Out-of-hospital cardiac arrest before and during the coronavirus disease 2019 pandemic in Hong Kong: A registry-based study from 2017 to 2023

Richard Huan Xu, Ruiqi Sun, Amy Fu

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Abstract

Background: The COVID-19 pandemic has led to changes in healthcare systems and behaviors. However, the impact of COVID-19 on the incidence and outcomes of out-of-hospital cardiac arrest (OHCA) throughout the entire pandemic period remains unclear.

Objective: This study aims to address these gaps by examining the incidence and outcomes of OHCA in Hong Kong (HK) before and during the pandemic.

Methods: This is a retrospective regional registry study. The researchers matched OHCA data from the Hong Kong Fire Service Department with COVID-19 confirmed case records from the Hong Kong Centre for Health Protection between December 2017 and May 2023. The data included information on response times, location of OHCA, witness presence, initial rhythm, bystander CPR, use of public-access defibrillation, resuscitation in the accident and emergency department, and survival to admission. Descriptive analyses were conducted, and statistical tests such as ANOVA and chi-square were used to examine differences between variables. The incidence of OHCA and survival rates were calculated, and logistic regression analysis was performed to assess associations. The prevalence of OHCA and COVID-19 during the peak of the pandemic was also described.

Results: A total of 43,882 cases of OHCA were reported in HK and included in our analysis. During the pandemic period, there was a significant increase in OHCA incidence, with a corresponding decrease in survival rates compared to the pre-pandemic period. The location of OHCA shifted, with a decrease in incidents in public places and a potential increase in incidents at home. Bystander cardiopulmonary resuscitation (CPR) rates increased, but survival rates to admission dropped significantly during the pandemic. There was a correlation between the development of OHCA and the prevalence of COVID-19 in HK.

Conclusions: The COVID-19 pandemic has had a significant impact on OHCA in HK, resulting in increased incidence and decreased survival rates. The findings highlight the importance of addressing the indirect effects of the pandemic, such as increased stress levels and strain on healthcare systems, on OHCA outcomes. Strategies should be developed to improve OHCA prevention, emergency response systems, and healthcare services during public health emergencies to mitigate the impact on population health.

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Declarations

Ethical Approval and consent to participate

The Institutional Review Board of HK Polytechnic University approved the study protocol (Ref No.: HSEARS 20211004004). The requirement for informed consent was waived.

Consent for publication

Not applicable

Availability of data and material

The datasets generated during and/or analyzed during the current study are not publicly available due to privacy concerns. However, they may be obtained from the corresponding author upon reasonable request.

Competing interests

None to declare.

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Author contribution

Conceptualization: RX and AF; Data curation: RX and RS; Formal Analysis: RX and RS; Methodology: RX;Project administration: RX and AF; Resources: RX and AF; Software: RX and RS; Supervision: RX and AF; Validation: RX and RS; Visualization: RX and RS; Writing – original draft: RX; Writing – review & editing: RX, RS, and AF.

Acknowledgement

Abstract

Background

The COVID-19 pandemic has exerted a significant toll on individual health and the efficacy of healthcare systems. However, the influence of COVID-19 on the frequency and outcomes of out-of-hospital cardiac arrest (OHCA) within the Chinese population, both prior to and throughout the entire pandemic period, remains to be clarified.

Objective

This study aimed to fill the gaps by investigating the prevalence and outcomes of OHCA in Hong Kong (HK) both before and during the whole pandemic period.

Methods

This is a retrospective regional registry study. The researchers matched OHCA data from the Hong Kong Fire Service Department with COVID-19 confirmed case records from the Hong Kong Centre for Health Protection between December 2017 and May 2023. The data included information on response times, location of OHCA, witness presence, initial rhythm, bystander CPR, use of public-access defibrillation, resuscitation in the accident and emergency department, and survival to admission. Descriptive analyses were conducted, and statistical tests such as ANOVA and chi-square were used to examine differences between variables. The incidence of OHCA and survival rates were calculated, and logistic regression analysis was performed to assess associations. The prevalence of OHCA and COVID-19 during the peak of the

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pandemic was also described.

Results

A total of 43,882 cases of OHCA were reported in HK and included in our analysis.

Around 13,946 cases were recorded during the pre-pandemic period (2017–2019), and

the remaining 29,936 cases were reported during the pandemic period (2020–2023).

During the pandemic period, the proportion of female patients increased to 44.1%,

and the average age increased slightly to 76.5 years (SD = 18.5). The majority of

OHCAs (61.1%; 18,143 cases) occurred at home. A witness was present in 45.9% of

the cases, and bystander cardiopulmonary resuscitation (CPR) was initiated in 44.6%

of the cases. There was a significant increase in OHCA incidence, with a

corresponding decrease in survival rates compared to the pre-pandemic period. The

location of OHCA shifted, with a decrease in incidents in public places and a potential

increase in incidents at home. We found that CPR (OR 1.48, 95% C.I. 1.17–1.86) and

public-access defibrillation (OR 1.16, 95% C.I. 1.05–1.28) were significantly

associated with a high STA rate during the pandemic period. There was a correlation

between the development of OHCA and the prevalence of COVID-19 in HK.

Conclusions

The COVID-19 pandemic has had a significant impact on OHCA in HK, resulting in

increased incidence and decreased survival rates. The findings highlight the

importance of addressing the indirect effects of the pandemic, such as increased stress

levels and strain on healthcare systems, on OHCA outcomes. Strategies should be

developed to improve OHCA prevention, emergency response systems, and healthcare

services during public health emergencies to mitigate the impact on population health.

Keywords: out-of-hospital cardiac arrest; OHCA; COVID-19; Pandemic; Survival;

Chinese; Asian

Introduction

Out-of-hospital cardiac arrest (OHCA) refers to the sudden cessation of cardiac activity outside a hospital setting. It is a critical medical emergency that poses significant challenges to individuals' health and healthcare systems. The escalating prevalence of OHCA in recent years has become a pressing concern. OHCA can affect individuals across all age groups and backgrounds, making it a universal health issue. According to data from 2020, the incidence of OHCA ranges from 30.0 to 97.1 per 100,000 population, with survival to hospital discharge varying from 3.1% to 20.4% worldwide [1]. This highlights the urgent need for effective preventive measures and improved emergency response systems.

The coronavirus disease 2019 (COVID-19) pandemic was associated with an increased incidence of several diseases. The stress on healthcare systems, disruptions to healthcare services, and changes in lifestyle and behavior due to lockdown measures contributed to these effects. Some diseases that showed an increased incidence included mental health disorders, cardiovascular diseases, and respiratory diseases. The COVID-19 pandemic negatively affected all components of systems-of-care related to OHCA, disrupting the chain of survival. A recent review demonstrated an increase of approximately 120% in the incidence of OHCA and a 65% decrease in OHCA-related survival to hospital discharge during the pandemic, compared to the pre-pandemic period [2].

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In addition, previous studies have reported significant changes in the incidence and epidemiological characteristics of OHCA and the prognosis of patients with OHCA during the pandemic compared to the pre-COVID-19 period. These reports have indicated a decrease in bystander cardiopulmonary resuscitation (CPR) and public-access defibrillator (PAD) use. In contrast, the emergency medical service (EMS) reaction time, frequency of arrests at home, and use of supraglottic airways have increased. Treatment-induced return of spontaneous circulation, survival to admission (STA), survival to discharge, 30-day survival, and favorable neurological outcomes all showed decreased incidence during the pandemic compared with pre-pandemic period[2–5]. Despite the end of the COVID-19 pandemic, comprehensive analyses of the entire period are scarce. This lack of evaluation of the effects of COVID-19 on OHCA during each wave of outbreak may skew the results.

While many studies have explored the effect of COVID-19 on OHCA during the pandemic, there are two research gaps that need to be filled. First, a significant limitation is that no studies have comprehensively monitored changes in the prevalence of OHCA in the population during the pre-pandemic period and during the entire duration of the COVID-19 pandemic. The lack of continuous monitoring data hinders our ability to fully comprehend the impact of the progression of the COVID-19 pandemic on OHCA. Second, there is a notable deficiency in data concerning the

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epidemiology of OHCA and the corresponding survival rates within the Hong Kong

(HK) population. HK, a highly developed region of China, exhibits a lower survival

rate for patients with OHCA compared to other industrialized countries [1]. A

previous study reported a local survival rate of 15.3% upon admission and a discharge

rate of 2.3% for patients with OHCA [6]. The lack of comprehensive data on OHCA

in HK during the pandemic hampers our ability to fully understand the scope of the

problem and develop effective strategies to improve survival rates for patients with

OHCA. It is crucial to conduct extensive research to gather detailed epidemiological

data on OHCA in the HK population. This would provide valuable insights into the

impact of COVID-19 on OHCA and inform the development of targeted interventions

to improve patient outcomes [1, 6]. Therefore, we aimed to conduct a large-scale

regional registry study to systematically explore the incidence and outcomes of

OHCA during the pre-pandemic and pandemic periods in HK.

Methods

Study design and participants

We established our database by matching OHCA data, based on electronic records

provided by the HK Fire Service Department (HKFSD), with confirmed COVID-19

case records from open-source data (chp.gov.hk/en/static/24012.html) provided by the

HK Centre for Health Protection (CHP). The HKFSD is the official sector that

provides publicly funded paramedic emergency ambulance services to more than 7.4

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million HK residents, operating from 41 ambulance depots. It maintains the electronic

records of individuals with OHCA who call for ambulance services. These records

include call triage and dispatch information, EMS response times, demographics, first

aid provided, and short-term clinical outcomes. From January 2020, the CHP began to

report the official number of confirmed cases of infection with severe acute

respiratory syndrome coronavirus 2 (SARS-CoV-2) variants in HK. Information on

the number of cases and daily deaths due to COVID-19 in HK at the peak of the

pandemic was obtained from the Hong Kong University (HKU) information hub

(covid19.sph.hku.hk/).

Data and procedures

The HKFSD provided general data on OHCA cases through its internal record system.

The research team collaborated with a superintendent from the HKFSD. This

superintendent, who is in charge of quality assurance and ambulance services training,

was appointed by the Chief Director of the HKFSD to provide the necessary data. The

data elicitation method followed the method used in a previous study aimed at

exploring the prevalence of OHCA in HK [6]. The senior author of that paper (YC

Siu) is a member of our research team. A list of variables of interest developed based

on internal discussion and a literature review was provided to the superintendent for

internal discussion. The research team, superintendent, and senior medical officers

from the HKFSD held three rounds of meetings to revise and confirm the data

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analysis protocol and the variable list. This study included patients of all ages. Victims

of OHCA who were directly transferred to the public mortuary from the scene by

EMS personnel and patients who did not use a ground ambulance were excluded from

the study.

We collected data from December 1, 2017 to May 31, 2023. These data included the

date of the incident, the response time (from the time of the call to arrival of

ambulance/EMS personnel), the location of the OHCA (home, en route to hospital,

nursing home, public place, or street), and the presence of an OHCA witness (yes/no).

Clinical data consisted of the initial rhythm (pulseless electrical activity, ventricular

fibrillation or ventricular tachycardia, asystole, or other), bystander CPR (yes/no), the

number of times a PAD was used, resuscitation in the accident and emergency (A&E)

department (yes/no), and STA (yes/no). Sociodemographic data included sex, age, and

area of residence.

Although cases of COVID-19 were first reported in late December 2019 in Wuhan,

the HK CHP started recording such cases in HK in January 2020. Therefore, we

defined the pre-pandemic period as December 1, 2017 to December 31, 2019 and the

pandemic period as January 1, 2020 to May 31, 2023, despite the World Health

Organization announcing the end of the pandemic on May 5, 2023. We compared

patient characteristics, the setting of OHCA occurrences, and OHCA outcomes

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between the pre-pandemic and pandemic periods.

Statistical analysis

Descriptive analyses were primarily used to present our findings. Continuous data are

presented as means with standard deviations (SDs), while categorical data are

presented as frequencies (N) and proportions (%). The differences between

continuous variables were examined using analysis of variance, the Mann–Whitney

test, or the Kruskal–Wallis test, as appropriate. Differences between categorical

variables were examined using the chi-square test.

The total incidence of OHCA (‰) in HK and the incidence stratified by three districts

(Hong Kong Island, Kowloon, and the New Territories) are presented as the number

of OHCA cases divided by the mid-year population and survival to A&E department

admission (%) from 2018 to 2022, respectively. Figures were created to visually

represent the changing incidence of OHCA across different years and its relationship

with the outbreak and progression of the COVID-19 pandemic. Additionally, we

present the change in the prevalence of OHCA at different key cutoff points (e.g.,

different waves of an outbreak) of the COVID-19 pandemic in HK.

Multivariate logistic regression analysis was used to assess the association between

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survival and A&E department admission, as well as the use of CPR and PAD during

the pre-pandemic and pandemic periods. The analysis was adjusted for factors

including sex, age, the cause of OHCA, the initial rhythm, the response time, whether

the OHCA was witnessed, the location of the OHCA, and the area of residence of the

patient. Adjusted odds ratios (aORs) and their 95% confidence intervals (95% CIs)

were calculated. Furthermore, we collected additional data and described the

prevalence of OHCA and COVID-19 during the peak of the pandemic (11 weeks from

February 7, 2022 to April 24, 2022). Differences with P-values less than 0.05 were

considered statistically significant. All statistical analyses were performed using

STATA version 16 (StataCorp LLC, College Station, TX, USA).

Ethical consideration

The Institutional Review Board of HK Polytechnic University approved the study

protocol (Ref No.: HSEARS 20211004004). The requirement for informed consent

was waived.

Results

Participants' background characteristics

From December 1, 2017 to May 31, 2023, HK reported 43,882 cases of OHCA (Table

1). Of these, 13,946 cases were recorded during the pre-pandemic period (2017–

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2019), and the remaining 29,936 cases were reported during the pandemic period (2020–2023). During the pre-pandemic period, 56.6% of the patients were men, with an average age of 75.81 years (SD = 17.12). The majority of OHCAs (54.3%; 7,566 cases) occurred at home. During the pandemic period, the proportion of female patients increased to 44.1%, and the average age increased slightly to 76.5 years (SD = 18.5). The majority of OHCAs (61.1%; 18,143 cases) occurred at home. A witness was present in 45.9% of the cases (10,723 cases), and CPR was initiated in 44.6% of the cases (13,318 cases). The average response time increased to 13.6 minutes (SD = 13.3), and only 8.3% of the patients (2,464 cases) were alive when admitted to an A&E department, which is half the rate observed in the pre-pandemic period.

Prevalence of OHCA during the COVID-19 pandemic

Figure 1 presents a comparative analysis of the prevalence of OHCA during the study period. The prevalence of OHCA was lower in 2018–2019 than in 2020–2023. During the pandemic, each wave of the COVID-19 outbreak in HK aligned with a significant increase in the prevalence of OHCA. Notably, the peak in OHCA incidents coincided with the onset of the Chinese New Year holiday in 2022, a surge that lasted for approximately 11 weeks. This period marked the highest recorded number of COVID-19 cases throughout the pandemic. We also found a significant increase in the prevalence of OHCA following the discontinuation of zero-tolerance measures in mainland China. However, the removal of mandatory mask-wearing regulations by

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the HK government in March 2023 did not result in a significant increase in the

prevalence of OHCA.

OHCA incidence stratified by year and region

Table 2 demonstrates the increased incidence of OHCA from 2018 (0.85‰,

6438/7,451,500) to 2022 (1.45‰, 10,618/7,345,000). However, the STA rate

significantly decreased from 16.9% (1,090/6,438) to 5.6% (584/10,424) during this

period. When stratified by region, the incidence of OHCA was higher in Kowloon and

Hong Kong Island than in the New Territories. During the pre-pandemic period, the

STA rate was approximately 4% higher in the New Territories than in the other two

districts. However, during the pandemic period, the gap in STA rates narrowed, with

the STA rate in the New Territories becoming slightly lower than the STA rates in

Kowloon in 2021 (7.2%, 245/3,407 vs. 7.6%, 212/2,805) and 2022 (5.7%, 277/4,837

vs. 5.9%, 215/3,636). Figure 2 provides additional information on the incidence of

OHCA in all 18 districts. Generally, the incidence of OHCA was lower in districts in

the north (New Territories) than in the other districts. Kwun Tong District (Kowloon,

mid-part of HK) reported the highest incidence of OHCA during both the pre-

pandemic and pandemic periods. The OCHA incidents, STA rate, and usage of CPR

among different demographic groups in the three regions over the study period are

detailed in Multimedia Appendix 1.

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Relationship between STA and patients' characteristics

Table 3 presents the results of the multivariate logistic regression analysis of the associations between the STA rate and various factors during the pre-pandemic and pandemic periods. The key findings included higher odds of OHCA among men during the pandemic period and higher odds of certain initial electrocardiogram rhythms during the same period. There were also higher odds of non-trauma causes of OHCA during both periods. Other factors, such as the response time, whether the OHCA was witnessed, the location of the OHCA, and the region exhibited varying aORs between the two periods. Notably, we found that bystander CPR administration (aOR 1.48, 95% CI 1.17–1.86) and PAD usage (aOR 1.16, 95% CI 1.05–1.28) were significantly associated with a high STA rate during the pandemic period.

Correlation between OHCA and COVID-19 cases during the pandemic

Figure 3 graphically presents the correlation between OHCA incidents and the progression of COVID-19 during the pandemic period in HK. Overall, there was a consistent relationship between these two variables, with a higher SARS-CoV-2 infection rate leading to an increased prevalence of OHCA. This correlation was particularly evident in 2022, which had the highest prevalence of COVID-19 and corresponded with the highest prevalence of OHCA. Table 4 provides a detailed

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overview of the OHCA and COVID-19 statistics from February 7, 2022 to April 24, 2022. This period marked the peak of COVID-19 cases, which coincided with a sharp increase in the number of OHCA incidents. During these 11 weeks, the number of OHCA cases increased dramatically, reaching a peak of approximately 114 cases per day in the fourth week. Concurrently, the number of COVID-19 cases increased, reaching a daily average of 67,583 cases during the same week. However, the highest daily death toll from COVID-19 was recorded in the fifth week. In contrast, the STA rate in cases of OHCA demonstrated a slightly different trend, with marginally higher numbers recorded during the most severe 5 weeks (weeks 3–7) of the COVID-19 outbreak.

Discussion

Primary findings

Data from the past 7 years show that, during the COVID-19 pandemic, the number of OHCA cases in HK increased significantly, almost quadrupling at the peak of the pandemic. Concurrently, the survival rate to hospital for OHCA cases decreased considerably, leading to a marked increase in OHCA-related deaths. This trend slowly decreased to normal levels by the end of the study period. Although fatalities directly attributed to COVID-19 may account for some of these findings, it is crucial to acknowledge the potential influence of various indirect effects. For instance, the widespread implications of lockdowns led to significant escalations in stress and

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anxiety levels, which may have increased the likelihood of OHCA [7]. Another

critical factor is the strain on the healthcare system owing to the pandemic, such as the

EMS being overwhelmed. Such disruptions adversely affect all components of the

chain of survival [8]. However, without data on the SARS-CoV-2 infection rate in the

OHCA population, it is challenging to estimate the direct impact of COVID-19 on the

STA rates of patients with OHCA.

Comparisons with previous studies

During the pandemic, a significant shift in OHCA location was observed. Compared

to before the pandemic, during the pandemic there was a decrease in the number of

OHCAs occurring in public places, likely due to the implementation of lockdowns

and social distancing measures, which resulted in fewer people being out in public.

This finding aligns with those of most previous studies [9–11], but a different trend

has been reported in some Asian populations. For instance, Riyapan et al. reported no

significant change in the occurrence of OHCA in public places in Thailand before and

during the pandemic [12]. Watanabe et al. also reported no decrease in the occurrence

of OHCA in public places [13]. However, the decrease observed in the number of

OHCAs in public places does not necessarily indicate a reduction in the overall

number of OHCAs. Instead, this may suggest a shift in the location of these incidents,

with a potential increase in the number of OHCAs occurring at home.

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There was a significant decrease in the number of OHCAs reported in nursing homes during the pandemic. This trend is surprising given the vulnerability of the older population to OHCA. The findings for this outcome in previous studies have been mixed. For example, a study in Portugal reported no difference between the number of OHCAs in nursing homes before and during the pandemic [11]. Another study in the United States found that the percentage of patients experiencing an OHCA in a nursing home was higher in 2020 than in 2019 [14]. A study in HK revealed that 96% of COVID-19-related deaths were among individuals aged 60 years and older, with 53% being nursing home residents [15]. Our findings suggest that, although the number of OHCAs in nursing homes decreased during the pandemic, this does not necessarily mean fewer older individuals experienced an OHCA. Many older individuals may have died from COVID-19, and their deaths were not classified as OHCA-related. This may result in an underestimation of the devastating impact of OHCA on the older population, particularly those in nursing homes, during this public health emergency. The government should update and standardize mortality calculations during future public health emergencies [16].

Another reason for the decrease in the number of OHCAs in nursing homes during the pandemic may be the effectiveness of non-pharmaceutical interventions (NPIs) at

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reducing the number of COVID-19 cases and fatalities within long-term care facilities and nursing homes. Previous studies have shown an association between a decrease in the number of COVID-19 cases and the rigor of various containment measures, notably school and workplace closures, and public information campaigns globally [17,18]. In HK, border restrictions, quarantine and isolation, social distancing, and behavioral changes in the population were significantly linked to control of the COVID-19 pandemic [19]. This may underscore the crucial role that NPIs can play in safeguarding vulnerable populations during pandemics.

Our study revealed an increase in the bystander CPR rate during both the pre-pandemic and pandemic periods, albeit at a slower rate during the pandemic. During the pre-pandemic period, the bystander CPR rate increased by approximately 10% from 2018 to 2019. However, this trend plateaued with the onset of the COVID-19 pandemic, resulting in a negligible difference in the CPR rate between 2019 and 2020. A Korean study reported a similar finding [20], but studies in some Western countries have reported notable decreases in CPR rates. For example, in France, the CPR rate dramatically fell from 63.9% to 47.8% between March and April 2020 [10]. A study in Spain also found a decrease in CPR rates from 51.1% to 42.6% between 2017/18 and 2020 [21]. These decreases in CPR rates highlight the profound effects of the pandemic on critical medical procedures across different nations. Nevertheless, we found that, as the pandemic progressed, the CPR rate showed another increase,

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stabilizing between 44% and 48%. Data on bystander CPR rates during the pandemic

are mixed. A systematic review of studies conducted in 2020 suggested a decline in

the incidence of bystander CPR at the onset of the pandemic, with one study noting

that this decline was observed only in patients diagnosed with COVID-19 [22].

Another review, including studies published in 2020 and 2021, indicated a change in

the community response to OHCA, with fewer occurrences of bystander CPR [23].

However, a recent review of studies published in 2022 found no significant difference

in bystander CPR rates between the COVID-19 pandemic and pre-pandemic periods

[4]. It is important to note that the pandemic also affected other aspects of the CPR

response and outcomes, such as EMS availability. A review of the relationship

between OHCA and EMS indicated that difficulties encountered by the first responder

system during the COVID-19 pandemic, such as dispatcher overload, increased

response times, and adherence to personal protective equipment requirements, were

superimposed on shortages in the supply of personal protection equipment [24]. Our

findings highlight the complex impact of the pandemic on OHCA outcomes.

Although the frequency of witnesses of OHCA and bystander CPR significantly

increased, we observed a drastic reduction in the rate of STA enroute to the A&E

department during the pandemic, which is consistent with the findings of previous

studies [4,22,23]. During the pre-pandemic period, the overall STA rate in 2018 was

approximately 16.9%, and this increased slightly to 18.5% in 2019. However, during

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the first year of the pandemic, the STA rate decreased by more than 25%, and further

decreased to approximately 5.6% at the peak of the pandemic in 2022. By the end of

the study period, the STA rate had slightly increased to 6.7% in the first 5 months of

2023, but remained approximately 65% lower than the rate observed in the final year

of the pre-pandemic period (2019). The STA rate was lower in HK than in other

countries/regions during the pandemic [10,25,26]. Several factors may have

accounted for this discrepancy. An overburdened healthcare system can lead to

delayed recognition of and intervention in unstable patients. For instance, following

the 2022 Chinese New Year holiday, public hospitals in HK were dealing with more

than 1,800 COVID-19 cases requiring EMS per day. Emergency medical systems,

especially emergency departments, which serve as the frontline of the healthcare

system, experienced severe overload and challenging working conditions. This was a

global issue [27]. Moreover, there were fewer cardiac arrests in public places during

the pandemic, which may have influenced the survival rate of patients with OHCA.

Additionally, the lack of sufficient CPR training in HK [28,29] and the fear of

COVID-19 may have affected the willingness of witnesses to perform CPR. Given

that CPR is considered an aerosol-generating procedure with a significant risk of viral

transmission, witnesses may have hesitated to perform it, potentially affecting the

STA rate [30].

A strong correlation was observed between outbreaks of COVID-19 and surges in

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OHCA cases in HK over the past 4 years. In particular, the fifth wave of the pandemic, which coincided with the Chinese New Year holiday, resulted in a significant surge in OHCA cases. The older population, the most vulnerable group to both COVID-19 and OHCA, bore the brunt of the pandemic. The average age of our sample was over 75 years, highlighting the insufficient protection provided by the government for this demographic during the pandemic. A previous review demonstrated a gradual age-associated increase in the COVID-19 mortality rate [31]. For example, one study showed a 10.5% fatality rate for older patients compared to 0.43% for younger patients [32]. As of April 2022, less than one-third of HK residents aged over 80 years had been fully vaccinated. The vaccination rate was even lower among residents of care homes when the Omicron variant arrived in HK, at less than 20%. This is not surprising, given that vaccine hesitancy to both the first vaccine dose and the booster were widespread [33]. Another study underscored the urgency of vaccination for older people, revealing that approximately one quarter of countries reported lower vaccination coverage among older adults compared to the overall population [34]. Additionally, as reported in a previous study [35], lockdown measures and no-visit policies resulted in older adults being unable to meet their families for extended periods, leading to heightened levels of anxiety and depression among this population, thereby increasing the risk of OHCA. It is crucial to develop comprehensive policies and strategies to mitigate the direct and indirect effects of public health emergencies on health outcomes in the older population.

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In 2019, the HK Legislative Council suggested promoting bystander intervention to improve the survival rates for patients with OHCA. The suggestions included adopting technologies to reduce rescue time, providing education and training to enhance the skills of the public, and urging the government to develop laws and regulations to protect bystanders legally and limit their liability [36]. Thus, the outcomes of our regression analysis revealed that, during the pandemic, bystander CPR and PAD usage significantly improved the STA rate for individuals with OHCA compared to the pre-pandemic period, during which the associations between STA rate and bystander interventions were insignificant. Furthermore, our regression analysis revealed a significant relationship between the response time and STA rate. To handle emergency situations during the pandemic, the HKFSD adopted a target-oriented approach to devise various emergency response strategies and measures. In the meantime, the Director's Command Post also established an artificial-intelligence-powered social media service platform capable of providing automated inquiries and instant replies 24 hours/day, 7 days/week [37]. The importance of reform and collaboration in multiple social sectors is paramount to improve the STA rate of patients with OHCA during public health emergencies.

Limitations

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Our study is among the first to delineate the relationship between COVID-19 and the

prevalence of OHCA at the population level during both the pre-pandemic and

pandemic periods. However, this study has certain limitations that need to be

acknowledged. First, although we observed a decrease in the STA rate during the

pandemic, we lacked information about patient survival rates upon discharge and their

short- and long-term health outcomes, because patient data in A&E departments and

hospital settings are managed by the Hospital Authority rather than the HKFSD.

Matching OHCA patient data with medical records would provide a more

comprehensive understanding of the impact of COVID-19 on OHCA in HK. Second,

the HKFSD did not collect information about whether patients with OHCA had

COVID-19 during the provision of services. Consequently, we lack knowledge about

the prevalence of COVID-19 among patients with OHCA, which may have led to an

inaccurate estimation of the impact of COVID-19 on the survival rate of patients with

OHCA in HK.

Conclusions

In our study of the prevalence of OHCA from 2017 to 2023, we observed a significant

increase in OHCA incidence and a considerable decrease in survival rates of patients

with OHCA during the COVID-19 pandemic compared to the period before the

pandemic. Moreover, we found that the spikes in the number of OHCA cases closely

matched the increase in the number of confirmed COVID-19 cases in HK.

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Components of both the social sector, such as the Home Office, and the healthcare

sector, such as EMS systems, should prepare for potential increases in the number of

OHCA cases during future public health crises. It is necessary to reform these sectors

to make them more resilient, efficient, and effective at meeting the needs of

individuals with OHCA. Developing an effective multi-disciplinary mechanism for

leveraging resources, sharing knowledge and expertise, and coordinating efforts are

key factors for improving the survival rates of patients with OHCA during future

pandemics.

References

1   Kiguchi T, Okubo M, Nishiyama C, *et al.* Out-of-hospital cardiac arrest across the

World: First report from the International Liaison Committee on Resuscitation

(ILCOR). *Resuscitation*. 2020;152. doi: 10.1016/j.resuscitation.2020.02.044

2   Lim ZJ, Ponnapa Reddy M, Afroz A, *et al.* Incidence and outcome of out-of-hospital

cardiac arrests in the COVID-19 era: A systematic review and meta-analysis.

Resuscitation. 2020;157. https://doi.org/10.1016/j.resuscitation.2020.10.025

3   Baldi E, Primi R, Bendotti S, *et al.* Relationship between out-of-hospital cardiac

arrests and COVID-19 during the first and second pandemic wave. The importance of

monitoring   COVID-19   incidence.   *PLoS   One*.   2021;16.   doi:

10.1371/journal.pone.0260275

4   Kim JH, Ahn C, Park Y, *et al.* Comparison of out-of-hospital cardiac arrests during the

25

COVID-19 pandemic with those before the pandemic: an updated systematic review and meta-analysis. Front Public Health. 2023;11. https://doi.org/10.3389/fpubh.2023.1180511

5   Liu CH, Tsai MJ, Hsu CF, *et al.* The Influence of the COVID-19 Pandemic on Emergency Medical Services to Out-of-Hospital Cardiac Arrests in a Low-Incidence Urban City: An Observational Epidemiological Analysis. *Int J Environ Res Public Health*. 2023;20. doi: 10.3390/ijerph20032713

6   Fan KL, Leung LP, Siu YC. Out-of-hospital cardiac arrest in Hong Kong: A territory-wide study. *Hong Kong Medical Journal*. 2017;23. doi: 10.12809/hkmj166046

7   Kerstin M, Martina G, Theresa T, *et al.* Depression and anxiety in relatives of out-of-hospital cardiac arrest patients: Results of a prospective observational study. *J Crit Care*. 2019;51. doi: 10.1016/j.jcrc.2019.01.026

8   Ball J, Nehme Z, Bernard S, *et al.* Collateral damage: Hidden impact of the COVID-19 pandemic on the out-of-hospital cardiac arrest system-of-care. *Resuscitation*. 2020;156. doi: 10.1016/j.resuscitation.2020.09.017

9   Mathew S, Harrison N, Chalek AD, *et al.* Effects of the COVID-19 pandemic on out-of-hospital cardiac arrest care in Detroit. *American Journal of Emergency Medicine*. 2021;46. doi: 10.1016/j.ajem.2021.03.025

10   Marijon E, Karam N, Jost D, *et al.* Out-of-hospital cardiac arrest during the COVID-19 pandemic in Paris, France: a population-based, observational study. *Lancet Public Health*. 2020;5. doi: 10.1016/S2468-2667(20)30117-1

11   Ladeira L, Rato F, Barros F. Out-of-Hospital Cardiac Arrest during the COVID-19

26

pandemic in Portugal. *Resuscitation.* 2020;155. doi: 10.1016/j.resuscitation.2020.08.113

12   Riyapan S, Chantanakomes J, Roongsaenthong P, *et al.* Impact of the COVID-19 outbreak on out-of-hospital cardiac arrest management and outcomes in a low-resource emergency medical service system: a perspective from Thailand. *Int J Emerg Med*. 2022;15. doi: 10.1186/s12245-022-00429-1

13   Watanabe K, Mori K, Sato K, *et al.* Out-of-hospital cardiac arrest patients during the coronavirus disease 2019 pandemic. *Sci Rep*. 2023;13:23005.

14   Glober NK, Supples M, Faris G, *et al.* Out-of-hospital cardiac arrest volumes and characteristics during the COVID-19 pandemic. *American Journal of Emergency Medicine*. 2021;48. doi: 10.1016/j.ajem.2021.04.072

15   Auyeung TW, Chan FHW, Chan TY, *et al.* COVID-19 and older adults: Experience in Hong Kong. *Asian Journal of Gerontology and Geriatrics*. 2020;15. doi: 10.12809/ajgg-2020-424-oa

16   Christian MD, Couper K. COVID-19 and the global OHCA crisis: An urgent need for system level solutions. Resuscitation. 2020;157. https://doi.org/10.1016/j.resuscitation.2020.11.004

17   Wong MC, Huang J, Teoh J, *et al.* Evaluation on different non-pharmaceutical interventions during COVID-19 pandemic: An analysis of 139 countries. J Infect. 2020;81. https://doi.org/10.1016/j.jinf.2020.06.044

18   Vogazianos P, Argyropoulos CD, Haralambous C, *et al.* Impact assessment of COVID-19 non-pharmaceutical interventions in long term care facilities in Cyprus:

27

Safety improvement strategy. *Saf Sci*. 2021;143. doi: 10.1016/j.ssci.2021.105415

19   Cowling BJ, Ali ST, Ng TWY, *et al.* Impact assessment of non-pharmaceutical

interventions against coronavirus disease 2019 and influenza in Hong Kong: an

observational study. *Lancet Public Health*. 2020;5. doi: 10.1016/S2468-

2667(20)30090-6

20   Jung H, Kim Jung H, Ryoo Hyun W, *et al.* Impact of COVID-19 pandemic on

bystander CPR in patient with OHCA: a registry-based before and after study in

Daegu, Korea. *Signa Vitae*. 2024;20:94–105.

21   Rosell Ortiz F, Fernández del Valle P, Knox EC, *et al.* Influence of the Covid-19

pandemic on out-of-hospital cardiac arrest. A Spanish nationwide prospective cohort

study. *Resuscitation*. 2020;157. doi: 10.1016/j.resuscitation.2020.09.037

22   Scquizzato T, Landoni G, Paoli A, *et al.* Effects of COVID-19 pandemic on out-of-

hospital cardiac arrests: A systematic review. Resuscitation. 2020;157. https://doi.org/

10.1016/j.resuscitation.2020.10.020

23   Husain AA, Rai U, Sarkar AK, *et al.* Out-of-Hospital Cardiac Arrest during the

COVID-19 Pandemic: A Systematic Review. Healthcare (Switzerland). 2023;11.

https://doi.org/10.3390/healthcare11020189

24   Ong J, O'Connell F, Mazer-Amirshahi M, *et al.* An international perspective of out-

of-hospital cardiac arrest and cardiopulmonary resuscitation during the COVID-19

pandemic. American Journal of Emergency Medicine. 2021;47.

https://doi.org/10.1016/j.ajem.2021.04.033

25   Chavez S, Huebinger R, Chan HK, *et al.* The impact of COVID-19 on incidence and

28

outcomes from out-of-hospital cardiac arrest (OHCA) in Texas. *American Journal of Emergency Medicine*. 2022;57. doi: 10.1016/j.ajem.2022.04.006

26   Phattharapornjaroen P, Nimnuan W, Sanguanwit P, *et al.* Characteristics and outcomes of out-of-hospital cardiac arrest patients before and during the COVID-19 pandemic in Thailand. *Int J Emerg Med*. 2022;15. doi: 10.1186/s12245-022-00444-2

27   Garcia-Castrillo L, Petrino R, Leach R, *et al.* European Society for Emergency Medicine position paper on emergency medical systems' response to COVID-19. European   Journal   of   Emergency   Medicine.   2020;27. https://doi.org/10.1097/MEJ.0000000000000701

28   Chair SY, Hung MSY, Lui JCZ, *et al.* Public knowledge and attitudes towards cardiopulmonary resuscitation in hong kong: Telephone survey. *Hong Kong Medical Journal*. 2014;20. doi: 10.12809/hkmj134076

29   Yim VWC, Ip CML, Siu AYC, *et al.* Cardiopulmonary resuscitation training in secondary education: A prospective cross-sectional survey of 110 Hong Kong secondary schools. *Hong Kong Journal of Emergency Medicine*. 2021;28. doi: 10.1177/1024907920971159

30   DeFilippis EM, Ranard LS, Berg DD. Cardiopulmonary Resuscitation during the COVID-19 Pandemic: A View from Trainees on the Front Line. Circulation. 2020;141. https://doi.org/10.1161/CIRCULATIONAHA.120.047260

31   Dadras O, SeyedAlinaghi SA, Karimi A, *et al.* COVID-19 mortality and its predictors in   the   elderly: A   systematic   review.   Health   Sci   Rep.   2022;5.

29

https://doi.org/10.1002/hsr2.657

32   Poletti P, Tirani M, Cereda D, *et al.* Age-specific SARS-CoV-2 infection fatality ratio

and associated risk factors, Italy, February to April 2020. *Eurosurveillance*. 2020;25.

doi: 10.2807/1560-7917.ES.2020.25.31.2001383

33   Shah A, Coiado OC. COVID-19 vaccine and booster hesitation around the world: A

literature   review.   Front   Med   (Lausanne).   2023;9.

https://doi.org/10.3389/fmed.2022.1054557

34   Wong MK, Brooks DJ, Ikejezie J, *et al.* COVID-19 Mortality and Progress Toward

Vaccinating Older Adults — World Health Organization, Worldwide, 2020–2022.

MMWR Morb Mortal Wkly Rep. 2023;72. doi: 10.15585/mmwr.mm7205a1

35   Vuilleumier S, Spichiger T, Dénéréaz S, *et al.* Not only COVID-19 disease impacts

ambulance emergency demands but also lockdowns and quarantines. *BMC Emerg

Med*. 2023;23. doi: 10.1186/s12873-023-00772-3

36   Legislative Council of the Hong Kong Special Administrative Region - Measures to

promote   bystander   intervention   in   medical   emergencies.   2019.

https://www.legco.gov.hk/research-publications/english/essentials-1819ise05-

measures-to-promote-bystander-intervention-in-medical-emergencies.htm   (accessed

27 February 2024)

37   HKFSD.   Director   Review   from   HKFSD.   2022.

https://www.hkfsd.gov.hk/images/review_22/tc_eng/02_director.pdf   (accessed   27

February 2024)

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Table 1 Background characteristics of individuals and the outcome of OHCA

Characteristics	n/N (%)		
	Pre-Pandemic (2017.12-2019.12)	Pandemic (2020.1-2023.5)	P-value
Sex			0.134
Male	7896/13946(56.6)	16721/29936(55.9)	
Female	6050/13946(43.4)	13215/29936(44.1)	
Region			0.243
Hong Kong Island	2679/13946(19.2)	5568/29985(18.6)	
Kowloon	4992/13946(35.8)	10747/29985(35.8)	
New Territories & Outlying Islands	6275/13946(45.0)	13670/29985(45.6)	
Location of OHCA			<0.001
Street	622/13944(4.5)	1077/29715(3.6)	
Home	7566/13944(54.3)	18143/29715(61.1)	
En-route to Hospital	692/13944(5)	1366/29715(4.6)	
Home for Aged	3439/13944(24.7)	6475/29715(21.8)	
Public Places	1625/13944(11.7)	2654/29715(8.9)	
Witnessed arrest			0.001
No	9165/13946(65.7)	19179/29902(64.1)	
Yes	4781/13946(34.3)	10723/29902(35.9)	
Initial ECG rhythm			<0.001
Asystole	11098/13942(79.6)	24327/29875(81.4)	
Pulseless electrical activity	1880/13942(13.5)	3730/29875(12.5)	
VF/VT	937/13942(6.7)	1712/29875(5.7)	
Others	27/13942(0.2)	106/29875(0.4)	
Apparent cause of arrest			<0.001
Trauma	659/13946(4.7)	1128/29972(3.8)	
Non-Trauma	13287/13946(95.3)	28844/29972(96.2)	
Resuscitation done in A&E			<0.001
No	6780/13946(48.6)	4264/8068(52.9)	
Yes	7166/13946(51.4)	3804/8068(47.1)	
Bystander CPR			<0.001

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No	9308/13945(66.7)	16534/29852(55.4)	
Yes	4637/13945(33.3)	13318/29852(44.6)	
Bystander PAD			0.37
No	13665/13946(98.0)	29423/29985(98.1)	
Yes	281/13946(2.0)	562/29985(1.9)	
Survival to admission			<0.001
No	11478/13946(82.3)	27309/29773(91.7)	
Yes	2468/13946(17.7)	2464/29773(8.3)	
	Mean (SD)		
Response time (min)	10.6(7.8)	13.6(13.3)	<0.001
Age (years)	75.8(17.1)	76.5(18.5)	<0.001

Note:

OHCA = out-of-hospital cardiac arrests

ECG = electrocardiogram

VF/VT = ventricular fibrillation/ventricular tachycardia

A&E = Accident & Emergency Department

CPR = cardiopulmonary resuscitation

PAD = public-access defibrillation

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Table 2 OHCA incidence, STA, and CPR ratio in HK and stratified by regions

| Year | Regions | | | |
	KW	HKI	N.T.	Overall
	OHCA incidence, N (‰)			
2018	2338 (1.03)	1232(0.98)	2868(0.73)	6438(0.86)
2019	2398(1.04)	1314(1.05)	3119(0.79)	6831(0.91)
2020	2922(1.27)	1504(1.23)	3642(0.92)	8068(1.08)
2021	2818(1.26)	1468(1.23)	3410(0.86)	7696(1.04)
2022	3695(1.68)	1978(1.71)	4945(1.24)	10618(1.45)
	STA, N (%)			
2018	342(14.6)	196(15.9)	552(19.2)	1090(16.9)
2019	369(15.4)	225(17.1)	667(21.4)	1261(18.5)
2020	348(11.9)	181(12.0)	570(15.7)	1099(13.6)
2021	212(7.6)	84(5.7)	245(7.2)	541(7.0)
2022	215(5.9)	92(4.7)	277(5.7)	584(5.6)
2023	99(7.5)	31(5.0)	110(6.6)	240(6.7)
	CPR, N (%)			
2018	674(28.8)	338(27.4)	851(29.7)	1863(28.9)
2019	872(36.4)	532(40.5)	1215(39.0)	2619(38.3)
2020	1095(37.5)	605(40.2)	1502(41.2)	3202(39.7)
2021	1147(40.8)	677(46.1)	1557(45.7)	3381(44.0)
2022	1715(46.8)	965(49.0)	2411(49.3)	5091(48.4)
2023	601(46.1)	291(47.6)	752(45.4)	1644(46.0)

Note:

KW = Kowloon

HKI = Hong Kong Island

N.T. = New Territories and Outlying Islands

OHCA = out-of-hospital cardiac arrests

STA = survival to admission

CPR = cardiopulmonary resuscitation

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Table 3 the associations of STA and patient's characteristics

	Pre-pandemic period			Pandemic period		
	Adjusted OR	95% C.I.		Adjusted OR	95% C.I.	
Sex						
Female						
Male	0.95	0.87	1.05	1.12*	1.02	1.24
Age	0.99***	0.99	0.99	0.99***	0.99	0.99
Cause of arrest						
Trauma						
Non-Trauma	4.35***	3.10	6.10	4.48***	3.05	6.56
Initial ECG rhythm						
Asystole						
VF/VT	2.92***	2.49	3.43	3.49***	3.03	4.01
PEA	2.31*	2.05	2.61	2.91***	2.60	3.25
Response time	0.99	0.98	1.00	0.97***	0.96	0.98
Witnessed arrest						
Yes						
No	0.48***	0.43	0.53	0.49***	0.45	0.54
Location of OHCA						
Street						
Home	0.47***	0.37	0.58	0.59***	0.48	0.72
En-route to Hospital	0.78	0.58	1.05	1.56***	1.19	2.05
Home for aged	0.45***	0.36	0.58	0.53***	0.42	0.67
Public area excluding street	0.75*	0.59	0.95	0.97	0.78	1.20
Region						
N.T.						
HKI	0.78	0.68	0.88	0.75***	0.66	0.85
KW	0.66***	0.60	0.74	0.86**	0.78	0.95
Bystander PAD						
No						
Yes	1.14	0.86	1.51	1.48**	1.17	1.86
Bystander CPR						
No						
Yes	1.04	0.93	1.16	1.16**	1.05	1.28
Pseudo R^2		0.102			0.125	
Akaike information criterion		11597.9			14440.9	
Bayesian information criterion		11725.9			14581.6	

Table 4 OHCA and COVID-9 cases in the peak (weeks) of the pandemic period in HK

		Median (IRQ)			
No.	Weeks	OHCA cases	STA of OHCA	COVID-19 cases	Daily death of COVID-19
1	2022.2.7-2022.2.13	30(26,38)	1(0,1)	1161(625,1347)	0(0,2)
2	2022.2.14-2022.2.20	47(38,50)	1(1,2)	4285(2071,6067)	11(3,17)
3	2022.2.21-2022.2.27	86(64,93)	2(1,4)	8798(7533,50976)	49(36,80)
4	2022.2.28-2022.3.6	114(104,126)	2(1,3)	67583(55658,76341)	203(183,238)
5	2022.3.7-2022.3.13	94(90,98)	3(2,4)	30493(27647,32430)	290(285,296)
6	2022.3.14-2022.3.20	63(54,80)	2(0,3)	21650(16597,27765)	284(254,294)
7	2022.3.21-2022.3.27	42(38,45)	3(1,3)	12240(8841,14068)	206(156,228)
8	2022.3.28-2022.4.3	32(31,36)	2(1,4)	6646(4475,7596)	120(116,156)
9	2022.4.4-2022.4.10	30(27,36)	2(0,3)	2644(2492,3138)	87(65,97)
10	2022.4.11-2022.4.17	22(19,30)	1(1,3)	1043(794,1407)	57(41,62)
11	2022.4.18-2022.4.24	21(17,26)	1(1,2)	600(523,628)	15(10,20)

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Figure 1 Perveance of OHCA in HK from 2017.12 to 2023.5 with key local time points of COVID-19 pandemic

Note:
23-Jan-20   First Wave of the COVID-19 outbreak
19-Mar-20   Second Wave of the COVID-19 outbreak
05-Jul-20   Third Wave of the COVID-19 outbreak
19-Nov-20   Fourth Wave of the COVID-19 outbreak
31-Dec-21   Fifth Wave of the COVID-19 outbreak
05-Feb-22   Chinese New Year Festival Holiday
07-Dec-22   Zero-tolerance measures are announced to be over in Mainland China
01-Mar-23   All mandatory mask-wearing requirements are lifted in HK
Blue line indicates pre-pandemic period
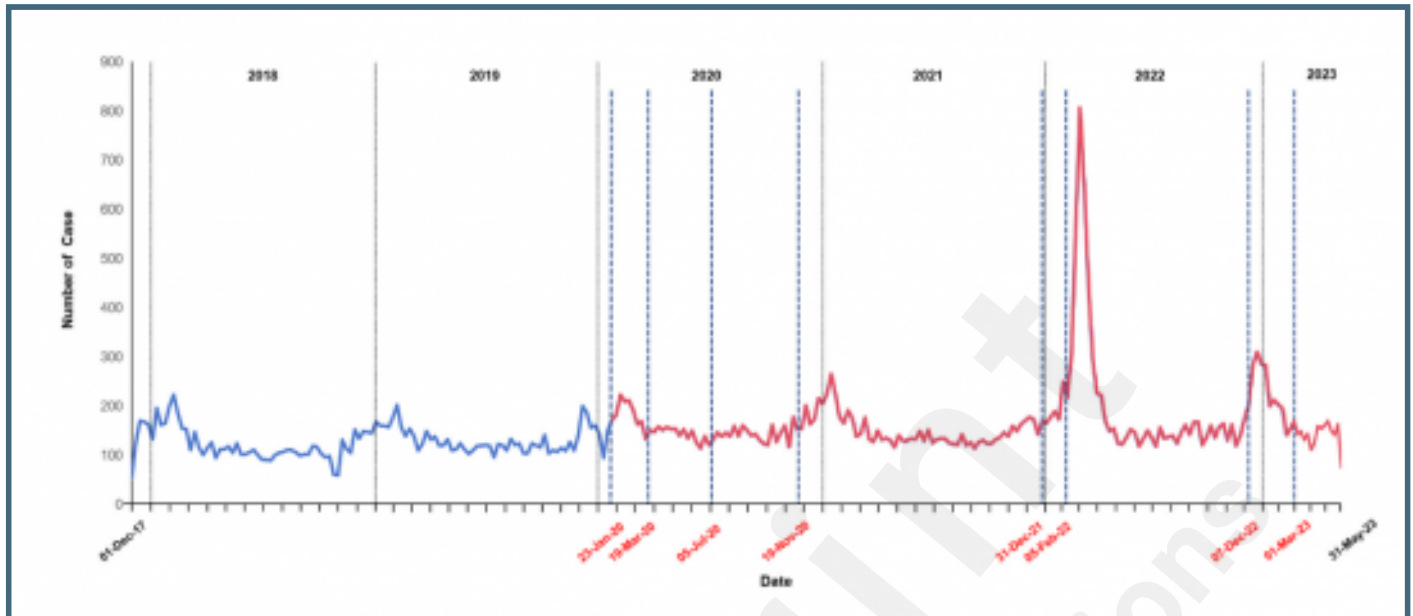Red line indicates pandemic period

Figure 2 Surge of OHCA incidence across HK districts Pre- (2018 and 2019) and during Pandemic (2020-2022)

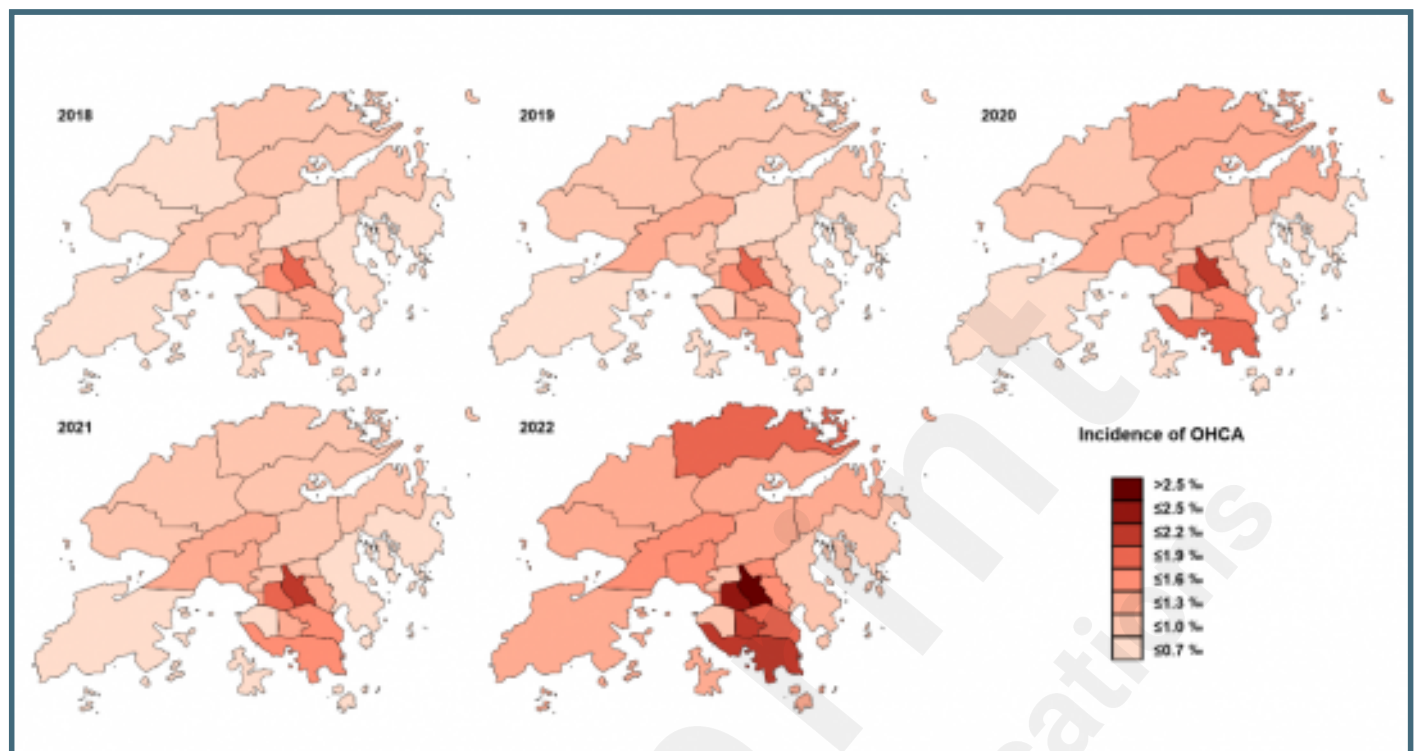**Figure 3 Correlation of perveance between OHCA & COVID during Pandemic (2020.1 to 2023.5)**
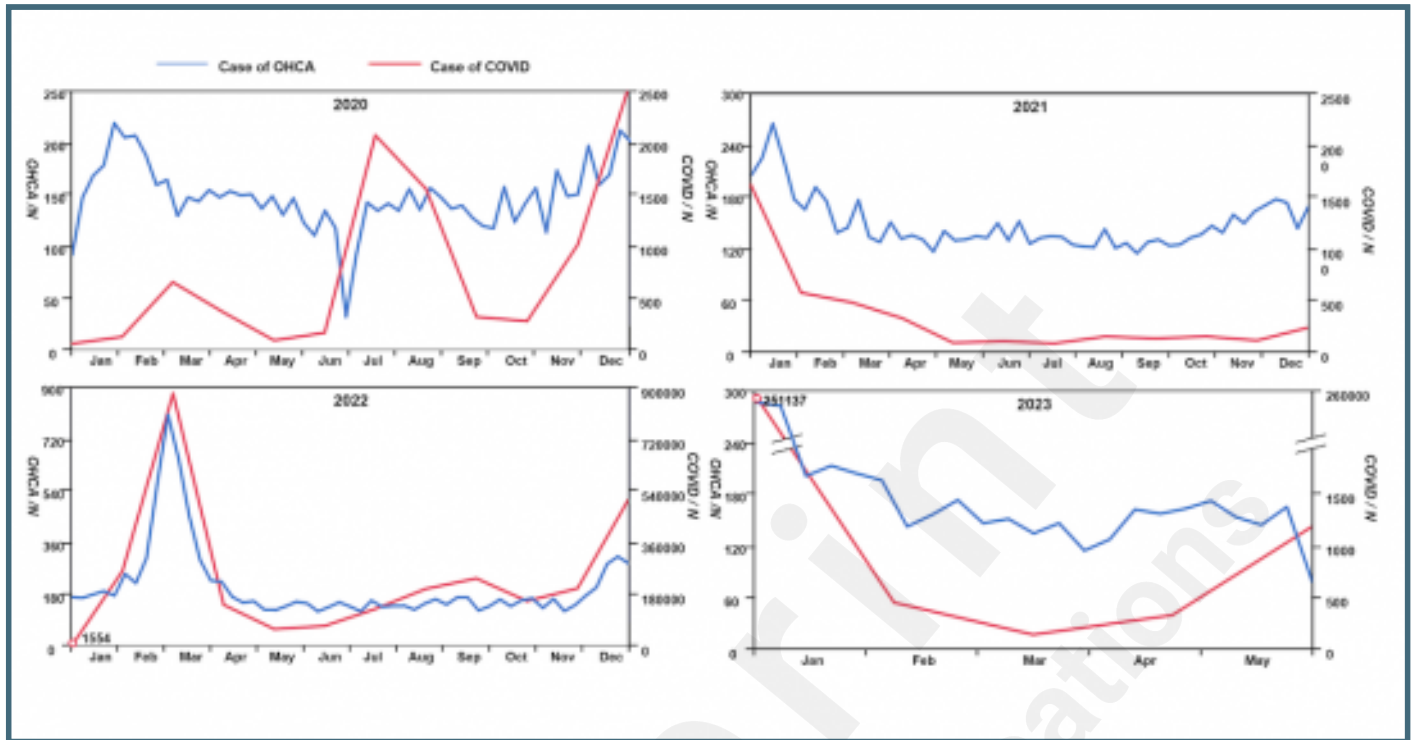
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Supplementary Files

Figures

Perveance of OHCA in HK from 2017.12 to 2023.5 with key local time points of COVID-19 pandemic.

Surge of OHCA incidence across HK districts Pre- (2018 and 2019) and during Pandemic (2020-2022).

Correlation of perveance between OHCA & COVID during Pandemic (2020.1 to 2023.5).

Multimedia Appendixes

OHCA incidence, STA, and CPR ratio in different demographic and geographic groups.
URL: http://asset.jmir.pub/assets/8b61ec367dd1abab7980490f91d11302.docx