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Clinical paper

Temporal trends of presumed cardiac origin out-of-hospital cardiac arrest incidence in Guangzhou, southern China: A 10-year consecutive analysis

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Abstract

Background: Despite the rising disease mortality rates, there is a dearth of studies on the incidence and trends of out-of-hospital cardiac arrests (OHCA) in China. This study aims to investigate the incidence and temporal trends of presumed cardiac origin OHCA in Guangzhou, Southern China, from 2011 to 2020.

Methods and results: In this population-based retrospective cohort study, pre-hospital data from the Guangzhou Emergency Medical Service (GZ-EMS) from 2011 to 2020 were analyzed. Crude incidence rates and age-standardized incidence rates (ASIRs) were calculated respectively. ASIRs were calculated using the 2000 national census population as the standard population. The Joinpoint software was used to calculate the Annual Percent Change (APC) and Average Annual Percent Change (AAPC) in the incidence of OHCA over the study period. From 2011 to 2020, 44,375 EMS-assessed OHCAs of presumed cardiac origin were recorded. Overall, the crude incidence rate of OHCA was 53.1 per 100,000 on average. AAPC was 7.0% (95% CI: 4.3%–9.8%). Age-standardized incidence rate(ASIR) was 38.4 per 100,000 on average, with an average annual increase of 4.8% (95% CI: 2.4%–7.3%). The crude and ASIR of OHCA increased in men, while the ASIR changed more moderately in women. The age group of ≥80 years had the highest rate of increase. The 20–29 and 70–79 age groups also demonstrated notable increases.

Conclusions: From 2011 to 2020, Guangzhou experienced a notable upward trend in both crude and ASIR of OHCA, with significant variations observed across gender and age demographics. This trend calls for a deeper investigation into the underlying factors.

Keywords: Out-of-hospital cardiac arrest, Incidence, Temporal trends

Introduction

Out-of-hospital cardiac arrest (OHCA) is defined as a critical medical emergency marked by the abrupt halt of cardiac function outside a healthcare setting[1,2] frequently resulting in elevated mortality rates in the absence of immediate intervention.[3] There were about 294,000 emergency medical service (EMS)-treated OHCA of any age in the United States[4] and 750,000 EMS-assessed OHCA in China per year.[5] The incidence and temporal trends of OHCA have garnered significant research attention globally due to their profound implications for public health and healthcare systems.[5–8] In China, the local incidence of OHCA has been previously reported in Beijing,[9] Hong Kong[10] and Shenzhen,[11] which showed considerable regional variation. However, Guangzhou, as the capital of Guangdong Province - the most populous province in China, still lacking a conspicuous amount of detailed information regarding OHCA. China has experienced rapid development over the past decade. Despite rising disease mortality, there is a paucity of studies on the incidence and trends of OHCA in China.[5,12] Insight into the recent trends in the epidemiology of OHCA is imperative for optimizing public health intervention strategies, allocating healthcare resources, and ultimately improving patient outcomes. This study aims to investigate the incidence

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and temporal trends of OHCA of presumed cardiac etiology in Guangzhou over the past decade.

Methods

Study design

The study is a population-based, retrospective cohort analysis focused on incidents of OHCA of presumed cardiac origin, spanning all age groups in Guangzhou, China, from January 1, 2011, through December 31, 2020. This study was approved by the Medical Ethics Committee of Sun Yat-sen Memorial Hospital (SYSKY-2023-1236-02).The project has been registered on clinicaltrials.gov.(NCTO6448156).

Data source

Data were collected from the GZ-EMS's dispatch system database of pre-hospital data for the central urban districts. The dispatch records of GZ-EMS are logged in a specialised information system. A dedicated team oversees the management of this data and conducts regular quality control reviews.

Study setting

Guangzhou is the capital city of Guangdong Province, which is the most economically significant province in China, with an area of approximately 7,434 square kilometres. It stands as a pivotal hub for economic, political, educational, scientific, technological, and cultural activities within Guangdong Province. As of 2020, the city's resident population reached 18.676 million, marking a significant increase of 20.9% from 2011. The core urban districts of Guangzhou, covering roughly 933 km2, are home to about 10 million people.

The EMS system in Guangzhou comprises GZ-EMS and its sub-centres, along with network hospitals responsible for pre-hospital emergency care, collectively serving the city's population. GZ-EMS is tasked with dispatching ambulances from network hospitals in the main urban areas. In contrast, the sub-centres in the non-main urban areas are responsible for dispatching ambulances to their respective regions. The average emergency centre response time was 14.11 min, with a median of 13.25 minutes.[13] Upon receiving a dispatch order, the network hospitals will send one doctor, one nurse, one driver, and at least one stretcher bearer. All personnel have undergone CPR training and possess the necessary medical qualifications. Except in the case of a clear "do not resuscitate order" or apparent signs of irreversible death (such as post-mortem lividity or decapitation), EMS personnel will provide essential life support to patients who have suffered an OHCA. Patients treated on-site by EMS are transported to the nearest hospital. After evaluating the patient, EMS doctors enter the diagnosis into the electronic medical record using an advanced text-search algorithm.

Data collection

The GZ-EMS database comprehensively compiles patient data, encompassing demographics, call time, incident location, responsible hospital, ambulance dispatching hospital, destination hospital, and preliminary and secondary diagnoses. However, it is noteworthy that GZ-EMS has not yet adopted a model conforming to the Utstein Style recommendations for reporting OHCA. Consequently, data pertaining to witnessed status, bystander cardiopulmonary resuscitation, initial cardiac arrest rhythm, and return of spontaneous circulation (ROSC) are not currently documented. To ensure privacy, patient data has been anonymised by excluding sensitive details such as names and phone numbers. "Presumed cardiac origin" refers to situations where cardiac arrest is believed to originate from the heart itself, and this definition also includes other medical scenarios where a significant cause for the cardiac arrest cannot be clearly identified.[14] Therefore, cases only with the diagnosis "cardiac arrest" or "sudden death" in the secondary diagnosis have been classified as cardiogenic cardiac arrest. Cases diagnosed as "cardiac arrest" or "sudden death" with other etiologies were excluded, which included non-cardiac causes such as asphyxia, suicide, drowning, advanced cancer, trauma, shock, poisoning, and cerebrovascular accidents. Additionally, cases that are entirely identical in the five aspects of gender, age, call time, the scene of the incident, and preliminary diagnosis have been excluded.

Statistical analysis

The crude incidence rate of OHCA was calculated annually, using the urban population of the urban area at year's end as the denominator. ASIRs were computed using the 5th National Population Census of 2000 as the reference to eliminate the impact of population age composition. Population data were extracted from the Guangzhou Municipal Bureau of Statistics and the National Bureau of Statistics.[15,16] The Joinpoint Regression Program (version 4.9.1.0) was employed to assess temporal trends in OHCA incidence, calculating the Annual Percent Change (APC) and Average Annual Percent Change (AAPC).[17] It uses validated segmented regression models to identify significant changes in the slope of a trending line over time. We used the Grid Search Method (GSM) to determine the maximum number of joinpoints that could be set (in this study, there were two joinpoints). We selected the best averaged data-weighted Bayesian Information Criterion (BIC) model to test the statistical significance of the joinpoints and determine the preferred model. Selection of the best model labeled by the software. The trend was considered increasing if the 95% CI of the APC was greater than zero and decreasing if the 95% CI of the APC was less than 0 or a two-sided p value <0.05. If the 95% CI of the APC contained 0, the trend was considered stable. If there were no joinpoints in the overall time period, then AAPC = APC.[18]

Missing gender and age data, deemed randomly absent, were addressed using single-value imputation: the most frequent gender and median age of the respective year were used to fill gaps.[19] The approach, while necessary, is noted for the potential introduction of bias.

Categorical variables were represented as numbers and percentages, while continuous variables were described using mean ± standard deviation or median ± interquartile range, depending on distribution normality. Group comparisons were conducted using the Mann-Whitney U test and the Kruskal-Wallis test, with the Mann-Kendall test for assessing temporal trend significance. A p-value <0.05 was considered statistically significant. Analyses were performed using R software (version 4.3.1), IBM SPSS (version 26), and the Joinpoint Regression Program.

Results

Establishment of the cohort

There were 48,334 EMS-assessed OHCAs selected from 375,233 cases assessed by the GZ-EMS. Excluding OHCAs with duplicate records (n = 3,627), with no cardiac etiology (n = 29), and in non-central urban districts (n = 303), 44,375 were included in our analysis (Fig. 1).

Trends in baseline characteristics of the general population

The mean annual crude incidence rate of OHCA of presumed cardiac origin assessed by EMS was 53.1 per 100,000 in Guangzhou central urban districts, showing an upward trend over the study period (Fig. 2A). In 2011, the crude incidence was 37.7 per 100,000 person-years, and by 2020, it had increased to 68.5 per 100,000 person-years, with a significant increase at an average rate of 7% per annum seen over the study period (95%CI:4.3%–9.8%, $p < 0.001$). Similarly, ASIRs also showed a significant upward trend, with an increase from 30.9 per 100,000 person-years in 2011 to 45.6 per 100,000 person-years in 2020 (AAPC = 4.8%, 95%CI:2.4%–7.3%, $p = 0.001$) (Fig. 2B).

Temporal trends of OHCA incidence by sex

For all eligible cases, 65.2% were male. The overall median age of patients was 72 years (IQR 57–83), with no significant change over 10 years ($p = 0.358$). The median age of OHCA patients was 70 years for males (IQR 53–80) and 80 years for females (IQR 68–86), and the median age of both male and female patients suffering from OHCA increased over the years, with a tendency to move backwards in time ($p = 0.004$; $p = 0.005$) (Table 1). The mean annual crude incidence of OHCA was 93.3 per 100,000 in men and 37.8 per 100,000 in women, with a significant rising trend over the 10-year period (AAPC = 8.0%, 95% CI: 3%–9.8%, $p = 0.002$; AAPC = 5.4%, 95% CI: 1.9%–9.0%, $p < 0.001$) (Fig. 2A). The mean ASIR for OHCA in men was 30.9 per 100,000 with a significant increasing trend (AAPC = 5.3%, 95% CI: 3%–7.5%, $p < 0.001$). In women, the mean OHCA ASIR was 27 per 100,000 with no significant trend (AAPC = 2.9%, 95% CI: −1.7%–7.7%, $p > 0.05$) (Fig. 2B).

Temporal trends of OHCA incidence by age

When the study cohort was divided into age subgroups, it was found that the percentage of patients with OHCA increased with age. The proportion of OHCA patients over 80 years old was increasing gradually, rising by 11.4% in 2020 compared to 2011(Table 1). The incidence rates of OHCA increased exponentially with age. The 80+ age group had the highest crude OHCA incidence at 1029.3 per 100,000, followed by the 70–79 age group at 304.9 per 100,000. The 80+ age group had the fastest increase (AAPC = 7.0%, 95% CI:5.3%–8.8%, $p < 0.001$), followed by the 20–29 age group (AAPC = 3.8%, 95% CI:0.1%-7.7%, $p = 0.047$) and the 70–79 age group (AAPC = 3.9%, 95%CI:1.6%-6.2%, $p = 0.004$). There was no significant upward trend in the crude incidence of OHCA in the 30–69 age group ($p > 0.05$); the 0–19 age group had the lowest crude incidence of OHCA, at 3.0 per 100,000, with a slight decrease over the 10-year period (AAPC = −0.8%, 95% CI: −3.9%–5.6%, $p = 0.689$) (Supplementary Material-Fig. 3A,3B). Temporal trends in ASIRs for OHCA by age group were similar to the crude incidence (Supplementary Material-Fig. 3C,3D).

Discussion

Our investigation represents the inaugural study of the incidence and temporal trends of OHCA over the previous decade in Guangzhou, a major southern city in mainland China. This research provides a comprehensive analysis of the shifts in trends across various genders and age strata, complete with reports on ASIRs. Our assessment reveals that, throughout the duration of the study, Guangzhou experienced an average crude incidence rate of OHCA of presumed cardiac origin assessed by EMS was 53.1 per 100,000 person-years. This discernible escalation in both crude and ASIRs underscores the intensifying challenge of OHCA within the populace. Regarding gender disparities, the data indicates that males exhibited a notably higher incidence of OHCA compared to females, with their acceleration rate in incidence surpassing that of females. Furthermore, the investigation into age-specific dynamics unveiled a marked

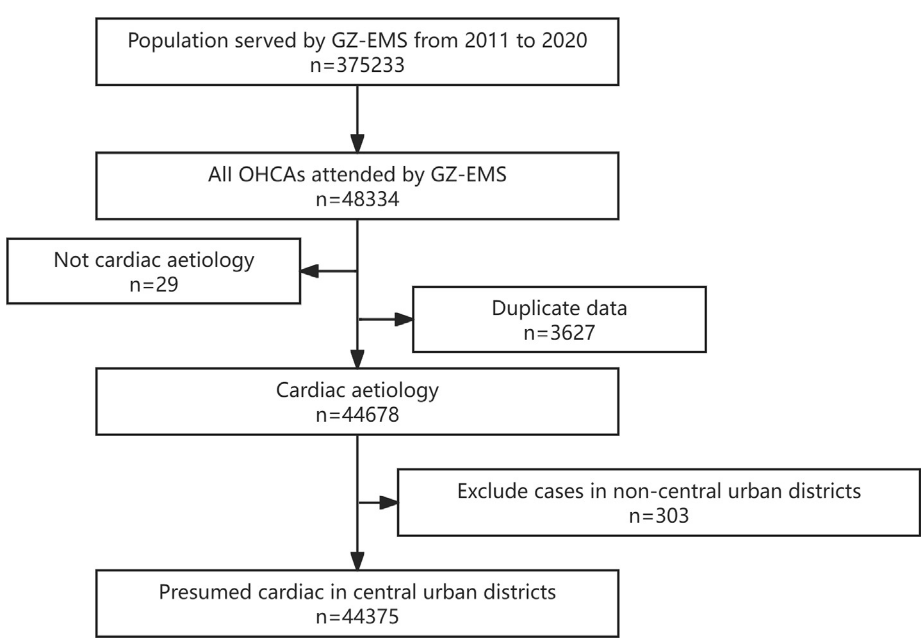

Fig. 1 – Study Participant Flowchart. GZ-EMS, Guangzhou Emergency Medical Service; OHCA, out-of-hospital cardiac arrest.

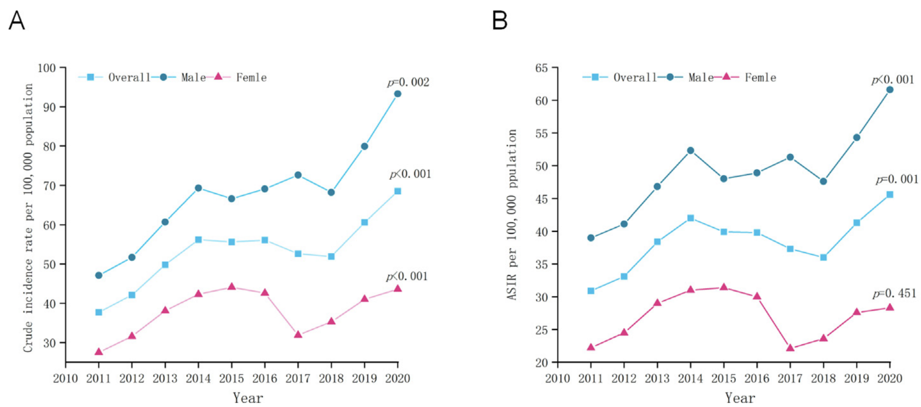

Fig. 2 – Temporal trends in crude and age-standardised incidence rates of OHCA of presumed cardiac aetiology in different sex and overall patients of Guangzhou, 2011–2020. OHCA, out-of-hospital cardiac arrest; ASIR: age-standardised incidence rates.

increase in incidence among the notably younger and older segments of the population.

The incidence of OHCA in the central urban area of Guangzhou is below the national average[5] and lower than that of northern cities such as Zhenzhou,[20] but higher than other southern cities like Shenzhen.[11] This variation in rates across regions could be attributed to factors such as population characteristics, climate, and dietary habits. The disparity in OHCA rates between northern and southern China may be indicative of the influences of diet and climate. When examining OHCA incidence rates internationally, Guangzhou's figures are below those of the United States,[21] Japan,[7] South Korea,[22] and Australia,[23] approximate the average across Asia, and exceed those reported in Singapore.[24] It is observed that most Asian nations report lower OHCA incidence rates compared to European countries and the United States. This discrepancy can be partly explained by racial differences in predisposition to OHCA and the inclusiveness of data within the OHCA registries. Moreover, the distribution of EMS resources in China is not optimal, and the non-transport of some OHCA cases by EMS might lead to an underestimation of the actual incidence rates.[5]

The incidence of OHCA in most age groups shows a rapid increase during the 2018–2020 period, and outbreaks of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) may be a factor that cannot be overlooked. Since December 2019, SARS-CoV-2, responsible for coronavirus disease 2019 (COVID-19), has led to significant illness and death globally. The interaction between SARS-CoV-2 and the cardiovascular system has emerged as a critical factor contributing to the development of myocarditis and arrhythmias,[25] conditions that may significantly elevate the risk of OHCA. Evidence from China indicates that approximately 20% of hospitalised patients with confirmed or suspected cases of SARS have experienced myocardial injury, a condition strongly linked to an increased likelihood of in-hospital mortality.[26] In addition, studies from various regions worldwide have repeatedly reported a rise in OHCA incidence during the pandemic compared to pre-pandemic periods.[4,27] These findings are consistent with the results of this study, which observed a marked increase in OHCA cases in 2020 compared to 2019.

Our study showed that the incidence of OHCA was significantly higher in men than in women by a factor of 1–2, with an increasing trend. The relatively lower risk of OHCA observed in women is thought to be due to the protective effect of oestrogen.[28] Additionally, men are subjected to a higher degree of exposure to significant cardiovascular risk factors such as smoking, drinking, and hypertension, which potentially increases their susceptibility to cardiovascular emergencies more so than in women.[28,29] Furthermore, the role of social and behavioural factors in the gender disparities observed in OHCA incidence rates cannot be overlooked. Males are often less likely to seek medical help and delay routine health screenings, potentially postponing the diagnosis and treatment of early signs of cardiovascular diseases, further increasing the risk of cardiovascular emergencies.[28,29] Thus, enhancing public education on early detection and prevention of cardiovascular diseases, significantly improving the health awareness of men, is a key strategy to reduce the incidence of OHCA.

A special point is that the incidence of OCHA in women decreased significantly in 2017, which may be the delayed effect of the initial impact of long-term health policy. The study by Liang et al. also found that cardiovascular mortality in women in Guangzhou in 2017 had a downward trend compared to previous years.[30] However, due to the limitations of the retrospective study and the data itself, we cannot determine a single factor that is related to this decline.

Our analysis indicates a dramatic increase in the incidence of OHCA among young people aged 20–29 years. Given that the young population aged 20–29 years represents a rapidly growing workforce in society, the swift rise in the incidence of OHCA warrants our serious attention, yet the underlying causes remain elusive. A plausible explanation could be the widespread prevalence of cardiovascular risk factors in this age group. The INTERHEART study revealed that more than 90% of young individuals at risk of myocardial infarction were affected by traditional cardiovascular risk factors such as hypertension, diabetes, and smoking.[31] In China, the past decade has witnessed a 1.9% and 0.4% increase in the prevalence of overweight and obesity among children under six, alongside a significant rise in hypertension and dyslipidaemia among children and adolescents.[32] An American study demonstrated an increasing trend in in-hospital mortality in all patients under 30 years of age with acute myocardial infarction since 2010.[33] In the context of our study, it may be important in the future to pay particular attention to the occurrence of acute cardiovascular events in people aged 20–29 years.

Due to cumulative effects,[34] the incidence of OHCA remained relatively stable in the 30–69-year-old population despite more pro-

Table 1 – Gender distribution, characteristics of age change and percentage of different age subgroups of OHCA patients in the central urban districts of Guangzhou, 2011–2020.

	Overall N = 44375	2011 N = 2957	2012 N = 3343	2013 N = 4007	2014 N = 4585	2015 N = 4596	2016 N = 4695	2017 N = 4453	2018 N = 4454	2019 N = 5263	2020 N = 6022	*p*-Value
Male,n(%)	28940(65.2)	1927（65.1)	2133(63.8)	2523(63.0)	2907(63.4)	2818(61.3)	2947(62.8)	3121(70.1)	2958(66.4)	3498(66.4)	4113(68.3)	<0.001[*]
Age(years) (median,IQR)												<0.001[#]
Male	70(53,80)	66(50,78)	67(51,79)	66(50,79)	67(52,79)	68(52,80)	67(53,80)	70(55,80)	70(55,80)	70(53,80)	70(56,82)	0.004[*]
Female	80(68,86)	78(66,85)	78(66,85)	79(68,86)	79(68,87)	80(69,87)	80(68,87)	80(65,86)	80(68,86)	80(67,87)	80(70,88)	0.005[*]
Overall	72(57,83)	70(55,81)	72(55,81)	72(55,82)	73(56,82)	74(57,83)	73(57,83)	71(59,81)	71(60,82)	72(58,83)	74(60,85)	0.358[*]
Age groups,n(%)												<0.001[&]
0–19	403(0.9)	38(1.3)	29(0.9)	49(1.2)	46(1.0)	33(0.7)	42(0.9)	45(1.0)	35(0.8)	43(0.8)	43(0.7)	
20–29	960(2.2)	80(2.7)	89(2.7)	123(3.1)	90(2.0)	104(2.3)	96(2.0)	85(1.9)	87(2.0)	111(2.1)	95(1.6)	
30–39	1644(3.7)	162(5.5)	138(4.1)	162(4.0)	179(3.9)	161(3.5)	168(3.6)	145(3.3)	144(3.2)	185(3.5)	200(3.3)	
40–49	3515(7.9)	273(9.2)	347(10.4)	363(9.1)	424(9.2)	379(8.2)	376(8.0)	301(6.8)	296(6.6)	385(7.3)	371(6.2)	
50–59	5594(12.6)	383(13.0)	427(12.8)	534(13.3)	613(13.4)	587(12.8)	627(13.4)	551(12.4)	535(12.0)	645(12.3)	692(11.5)	
60–69	6660(14.8)	456(15.4)	465(13.9)	572(14.3)	683(14.9)	702(15.3)	807(17.2)	650(14.6)	687(15.4)	736(14.0)	902(15.0)	
70–79	9282(20.9)	661(22.4)	765(22.9)	867(21.6)	990(21.6)	882(19.2)	849(18.1)	1061(22.8)	970(21.8)	1058(20.1)	1224(20.3)	
80+	16317(36.3)	904(30.6)	1083(32.4)	1337(33.4)	1560(34)	1748(38.0)	1730(36.8)	1660(37.3)	1700(38.2)	2100(39.9)	2495(41.4)	

[*] *p*-values are calculated for the Mann-Kendall test.

[#] *p*-values are calculated for the Mann-Whitney *U* test.

[&] *p*-values are calculated for the Kruskal-Wallis test.

longed exposure to risk factors than in the 20–29-year-old population. This stability may reflect the fact that preventive measures are implemented more aggressively in the 30–69-year age group,[32] as well as the fact that there may be specific factors influencing the clinical manifestations of cardiovascular disease in a younger population. These factors could predispose young adults to present cardiovascular diseases as OHCA, necessitating further research in the future.

In some countries across Europe,[34,35] North America,[21] and Australia,[36,37] the incidence of OHCA has begun to either decline or stabilise, mirroring the significant drop in mortality rates from coronary atherosclerosis.[21,38] Additionally, the decrease in OHCA incidence rates among the elderly has contributed to an overall positive trend.[37] This contrasts with trends observed in certain Asian countries.[7,23,39] During our study period, the incidence rate of OHCA in individuals aged 80 and above was more than triple that of those in the 70–79 age bracket, and nearly tenfold compared to the 60–69 age group, with a 5% increase in proportion. By 2030, the projected number of deaths from coronary heart disease among individuals aged 65–94 in China is anticipated to rise by 3% compared to the previous decade, exacerbating the cardiovascular disease burden among China's ageing population.[40] The increased vulnerability to acute cardiac events in the elderly can be attributed to degenerative changes in the cardiovascular system and diminished physiological reserves, along with a higher prevalence of conditions such as hypertension, diabetes, and coronary artery disease as age progresses. Furthermore, factors such as delayed medical help-seeking behaviour,[41] reduced healthcare access, and a lack of awareness about cardiac symptoms in the elderly could also play a significant role in the heightened incidence of OHCA within this demographic.[42]

The notable strength of this study lies in its foundation on extensive data concerning OHCA across a diverse all-age population, spanning a significant time frame and encompassing a vast dataset. This has enabled a relatively precise assessment of the trends in OHCA incidence in Guangzhou, one of the cities most representative of China's economic development, over ten consecutive years. Additionally, our study offers age-standardized OHCA incidence rates, enhancing the potential for accurate future comparisons across various populations.

One limitation of the study was that the database did not strictly adhere to the Utstein model for collecting cases of OHCA, which resulted in our inability to obtain detailed information about the resuscitation process, in-hospital treatment, and prognosis of OHCA patients from EMS. In addition, our study only included data from the central urban districts of Guangzhou and could not adequately reflect the situation in the suburban areas. Finally, this study cannot avoid the potential biases inherent in retrospective research, such as selection and information bias. Nonetheless, the Guangzhou EMS database stands as the sole repository of case information presently available to us, offering the most comprehensive overview of OHCA within Guangzhou. Consequently, future research endeavours should pivot towards enhancing data collection methodologies to refine and update our understanding of OHCA incidence in Guangzhou.

Conclusion

Throughout the ten-year period from 2011 to 2020, Guangzhou experienced a significant escalation in both crude and age-standardised incidence rates of OHCA, with male incidence rates markedly exceeding those of females. Furthermore, the growth in OHCA incidence was particularly pronounced among younger individuals aged 20–29 years and seniors aged 70 years and above. These findings necessitate a deeper investigation into the factors driving these trends and call for the creation of focused interventions to lessen the burden of OHCA.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used ChatGPT in order to improve the language. After using this tool, we reviewed and edited the content as needed and take full responsibility for the content of the publication.

CRediT authorship contribution statement

Tianqi Yang: Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Cai Wen:** Writing – review & editing, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Yan Zhang:** Formal analysis, Data curation. **Yanjun Xu:** Formal analysis, Data curation. **Junpeng Liu:** Formal analysis, Data curation. **Zhenzhou Li:** Formal analysis, Data curation. **Shuangming Li:** Resources. **Na Peng:** Validation. **Hao Wu:** Validation. **Li Li:** Validation, Supervision, Project administration, Funding acquisition, Conceptualization. **Tao Yu:** Visualization, Supervision, Project administration, Funding acquisition, Conceptualization.

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Declaration of competing interest

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

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Appendix A. Supplementary material

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