (15.6)
Not administered	2285 (86.0)	265 (88.9)	337 (90.3)	403 (95.0)	394 (83.8)	390 (77.5)	496 (84.4)
Survival outcomes							
Survival to discharge	432 (16.3)	73 (24.5)	76 (20.4)	74 (17.5)	70 (14.9)	62 (12.3)	77 (13.1)
Favorable neurological outcome	162 (6.1)	30 (10.1)	20 (5.4)	30 (7.1)	31 (6.6)	17 (3.4)	34 (5.8)

Figs are presented as numbers (percentages).
IQR: interquartile range; EMS: emergency medical services; AED: automated external defibrillator; CPR: cardiopulmonary resuscitation; RTI: response time interval; STI: scene time interval; TTI: transport time interval; IV: intravenous.

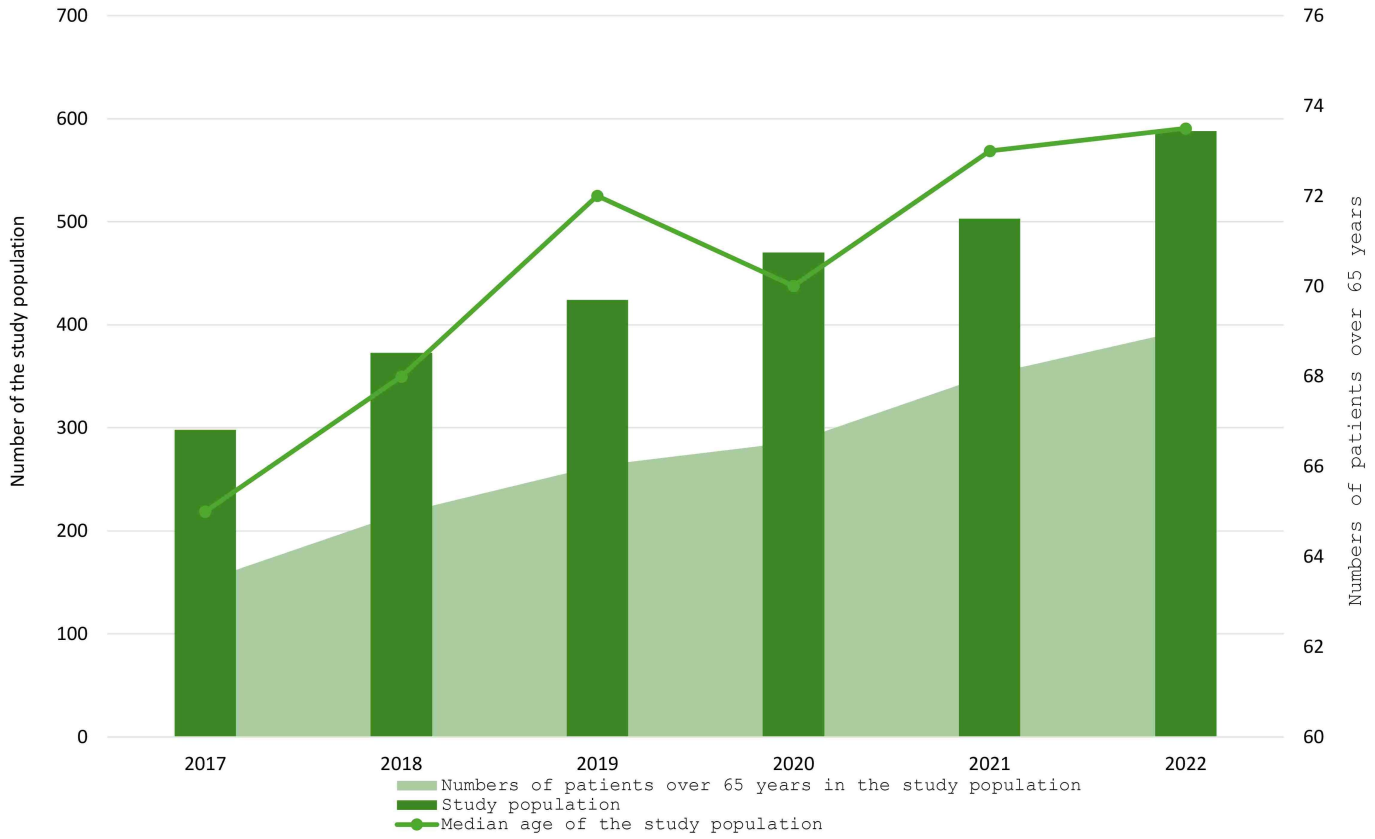

FIGURE 3. The annual trends of the study population.

TABLE 3. Factors associated with survival to hospital discharge in the study population: multivariable logistic regression analysis.

Variables	Odds Ratio (95% Confidence Interval)	*p*-value
	Patient variables	
Age	0.970 (0.961–0.978)	<0.001
Sex		
Male	Reference	0.748
Female	1.048 (0.787–1.395)	
Comorbidities[1)]		
Hypertension	1.164 (0.847–1.600)	0.349
Diabetes mellitus	1.017 (0.712–1.452)	0.927
Cerebrovascular disease	0.941 (0.524–1.691)	0.840
Cardiovascular disease	1.638 (1.163–2.306)	0.005
Pulmonary disease	0.912 (0.481–1.729)	0.779
Liver disease	1.052 (0.386–2.868)	0.921
Renal failure	1.930 (1.036–3.597)	0.038
Malignancy	0.569 (0.334–0.967)	0.037
Arrest location		
Public	Reference	0.001
Non-public	0.640 (0.473–0.867)	0.004
Ambulance	2.199 (0.928–5.211)	0.073
Witnessed status		
Witnessed	Reference	<0.001
Unwitnessed	0.532 (0.403–0.702)	

TABLE 3. Continued.

Variables	Odds Ratio (95% Confidence Interval)	*p*-value
	Bystander variables	
Bystander AED		
Applied	Reference	0.663
Not applied	1.168 (0.580–2.351)	
Bystander CPR		
Performed	Reference	0.784
Unperformed	0.962 (0.729–1.270)	
	EMS variables	
Initial rhythm at the scene		
Shockable	Reference	<0.001
Non-shockable	0.273 (0.203–0.366)	
EMS process time (min)		
RTI	0.968 (0.935–1.003)	0.073
STI	0.972 (0.946–0.998)	0.037
TTI	1.026 (1.005–1.049)	0.017
Advanced airway		
No advanced airway	Reference	0.253
Tracheal intubation	0.689 (0.419–1.133)	0.142
I-gel/Supraglottic airway	0.761 (0.533–1.088)	0.134
Mechanical compression		
Applied	Reference	<0.001
Not applied	2.218 (1.664–2.957)	
IV access		
Present	Reference	0.265
Not present	0.853 (0.645–1.128)	
Epinephrine use		
Administered	Reference	0.091
Not administered	1.432 (0.944–2.174)	

[1)]: *The reference for comorbidities is the absence of diseases.*
AED: automated external defibrillator; CPR: cardiopulmonary resuscitation; EMS: emergency medical services; RTI: response time interval; STI: scene time interval; TTI: transport time interval; IV: intravenous.

TABLE 4. Factors associated with favorable neurological outcome in the study population: multivariable logistic regression analysis.

Variables	Odds Ratio (95% Confidence Interval)	*p*-value
	Patient variables	
Age	0.957 (0.941–0.973)	<0.001
Sex		
Male	Reference	0.971
Female	1.011 (0.556–1.837)	
Comorbidities[1)]		
Hypertension	1.315 (0.737–2.345)	0.354
Diabetes mellitus	1.552 (0.766–3.142)	0.222
Cerebrovascular disease	1.422 (0.416–4.862)	0.575
Cardiovascular disease	2.509 (1.357–4.637)	0.003
Pulmonary disease	0.000 (0.000–0.000)	0.996
Liver disease	1.130 (0.083–15.369)	0.927
Renal failure	0.788 (0.164–3.794)	0.766
Malignancy	1.016 (0.346–2.986)	0.977

TABLE 4. Continued.

Variables	Odds Ratio (95% Confidence Interval)	p-value
Arrest location		
Public	Reference	0.397
Non-public	0.707 (0.429–1.166)	0.174
Ambulance	0.544 (0.231–1.283)	0.997
Witnessed status		
Witnessed	Reference	0.003
Unwitnessed	0.442 (0.256–0.762)	
	Bystander variables	
Bystander AED		
Applied	Reference	0.743
Not applied	1.247 (0.332–4.686)	
Bystander CPR		
Performed	Reference	0.124
Unperformed	0.645 (0.369–1.128)	
	EMS variables	
Initial rhythm at the scene		
Shockable	Reference	<0.001
Non-shockable	0.055 (0.031–0.096)	
EMS process time (min)		
RTI	0.880 (0.814–0.951)	0.001
STI	0.978 (0.933–1.025)	0.346
TTI	1.080 (1.045–1.116)	<0.001
Advanced airway		
No advanced airway	Reference	0.007
Tracheal intubation	0.255 (0.107–0.606)	0.002
I-gel/Supraglottic airway	0.521 (0.289–0.937)	0.030
Mechanical compression		
Applied	Reference	<0.001
Not applied	8.405 (4.203–16.806)	
IV access		
Present	Reference	0.884
Not present	0.964 (0.590–1.575)	
Epinephrine use		
Administered	Reference	0.120
Not administered	1.877 (0.849–4.150)	

[1)]: *The reference for comorbidities is the absence of diseases.*
AED: automated external defibrillator; CPR: cardiopulmonary resuscitation; EMS: emergency medical services; RTI: response time interval; STI: scene time interval; TTI: transport time interval; IV: intravenous.

3.3 Association between age groups and survival outcomes

To perform the cubic spline models, age categories were placed based on cumulative percentiles of the study population at the 5th, 25th, 50th, 75th and 95th percentiles. Age categories were placed based on cumulative percentiles of the study population at the 5th, 25th, 50th, 75th and 95th percentiles. Accordingly, categories were used: age <42 (147 patients, 5.5%), 42 $\leq$ age $<$ 59 (522 patients, 19.7%), 59 $\leq$ age $<$ 72 (680 patients, 25.6%), 72 $\leq$ age $<$ 81 (690 patients, 26.0%), 81 $\leq$ age $<$ 91 (458 patients, 17.2%) and age $\geq$91 (159 patients, 6.0%). Patients aged between 72 and 81 years exhibited significantly decreased survival in both unadjusted and adjusted analyses after controlling for covariates including sex, comorbidities, witnessed status, bystander AED, bystander CPR, initial rhythm, EMS process time, advanced airway, mechanical compression, IV access and epinephrine use (unadjusted OR = 0.336, CI: 0.218–0.518, p-value < 0.001; adjusted OR = 0.422, CI: 0.253–0.703, p-value = 0.001). However, for patients aged ≥81 years, the lack of significant results was attributed to the absence of cases in this age group (Table 5).

The spline curve depicting the survival to hospital discharge reveals a notable decline around the age of 50, with a gradual slowing of this decline observed after the age of 80 years. A similar pattern was observed for the OR curve for favorable neurological outcomes (Fig. 4).

4. Discussion

This study aimed to investigate the temporal trends of survival outcomes in OHCA and their association with age and survival outcomes in Ulsan, a rapidly aging and aged urban center in South Korea. Our findings revealed a consistent yearly increase trend in EMS assessed and treated OHCA cases. Survival to hospital discharge rates shows a decreasing trend, while favorable neurological outcomes rates show an increasing trend from 2017 to 2022. Age, comorbidities, arrest location, witnessed status, initial rhythm and EMS interventions emerged as significant factors influencing both survival to hospital discharge and favorable neurological outcomes. An important finding is the observed correlation between age and survival outcomes, with odds ratios decreasing around age 50 and showing a gradual stabilization after age 80. These results provide insights into the impact of age on OHCA dynamics, particularly in the context of survival outcomes in aging populations.

The proportion of OHCA patients aged over 65 years varies among countries. In Japan, 75.1% of OHCA patients in 2015 were over 65 years of age, increasing to 75.7% in 2018 [14, 15]. In contrast, a Danish study conducted in 2015 reported a proportion of 66.3% [16]. In our study, the average proportion of patients aged over 65 years during the study period was 62.7%, with a notable increase from 51.0% in 2017 to 70.0% in 2021. This rise in OHCA cases can strain the dedicated EMS system, considering the time required to train EMS personnel.

The higher survival outcome of OHCA patients around 50 is likely attributable to the substantial proportion of the population in Ulsan currently being within their 50s age group (Fig. 1). The increase in the proportion of the population aged over 65 years in the community implies a corresponding rise in the average age of OHCA patients. According to the cubic spline mode derived from this study, even after adjusting for confounding factors such as sex, comorbidities, bystander and EMS-associated variables, survival outcomes decreased when the age of OHCA patients exceeded around 50 years. This suggests that if the local EMS system remains unchanged and the health status of the Ulsan population remains stable, any de-

TABLE 5. Age-related survival outcomes in the study population.

Survival to hospital discharge					
		Unadjusted logistic regression		Adjusted logistic regression	
Age group (yr)	Patients (%)	Odds Ratio (95% Confidence Interval)	p-value	Odds Ratio (95% Confidence Interval)	p-value
Age <42	40 (27.2)	Ref.	<0.001	Ref.	<0.001
42 ≤ age < 59	131 (25.1)	0.896 (0.593–1.355)	0.604	0.761 (0.471–1.229)	0.264
59 ≤ age < 72	160 (23.5)	0.823 (0.549–1.233)	0.345	0.812 (0.504–1.308)	0.392
72 ≤ age < 81	77 (11.2)	0.336 (0.218–0.518)	<0.001	0.422 (0.253–0.703)	0.001
81 ≤ age < 91	22 (4.8)	0.135 (0.077–0.237)	<0.001	0.160 (0.085–0.302)	<0.001
Age ≥91	2 (1.3)	0.034 (0.008–0.144)	<0.001	0.041 (0.009–0.180)	<0.001
Favorable neurological outcomes					
		Unadjusted logistic regression		Adjusted logistic regression	
Age group (yr)	Patients (%)	Odds Ratio (95% Confidence Interval)	p-value	Odds Ratio (95% Confidence Interval)	p-value
Age <42	22 (15.1)	Ref.	<0.001	Ref.	0.085
42 ≤ age < 59	66 (12.8)	0.827 (0.491–1.393)	0.475	0.777 (0.376–1.605)	0.496
59 ≤ age < 72	58 (8.6)	0.527 (0.311–0.893)	0.017	0.647 (0.308–1.357)	0.249
72 ≤ age < 81	16 (2.3)	0.134 (0.069–0.263)	<0.001	0.294 (0.122–0.708)	0.006
81 ≤ age < 91	0 (0.0)	N/A*	N/A*	N/A*	N/A*
Age ≥91	0 (0.0)	N/A*	N/A*	N/A*	N/A*

*The age categories were determined based on the cumulative percentiles of the study population at the 5th, 25th, 50th, 75th and 95th percentiles as follows: age <42 (5.5%), 42 ≤ age < 59 (19.7%), 59 ≤ age < 72 (25.6%), 72 ≤ age < 81 (26.0%), 81 ≤ age < 91 (17.2%) and age ≥91 (6.0%). The covariates used in this analysis include sex, comorbidities, witnessed status, bystander AED, bystander CPR, initial rhythm, EMS process time, advanced airway, mechanical compression, IV access and epinephrine use. *No cases in this age group. N/A: Not applicable; Ref.: Reference.*

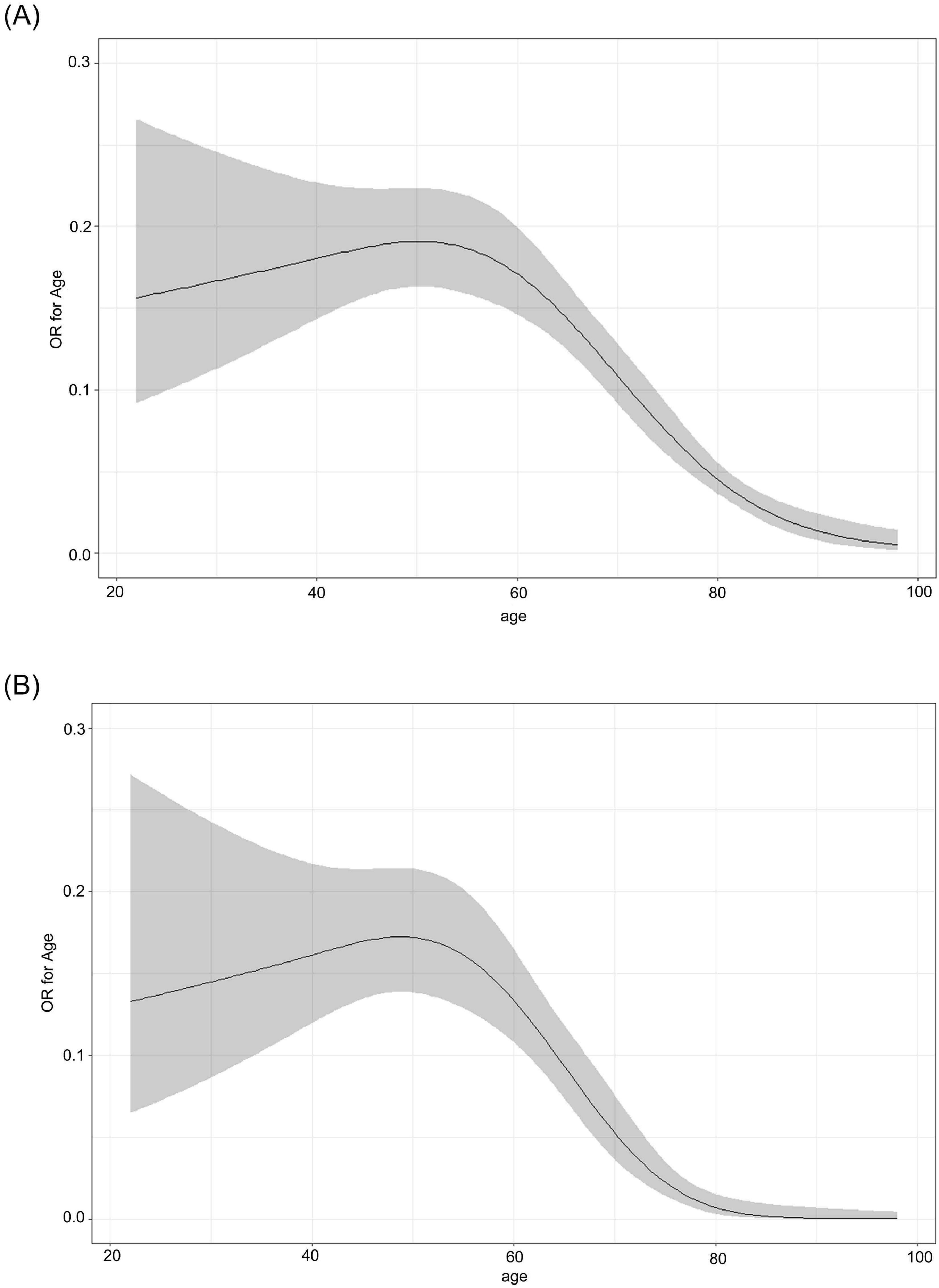

FIGURE 4. Cubic spline model of age and its impact on survival outcomes in the study population. (A) survival to hospital discharge; (B) favorable neurological outcome. The gray area represents the 95% confidence interval. OR: odds ratios.

cline in future survival outcomes would be solely attributed to population aging. Several studies have documented a decrease in survival outcomes as the age of OHCA patients advances [17, 18].

In the context of OHCA survival dynamics, it is important to acknowledge that age is not a modifiable factor. However, among the comorbidities, conditions such as renal disease and malignancy may be amenable to management even though these conditions are known risk factors for poor survival after OHCA [19, 20]. Investigation of OCHA cases among patients with renal disease, including those on dialysis can offer valuable insights [21, 22]. Similarly, analysis of OHCA cases among patients with malignancies can assist in determining whether CPR was warranted or indicated [23]. An interesting finding from our study is the favorable survival outcomes observed among patients with cardiovascular disease, despite it being a known risk factor for OHCA [24, 25]. This may suggest proactive measures taken by individuals with cardiovascular disease, such as promptly contacting the EMS system during emergencies. Alternatively, the EMS response for cardiovascular diseases, including procedures like coronary angiography and percutaneous coronary intervention, may have contributed to better survival outcomes in these patients. A similar finding has been reported in a study conducted in the Netherlands [26].

The findings of this study emphasize the significance of thorough discussion concerning the survival outcomes of elderly OHCA patients. Discussions regarding OHCA in older adult patients should encompass not only the effective allocation of resources within EMS systems but also the vital consideration of dignified end-of-life care. Achieving this balance is crucial to mitigate the burden of unnecessary treatment and associated harm while ensuring older adult patients receive compassionate care. However, making such balanced decisions swiftly in real time presents a significant challenge. Deciding whether to initiate resuscitation efforts in older adults is an ethical challenge frequently faced by physicians and EMS personnel. Resuscitation guidelines place the importance of patient autonomy and the principle of beneficence in ethical considerations related to resuscitation and end-of-life prognostication [27, 28]. These guidelines stress that performing CPR, given its low likelihood of success, should be avoided in cases where it is likely to be futile. Nevertheless, prospective assessment of futility in OHCA presents challenges, indicating the need for future research in this area [29, 30]. Not starting CPR in a futile patient (resuscitation withhold) will be bioethically equivalent to stopping (resuscitation withdrawal). Korea currently has very limited criteria for this, such as the return of spontaneous circulation, confirmation of death or DNR order. As the population rapidly ages, it will be crucial to discuss these criteria to prevent the automatic administration of CPR in futile situations.

Several limitations of this study should be acknowledged. Firstly, its retrospective nature may have introduced selection bias, potentially hindering the establishment of causal relationships and the generalizability of findings. For example, we excluded cases associated with DNR orders, which are more prevalent among the oldest adults in Korea. Secondly, despite adjustments, unmeasured confounding variables, such as the impact of the 2018 Act on Decisions on Life-Sustaining Treatment for Patients in Hospice and Palliative Care or at the End-of-Life and the influence of the COVID-19 pandemic in 2020, may have affected the results. While Korea had low COVID-19 mortality rates, studies have indicated its impact on EMS utilization, potentially influencing survival outcomes [10, 31]. Given this context, we considered COVID-19 as a mediator indirectly influencing key aspects of other independent factors, such as AED use, arrest location, advanced airway types and mechanical compression use. With this in mind, we believe that the changes brought about by the COVID-19 pandemic were captured as much as possible in the independent variables used in our study. Thirdly, the study primarily focused on short-term outcomes, specifically survival to hospital discharge and favorable neurological outcomes. While these are vital metrics, the investigation did not cover long-term outcomes, such as post-discharge care and rehabilitation, which can significantly shape the overall well-being and quality of life of patients. Lastly, the study's geographic specificity to Ulsan, South Korea, limits its applicability to regions with different demographics, healthcare systems or EMS protocols.

5. Conclusions

This study underscores the significant impact of demographic changes on OHCA outcomes in Ulsan, South Korea. The findings reveal an increasing trend in the ratio of EMS assessed and treated OHCA cases to the total EMS calls alongside a declining trend in survival to hospital discharge rate, particularly evident after around 50 years of age, with stabilization thereafter around 80 years of age. Acknowledging the unmodifiable nature of age and aging, it is suggested with a stable EMS system and the health status within the community population, there may be a natural decrease in OHCA survival to hospital discharge as the community ages. These findings stress the need to optimize EMS systems and tailor care for older adult nontraumatic OHCA patients. Moreover, they underscore the critical role of healthcare planning and policy in addressing the evolving needs of aging populations and ensuring effective EMS amid demographic changes.

ABBREVIATIONS

OHCA, out-of-hospital cardiac arrest; EMS, emergency medical service; EMT, emergency medical technician; CPR, cardiopulmonary resuscitation; ED, emergency department; DNR, do not resuscitate; IV, intravenous; AED, automated external defibrillator; RTI, response time interval; STI, scene time interval; TTI, transport time interval; CPC, cerebral performance categories; IQR, interquartile range; OR, odds ratio; CI, confidence intervals.

AVAILABILITY OF DATA AND MATERIALS

The data are available from the corresponding author upon request.

AUTHOR CONTRIBUTIONS

SYP, SHK and BC—designed the research study; performed the research; provided help and advice on this study. SYP and SHK—analyzed the data; wrote the manuscript. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study complies with the Declaration of Helsinki and its protocol was approved by the Institutional Review Board of Ulsan University Hospital (IRB No. UUH-IRB-2023-06-017), and the need of informed consent was waived by Institutional Review Board of Ulsan University Hospital. The data used in this study was anonymized before its use. The study adheres to the ethical principles outlined in the Declaration of Helsinki, ensuring the protection of participants' rights and welfare.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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