The effect of age, gender, economic state, and urbanization on the temporal trend in sudden cardiac arrest: a nationwide population-based cohort study

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Abstract

Background: Sudden cardiac arrest (SCA) has not been well studied in Asian countries. This study investigated the temporal trends in the incidence and outcomes of SCA and the impact of age, gender, economic state, and urbanization on SCA using a nationwide population-based sample cohort of South Korea.

Methods: In the Korean National Health Insurance Service—Sample Cohort consisting of one million persons from 2003 through 2013, we identified 5,675 (0.56%) patients with SCA using ICD-10 code I46 and I49.0. We evaluated the impact of the age, gender, household income, and urbanization level on the incidence and outcome of SCA.

Results: During the study period, the overall age- and gender-adjusted annual incidence of SCA increased by 46.9% from 30.9 in 2003 to 45.4 in 2013 (per 100,000 person-years, \( p < 0.001 \) for trend). The medical cost per 100,000 person-years also greatly increased about four times \( (p < 0.001 \) for trend). The overall adjusted survival to hospital discharge rate increased from 8.9% in 2003 to 13.2% in 2013 \( (\text{adjusted rate ratio per year} 1.05; p < 0.001 \) for trend). Old age and low household incomes of the population was related to increased SCA and poor survival to hospital discharge rate. The proportion of patients with intensive or advanced therapeutic modalities after SCA greatly increased from 1.6% in 2003 to 10.0% in 2013 \( (p < 0.001 \) for trend). This increase was consistent regardless of age, gender, economic state, and urbanization level.

Conclusions: Although the incidence of SCA was increased, the outcome was improved for the decade. However, in the elderly and low-income population, the incidence of SCA continued to rise and survival outcome was not improved.

Keywords: Sudden cardiac arrest, Incidence, Outcome, Economic state, Aging

Introduction

Despite the tremendous advances in the field of cardiovascular medicine, sudden cardiac arrest (SCA) is a significant clinical and public health problem worldwide [1]. The epidemiology of SCA has been studied as an indicator of the national health. However, the estimates on the incidence and survival rate of SCA vary widely depending on the ethnicities, regions, and data sources for case ascertainment. The majority of estimates about SCA are
based on data from the emergency medical service (EMS) for out-of-hospital SCA. In a global systemic review, the annual incidence and survival to hospital discharge rates of EMS-assessed out-of-hospital SCA were 52.5 (per 100,000 person-years) and 2% in Asia, 86.4 (per 100,000 person-years) and 9% in Europe, 98.1 (per 100,000 person-years) and 6% in North America, and 112.9 (per 100,000 person-years) and 11% in Australia, respectively [2]. In comparison to the out-of-hospital SCA, few studies have reported the incidence and outcomes of in-hospital SCA. Between one and five of every 1,000 hospital inpatients are estimated to have an in-hospital SCA in the developed countries, and less than 20% of such patients survive to discharge [3–5]. However, the epidemiology of SCA has not been well revealed in Asian countries.

South Korea is aging faster than any other country. And the lifestyle and diet of Korean people has become more westernized with the economic growth. The disease spectrum in South Korea has changed profoundly in the last few decades. Coronary artery disease (CAD) has already become the major type of heart disease and a heavy healthcare burden. Therefore, it can be expected that the incidence of SCA has been increasing in South Korea [6]. On the other hand, an improvement in the survival outcome from SCA can also be expected because of the advances in the resuscitation science, development of public education and training programs for cardiopulmonary resuscitation, and compulsory installation of automatic external defibrillators (AEDs) in public places. However, the trend of the prevalence and outcome of SCA has not been demonstrated in South Korea’s general population. Only several studies about EMS-assessed out-of-hospital SCA are available [7, 8]. Therefore, we analyzed the contemporary trends in the rate of the incidence and survival to hospital discharge from SCA from 2003 to 2013 in a Korean population-based sample cohort. We also evaluated the impact of the age, gender, household income, and urbanization level on the incidence and outcome of SCA.

Methods
Data source
In South Korea, registration with the national health insurance system is compulsory for all citizens, and hence, its coverage rate is more than 99% of the country’s population. Currently, the National Health Insurance Service (NHIS) manages all databases of Korea’s health service utilization, including outpatient care, inpatient care, emergency medicine, dental care, and all other medically necessary services. The NHIS released a National Sample Cohort database (NHIS-NSC) for research purposes. It consists of 1,025,340 Koreans (about 2.2% of the total population of South Korea) as an initial 2002 cohort and has followed the subjects for 12 years (2002–2013). The cohort data were sampled systematically within 1,476 strata defined by combinations of the age, gender, eligibility status, and household income. All information on the clinical visits, hospitalization, medical treatment, and prescribed drugs are included in the NHIS-NSC. The information of the subject’s mortality, obtained from the Korean National Statistical Office, was also included. Disease diagnoses for all individuals were classified according to the International Classification of Diseases 10th (ICD-10) codes. The details of the NHIS-NSC are described in previous reports [9–11].

Informed consent was not specifically obtained individually because this study was based on the data from the NHIS-NSC. The data were fully anonymized and de-identified for the analysis. This study was approved by the institutional review board of Yonsei University Health System. The first author vouches for the integrity of the data and the accuracy of the results.

Data collection and study population
In the NHIS-NSC, we identified the patients with SCA using ICD-10 code I46.x (cardiac arrest) and I49.0 (ventricular fibrillation). The patients who were discharged from an emergency department or inpatient clinic with diagnosis code I46.x or I49.0 were included. The dead-on-arrival subjects with an underlying cause of death reported as I46.x or I49.0 were also included. We did not use the 2002 cohort data because the initial 2002 cohort started with subjects who did not die in 2002. A total of 5,675 patients with SCA were identified between 2003 and 2013. The study population included both in-hospital and out-of-hospital SCA. The patients’ age, gender, household income, and urbanization level of the region were identified. The household income levels were stratified into 10 quantiles from grade 1 to 10, and grade 0 meant medical aid beneficiaries (low household income: grade 0–3, middle household income: grade 4–7, and high household income: grade 8–10). The urbanization level of the region was classified into populated urban regions (regions with a population of more than a million) and other regions. The outcome of SCA was evaluated by the rate of survival to hospital discharge.

Definition and validation of SCA
We defined the SCA by ICD-10 codes I46.x (cardiac arrest) and I49.0 (ventricular fibrillation) after excluding non-cardiac arrest. Patients diagnosed with sudden arrest accompanied by the following diagnosis were considered non-cardiac arrest; respiratory arrest (R09.0, R09.2), gastrointestinal bleeding (I85.0, K25.0, K25.4, K26.0, K26.4, K27.0, K27.4, K92.0-K92.2), brain hemorrhage (I60.x–I62.x, S06.4–S06.6), septic shock
(A41.9, R57.2), pregnancy and delivery (O00–O99),
diabetic ketoacidosis (E14.1), anaphylaxis (T78.2), and
accidents including asphyxiation, drowning, poisoning,
traffic accident, fall, and suicide (T71, T75.1, T36–T65,
V01–V99, W00–99, X60–X84).

To evaluate the accuracy of our definition of SCA, we
conducted a validation study with medical records of
two independent tertiary hospitals from 2009 to 2013.
We found 731 patients with code I46.x or I49.0 after
excluding those with diagnosis codes for non-cardiac
causes, as mentioned above. Their medical records
were then reviewed by five physicians, and we ascer-
tained the patients with true SCA. The positive predic-
tive value was 80.2% (586 of 731) by using our criteria
of SCA, suggesting the good diagnostic accuracy of our
definition. False-positive cases were respiratory arrest
(7.0%), history of SCA (4.2%), arrest due to cancer
progression (1.9%), accidents (1.8%), bleeding (1.8%),
metabolic acidosis (1.0%), septic shock (0.8%), stroke
(0.5%), and others (0.9%).

Statistical analysis
To evaluate the changes in the variables by the calendar
year, we used the Cochran-Armitage trend test for cat-
egorical variables and linear regression for continuous
variables. The age and gender standardized incidence
rates per 100,000 person-years for the study population
were calculated to compare the trends by years and strata
with the year 2003 as the reference (direct standardiza-
tion method).

To assess whether survival to hospital discharge had
changed over time, multivariable Poisson regression
models were constructed. The adjusted variables in the
model were the age, gender, household income, and
urbanization level of the region. The Poisson distribution
was used to directly estimate the rate ratios instead of the
odd ratios to avoid any potential exaggeration [12]. Our
independent variable, the calendar year, was included as
a categorical variable, with 2003 as the reference year.
We multiplied the adjusted rate ratio for each year (2004
through 2013) by the observed survival rate for the refer-
ence year to obtain the yearly risk-adjusted survival rates
for the study period. Those rates represented the esti-
mated survival for each year if the patient case mix was
identical to that in the reference year [5]. We also evalu-
ated the calendar year as a continuous variable to obtain
the adjusted rate ratios for the year-to-year survival
trends.

All statistical analyses were conducted with the use
of SPSS 20, R 3.2.1, or GraphPad Prism 6 software. All
hypothesis tests were two-sided, with a significance level
of 0.05.

Results
Patient characteristics, incidences, and medical care cost
From 2003 to 2013, a total of 5,675 patients with SCA
were identified in the NHIS-NSC. Table 1 shows the
temporal trends in the number and characteristics of the
patients with SCA over 11 years. The absolute number
of patients with SCA increased from 314 in 2003 to 677
in 2013 ($p<0.001$ for trend). The mean age of the SCA
patients increased from 64.6±15.9 in 2003 to 68.1±16.3
in 2013 ($p=0.003$ for trend), and consequently, the propor-
tion of the elderly (≥ 60 years old) in the SCA patients
gradually increased ($p=0.027$ for trend). SCA occurred
more frequently in men (59.3%) than women (40.7%)
($p<0.001$). However, the ratio of the genders did not
significantly change during 11 years. The proportion of
patients with SCA in the middle- and high-income brack-
ets decreased ($p<0.001$ and $p=0.002$ for trend, respec-
tively), and that in the low-income bracket increased
($p<0.001$ for trend).

Figure 1 shows the temporal trends in the annual inci-
dence and medical care cost of SCA per 100,000 person-
years. The crude annual incidence rate of SCA without an
adjustment for the age and gender increased from 30.9 in
2003 to 66.7 in 2013 (per 100,000 person-years, $p<0.001$
for trend). After adjusting for the age and gender, the
annual incidence of SCA increased by about 1.5 times
from 30.9 in 2003 to 45.4 in 2013 (per 100,000 person-
years, $p<0.001$ for trend). Along with the increasing inci-
dence of SCA, the medical care cost for SCA per 100,000
person-years also greatly increased from $65,866 in 2003
to $241,534 even after an adjustment for the inflation rate
in South Korea during the 11 years ($p<0.001$ for trend).

The effect of the age, gender, household income,
and urbanization level of the region on the incidence
The age, gender-adjusted incidence rate of SCA accord-
ing to the age, gender, household income, and urbani-
ization level of the region are presented in Fig. 2. The
increase of SCA was particularly predominant in the
elderly ≥ 60 years of age (from 160.0 in 2003 to 238.9
in 2013, per 100,000 person-years, $p<0.001$ for trend)
(Fig. 2a). There were no temporal differences in the
patients’ gender during the study period (all $p<0.001$
for trend, the ratio of two groups: $p=0.209$ for trend)
(Fig. 2b). The incidence of SCA per 100,000 person-years
increased significantly in the subjects with a low eco-
nomic status (from 31.5 in 2003 to 65.9 in 2013, $p<0.001$
for trend), and a statistically significant difference
between the low and middle-high household income
groups has arisen after 2011 (Fig. 2c). There was no tem-
poral difference in the proportion of patients with SCA
according to the urbanization level of the region during
Table 1  Characteristics and incidence of sudden cardiac arrests in the nationwide cohort data in South Korea from 2003 to 2013

| Characteristics                  | 2003   | 2004   | 2005   | 2006   | 2007   | 2008   | 2009   | 2010   | 2011   | 2012   | 2013   | p for trend | Overall |
|----------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|------------|---------|
| Cohort population                | 1,017,468 | 1,016,580 | 1,016,820 | 1,002,005 | 1,020,743 | 1,000,785 | 998,527 | 1,002,031 | 1,011,123 | 1,014,730 | –        | –         |
| Number of SCAa                    | 314    | 390    | 443    | 442    | 465    | 512    | 521    | 545    | 661    | 705    | 677    | < 0.001    | 567.5   |
| Crude incidenceb                  | 30.9   | 38.4   | 43.6   | 44.1   | 45.6   | 51.2   | 52.2   | 54.4   | 65.7   | 69.7   | 66.7   | < 0.001    | 51.4    |
| Adjusted incidencec               | 30.9   | 37.1   | 40.5   | 39.3   | 38.9   | 41.7   | 41.3   | 41.4   | 47.5   | 49.8   | 45.4   | < 0.001    | 41.2    |
| Age (years)                      | 64.6 ± 15.9 | 64.7 ± 16.8 | 67.1 ± 15.9 | 66.9 ± 15.8 | 67.2 ± 15.4 | 68.9 ± 15.3 | 67.6 ± 15.0 | 67.3 ± 16.5 | 68.9 ± 16.1 | 68.4 ± 16.4 | 68.1 ± 16.3 | 0.003   | 67.5 ± 16.0 |
| Male (%)                         | 60.2%  | 60.5%  | 59.4%  | 60.9%  | 60.4%  | 60.2%  | 62.2%  | 56.3%  | 56.0%  | 58.7%  | 59.5%  | 0.209      | 59.3%   |
| Proportion by age                 |        |        |        |        |        |        |        |        |        |        |        |            |         |
| <20 years                        | 2.5%   | 2.6%   | 1.4%   | 1.1%   | 0.6%   | 0.4%   | 1.0%   | 1.3%   | 0.9%   | 1.8%   | 1.5%   | 0.353      | 1.3%    |
| 20–39 years                      | 5.1%   | 5.6%   | 5.0%   | 5.9%   | 6.2%   | 3.7%   | 3.6%   | 6.2%   | 4.7%   | 4.0%   | 4.1%   | 0.130      | 4.8%    |
| 40–59 years                      | 26.1%  | 23.6%  | 22.3%  | 22.9%  | 21.3%  | 20.5%  | 24.6%  | 21.8%  | 22.1%  | 21.1%  | 21.7%  | 0.174      | 22.3%   |
| ≥60 years                        | 66.2%  | 68.2%  | 71.3%  | 70.1%  | 71.8%  | 75.4%  | 70.8%  | 70.6%  | 72.3%  | 72.3%  | 72.7%  | 0.027      | 71.5%   |
| Proportion by income              |        |        |        |        |        |        |        |        |        |        |        |            |         |
| Low                              | 22.6%  | 19.5%  | 22.1%  | 24.0%  | 27.5%  | 25.2%  | 28.2%  | 26.6%  | 37.8%  | 32.6%  | 31.9%  | < 0.001    | 28.1%   |
| Middle                           | 31.2%  | 37.9%  | 35.9%  | 36.0%  | 28.2%  | 36.1%  | 33.2%  | 34.9%  | 27.4%  | 26.2%  | 30.7%  | < 0.001    | 32.0%   |
| High                             | 46.2%  | 42.6%  | 42.0%  | 40.0%  | 44.3%  | 38.7%  | 38.6%  | 38.5%  | 34.8%  | 41.1%  | 37.4%  | 0.002      | 39.9%   |
| Proportion by region              |        |        |        |        |        |        |        |        |        |        |        |            |         |
| Populated urban region            | 46.5%  | 45.6%  | 42.7%  | 42.8%  | 48.0%  | 49.4%  | 44.3%  | 47.9%  | 45.4%  | 48.1%  | 48.4%  | 0.013      | 46.5%   |
| Other regions                     | 53.5%  | 54.4%  | 57.3%  | 57.2%  | 52.0%  | 50.6%  | 55.7%  | 52.1%  | 54.6%  | 51.9%  | 51.6%  | 0.013      | 53.5%   |

a Number of SCAs include both out-of-hospital and in-hospital cases that met the criteria for analysis
b Crude incidence: unadjusted incidence rate per 100,000 person-years
c Adjusted incidence: age and gender standardized incidence rates per 100,000 person-years to compare with the year 2003 as the reference
d Household income levels are stratified into 10 quartiles from grade 1 to 10, and grade 0 means medical aid beneficiaries (Low: grade 0–3, Middle: grade 4–7, High: grade 8–10)

p < 0.05 is marked in boldface. SCA: sudden cardiac arrest
the study period (all \( p < 0.001 \) for trend, the ratio of two groups: \( p = 0.113 \) for trend) (Fig. 2d).

Survival to hospital discharge

During the study interval of 2003 to 2013, the overall rate of survival to discharge was 8.6% (487 of 5,675 patients). There was a significant trend toward an increased survival to hospital discharge for all study patients from 8.9% in 2003 to 11.2% in 2013 (\( p = 0.006 \) for trend) (Fig. 3a). In a subgroup analysis, the survival to hospital discharge rates significantly improved in the subjects younger than 60 years (\( p < 0.001 \) for trend) (Fig. 3b), males (\( p < 0.001 \) for trend) (Fig. 3c), and the middle-high household income groups (\( p = 0.001 \) for trend) (Fig. 3d). However, the trend toward an increased survival was not observed in the patients older than 60 years (\( p = 0.492 \) for trend) (Fig. 3b), females (\( p = 0.960 \) for trend) (Fig. 3c), and those with a low household income (\( p = 0.120 \) for trend) (Fig. 3d).

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**Fig. 1** Annual incidence and medical care cost of sudden cardiac arrests per 100,000 persons in South Korea from 2003 to 2013. The medical care cost was adjusted for the inflation rate in South Korea. \( p < 0.001 \) for trends for all variables

**Fig. 2** Annual incidence of sudden cardiac arrest per 100,000 persons according to the age (a), Gender (b), Household income (c), and Region (d) from 2003 to 2013. All annual incidences were adjusted for the age and gender. \( *p \leq 0.001 \) for trend
There was no difference in the survival improvement between the populated urban, and other regions (all $p < 0.001$ for trend, the ratio of two groups: $p = 0.544$ for trend) (Fig. 3e).

After an adjustment for the temporal trends in the patient characteristic such as the age, gender, household income, and regions, the overall survival improved from 8.9% in 2003 to 13.2% in 2013 (adjusted rate ratio per year, 1.05; 95% confidence interval [CI], 1.02 to 1.08; $p$ for trend $< 0.001$, Table 2).

**Trends in the treatment modality for SCA**

The temporal trends in the treatment modality for SCA are presented in Fig. 4. The proportion of patients with any intensive or advanced therapeutic modalities after SCA greatly increased from 1.6% in 2003 to 10.0% in 2013 ($p < 0.001$ for trend) (Fig. 4a). The proportion of patients who underwent percutaneous transluminal coronary angioplasty (PTCA) during the hospitalization for SCA increased from 0.68% in 2003 to 2.68% in 2013 ($p < 0.001$ for trend). The proportion of patients who underwent continuous renal replacement therapy (CRRT) also increased from 1.02% in 2003 to 5.52% in 2013 ($p < 0.001$ for trend). Insurance claims for implantable cardioverter defibrillators (ICDs) and therapeutic hypothermia were first recorded in 2008 and 2010, respectively. ICD implantations after SCA increased from 0.21% of cases in 2008 to 0.79% of cases in 2013 ($p < 0.001$ for trend). Therapeutic hypothermia for SCA increased from 0.4% of cases in 2010 to 3.0% of cases in 2013 ($p < 0.001$ for trend).

This proportion of patients with any intensive or advanced therapeutic modalities after SCA increased regardless of age, gender, household income and urbanization level (Fig. 4b–e).

**Discussion**

The main findings are as follows. First, the annual incidence of SCA in South Korea increased over the past decade and that increase was particularly predominant in the elderly ($\geq 60$ years old) and those with a low economic status. Second, the survival outcome from SCA improved...
overall, particularly in the young and middle-aged populations, but not in the elderly patients (≥ 60 years old), females, and those with a low household income. Finally, intensive or advanced modalities were increasingly used for the treatment of SCA.

**Increasing incidence of SCA**

In Western countries, the incidence of SCA has declined, in parallel with the decline in CAD mortality [13, 14]. In contrast, the incidence of SCA in South Korea has increased over the past decade. Lifestyle changes with economic growth and a rapidly aging population might be the main cause of the increased incidence of SCA in South Korea. Although the incidence of CAD in South Korea is lower than that in Western countries [15], CAD has increased in recent years [6] due to changes in lifestyle. In addition, the overall incidence of SCA is higher among older patients [16]. Consistently, this study showed that the increase in SCA was particularly predominant in patients ≥ 60 years of age.

The incidence of SCA was higher in the lower-income rather than higher-income groups in the United States and Canada [17, 18]. In South Korea, the age and gender standardized incidence rate of SCA was also higher in the low household income group rather than the middle-high household income group. Looking more closely, there was no statistically significant difference in the incidence of SCA between the low and middle-high income groups from 2003 to 2010. However, a significant difference in the incidence of SCA between the low and middle-high income groups was observed after 2011 because of the marked increase in SCA in patients with a low economic status. This finding suggests that the social imbalances are deepening in South Korea. A lower economic status has been associated with an increased burden of risk factors [19], and a decreased likelihood of receiving proper risk management or treatment for cardiovascular disease [20]. Thus, the population-based interventions from the National Health Insurance Database Cohort in South Korea to reduce the cardiovascular risk factors and treat unrecognized cardiovascular disease in low-income communities may prove to be effective in reducing the disparities in the incidence of SCA.

**Improved outcome of SCA**

Several studies from Western countries have reported improved survival rates of SCA during the past decade [5, 21]. Survival from SCA in South Korea also improved between 2003 and 2013. In the past ten years, many advances in resuscitation science such as therapeutic hypothermia and AEDs have been introduced into South Korea. We showed that the utilization of intensive or advanced modalities for the treatment of SCA such as PTCA, ICDs, CRRT, and therapeutic hypothermia have increased. Moreover, government activities and laws to develop public education and training programs for cardiopulmonary resuscitation were enacted in 2002, and the actual training program began later in 2006. AEDs in public places became compulsory in 2008 and were expanded to more private places in 2012. These changes might have been what made the improvement in the survival from SCA in South Korea during the past ten years.

In this study, the overall rate of survival to hospital discharge after SCA in South Korea was 8.6%. Although it is comparable to that reported by studies conducted in North America (7.9–11.4%), Europe (10.7%), and Japan (12%) during the same time [22–25], the outcome of SCA in South Korea is still relatively backward compared to the other developed countries. Moreover, a disparity in the outcome of SCA among the social stratum existed. The improvement in the SCA outcome in the overall population was attributable to the increased survival rate in the young and middle-aged populations (< 60 years old), a male gender, and those with middle-high household incomes. The outcomes of SCA in the elderly (≥ 60 years old), females, and those with a low household income did not improve. The social and medical systems in South Korea for SCA are still less than optimal compared to Western developed countries, and we need to make more effort.
There is no significant difference in intensive therapeutic modalities according to the household income. The reason why the proportion of SCA patients who receive intensive therapeutic modalities does not differ significantly depending on household income may be because South Korea has a well-established national health insurance system covering the entire citizens. Nevertheless, the survival rate of the low household income group was relatively low, there was no improvement compared to the middle-high household income group. It can be explained by several reasons. First, it is well known that a lower economic status has been associated with an increased burden of cardiovascular risk factors. Higher rates of cardiovascular risk factors in the low-income group will affect not only the higher incidence rate of SCA but also the lower survival rate after SCA compared to the high-income group. Second, the subjects in the low-income group are more likely to live alone and are more likely to be excluded from the daily care. This reduces the chances of being discovered by a witness in an SCA, receiving bystander CPR, and surviving transport to the hospital. To examine the relationship between income level and the likelihood that a patient with SCA would be discovered by a witness, we identified patients whose cause of death was listed as SCA on the death certificate and had no hospital records. They died without being found alive and were unable to visit the hospital. The proportion of these patients was higher with lower income (9.0%, 6.3%, and 4.9% in the low, middle, and high household income groups, respectively).

In our analysis, survival after SCA improved gradually over 10 years in men but not in women. Among the elderly living alone who have a high risk of death in the event of SCA, the proportion of women was more than
twice that of men in South Korea (From Korean Statistical Information Service; https://kosis.kr). The average number of diseases among elderly females living alone was 1.6 times higher than that of men. Nearly half of the elderly females living alone also lived in isolation from social networks. These social differences between men and women may be one of the reasons why survival rates after SCA did not improve in female patients.

Data for SCA in South Korea
Several studies about EMS-assessed out-of-hospital SCAs in South Korea have been published [7, 8]. However, those data could be an underestimate, because out-of-hospital SCAs not attended by emergency medical personnel were not included. Moreover, there is little data for in-hospital SCAs in South Korea. Understanding the accurate characteristics and temporal trends of SCAs in the community are critical for developing appropriate interventions. Because the nationwide cohort such as the NHIS-NSC used in this study would enable a more accurate determination of the overall SCA burden in the community including both out-of-hospital and in-hospital cases, it can complement the EMS-based registry data on SCAs.

Study limitations
This study has several limitations. First, all patient data were from the insurance claim data provided by the NHIS-NSC. The precision of the SCA diagnosis, which was based on ICD-10 code from the administrative data reported by physicians, may be a concern. Potential misclassifications might have existed. Second, the site of the SCA including the in-hospital and out-of-hospital settings and initial rhythm status of the patients could not be classified in the NHIS-NSC database despite those factors being closely associated with the outcome of SCA.

Conclusions
The incidence of SCA in South Korea continues to have risen over the decade, especially in the elderly and low-income bracket. The survival after SCA has improved significantly with the increase in the utilization of intensive or advanced modalities. However, survival improvement was not observed in the elderly patients, females, and those with a low household income.

Abbreviations
AED: Automatic external defibrillator; CRRT: Continuous renal replacement therapy; CAD: Coronary artery disease; EMS: Emergency medical service; ICD: Implantable cardioverter defibrillator; ICD-10: International classification of diseases 10th; NHIS: National health insurance service; NHIS-NSC: National health insurance service—National sample cohort; PTCA: Percutaneous transluminal coronary angioplasty; SCA: Sudden cardiac arrest.

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Authors’ contributions
BJ and J-HS contributed to the conception and design of the work and critical revision of the manuscript. P-SY and DK contributed to the conception and design of the work, interpretation of data for the work, and drafting of the manuscript.

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Availability of supporting data
The data underlying this article are available in the National Health Insurance Sharing Service (NHISS) of Korea at https://nhiss.nhis.or.kr. Applications to use the data will be reviewed by the inquiry committee of research support and, once approved, raw data will be provided to the authorized researcher with a fee at several permitted sites.

Declarations
Ethics approval and consent to participate
This study was approved by the Institutional Review Board of the Yonsei University Health System (4-2016-0329). The requirement for informed consent was waived because personal identification information was removed after cohort generation, in accordance with the strict confidentiality guidelines.

Competing interests
Dr. Boyoung Joung has served as a speaker for Bayer, BMS/Pfizer, Medtronic, and Daiichi-Sankyo and received research funds from Medtronic and Abbott. Neither author has received any fees directly. The other authors have nothing to declare.

Consent for publication
All authors have permitted the publication.

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