# Changes in emergency department attendance, diagnostic groups and 28-day mortality associated with the COVID-19 pandemic in Hong Kong: a territory-wide, retrospective, cohort study

**Abraham K.C. Wai**[1,3*], MBChB, FHKAM

**Carlos K.H. Wong**[5,6*], PhD

**Janet Y.H. Wong**[2], RN, PhD

**Owen C.K. Chu**[1], BSc (Hons)

**Charles M.S. Wong**[4], PhD

**Matthew S.H. Tsui**[3], MBBS, FHKAM

**Timothy H Rainer**[1,3], MD, FHKAM

[1]Emergency Medicine Unit, Li Ka Shing Faculty of Medicine, The University of Hong Kong, Hong Kong SAR, China

[2]School of Nursing, Li Ka Shing Faculty of Medicine, The University of Hong Kong, Hong Kong SAR, China

[3]Accident and Emergency Department, Queen Mary Hospital, Hong Kong SAR, China

[4]Department of Land Surveying and Geo-informatics, The Hong Kong Polytechnic University, Hong Kong SAR, China.

[5]Department of Pharmacology and Pharmacy, Li Ka Shing Faculty of Medicine, The University of Hong Kong, Hong Kong SAR, China

[6]Department of Family Medicine and Primary Care, Li Ka Shing Faculty of Medicine, The University of Hong Kong, Hong Kong SAR, China

* contributed equally as co-first author

**Corresponding author**

Timothy Hudson Rainer, Emergency Medicine Unit, Li Ka Shing Faculty of Medicine, The University of Hong Kong, Hong Kong SAR, China

Address: Room 26A, One Island South, 2 Heung Yip Road, Wong Chuk Hang, Hong Kong SAR, China
Email: thrainer@hku.hk

**KEY POINTS (101 words)**

**Question**

What is the impact of the COVID-19 pandemic on mortality in emergency patients in Hong Kong?

**Findings**

The pandemic is associated with a 27.4% reduction in emergency department (ED) attendances and a 42.6% increase in overall mortality rate. 95% excess period deaths is ED mortality of which none were caused directly by COVID-19. All excess hospital deaths were accounted for by COVID-19.

**Meaning**

Public health measures in Hong Kong have successfully contained the pandemic so far and hospitals have remained safe. The significant cost in non-COVID mortality for both communicable and non-communicable diseases associated with reduced ED attendance needs to be addressed.

## ABSTRACT

**Importance:** Other countries affected by the COVID-19 pandemic have reported a reduction in attendances in emergency departments (ED) but the non-COVID-19 related impact on mortality is poorly characterized. We aimed to evaluate, understand and characterize the scale and relationships of ED attendance and excess mortality associated with the COVID-19 pandemic in Hong Kong.

**Objective:** We compared the ED attendance and related impact of the COVID-19 pandemic on the mortality in Hong Kong between 2019 and 2020.

**Design:** Territory-wide, retrospective, cohort study.

**Setting:** Hong Kong, China.

**Patients:** All emergency attendances at 18 public acute hospitals in Hong Kong between January 1st and August 31st, 2019 (n=1,441,319); and between January 1st and August 31st, 2020, during the COVID-19 pandemic (n=1,047,805).

**Measurements:** We analyzed demographics, ED attendance, 28-day all-cause mortality, ED mortality, hospital mortality and diagnostic groups.

**Results:** ED attendances decreased by 27.4% from 1,426,259 in 2019 to 1,032,974 in 2020. Overall period mortality increased from 29400 to 30531 (3.8%) in 2019 and 2020 respectively. Direct ED mortality rather than post-hospital admission mortality accounted for 95.8% excess deaths of which none were caused or associated with COVID-19. The 0.2% increase in hospital mortality was accounted for by COVID-19 cases. The Incidence rate ratio for ED mortality was 1.76 % (95%CI 1.69-1.83). The 28-day all-cause mortality adjusted odds ratio (OR) in the pandemic period of 2020 relative to 2019 was 1.26 (95%CI 1.23-1.28). Higher adjusted ORs for all-cause mortality were found for both genders, ages >45 years, all triage categories, all social classes, ED attendance periods and for epilepsy (OR 1.58, 95%CI 1.20-2.07), lower respiratory tract infection (OR 1.40, 95%CI 1.35-1.45) and airway disease (OR 1.35, 95% CI 1.22-1.48).

**Conclusion:** A significant reduction in ED patient attendance in the first eight months of the COVID-19 pandemic was associated with an increase in ED-related deaths. 95% of the excess mortality occurred in the ED and none were due to COVID-19. Provision must be made to encourage patients with alarming symptoms, mental health conditions and co-morbidities to seek timely emergency care, regardless of the pandemic.



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## INTRODUCTION

Coronavirus Disease-2019 (COVID-19) represents the third coronavirus-associated epidemic to emerge from a species leap from wild animals to humans.[1, 2] The coronavirus causes a spectrum of presentations from asymptomatic through mild disease with respiratory symptoms to life-threatening acute respiratory illness.[3, 4] By 2020 ends, worldwide there were at least 80 million cases with positive Systemic Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV2) serology and over 1.5 million reported SARS-CoV2-associated deaths.[5]

Emergency departments (ED) are on the frontline of the COVID-19 pandemic and need to manage both COVID and the full spectrum of non-COVID cases such as myocardial infarction,[6] acute-onset leukemia[7] and trauma and injuries.[8] In some jurisdictions pressure on the system has been alleviated by reduced attendances. For example, during the pre-pandemic or early pandemic period, total ED attendances reduced in the United States (US),[9] United Kingdom[10] and Spain.[8] In the US, reductions in ED attendances ranged from 41.5% in Colorado to 63.5% in New York.[11] The factors contributing to these reductions await clarification. However, the early message in the United Kingdom was that the system was under huge pressure and that there was a need to 'Protect the NHS'[12]. It is likely that fear of the virus, concern that hospitals may not be healthy and safe places and a strong public health message discouraging 'unnecessary' ED attendances contributed to some of the reductions.

The reduced hospital and ED attendances during the pandemic outside Hong Kong included patients with heart attacks (23%), strokes (20%) and hyperglycemic crises (10%).[13] Increased non-COVID mortality affected patients with heart disease,[14] Alzheimer disease and dementia[15]. In general these reports reflect communities directly overwhelmed directly by COVID-19.[15-19] Hong Kong has experienced three small waves of COVID-19, which were well contained by public health measures.

We aimed to 1) evaluate and characterize the scale and relationships of ED attendance and excess mortality associated with the COVID-19 pandemic in Hong Kong that were not directly caused by SARS-CoV2. We compared the 2019 and 2020 (January through August) HK territory-wide ED attendance, ED deaths, 28-day mortality rate, demographics and diagnostic groups in all 18 public Emergency Departments (EDs).

## METHODS

We followed the STROBE[20] (Strengthening the reporting of observational studies in epidemiology) statement for reporting observational studies. The institutional review board of the University of Hong Kong/Hospital Authority West Cluster (UW 20-112) approved the study and granted waiver of participant consent.

*Data source*

We performed a territory-wide, retrospective, cohort study using data from an electronic administrative healthcare repository – the Clinical Data Analysis and Reporting System (CDARS)[21] – which is managed by the management of the Hospital Authority of the Hong Kong Special Administrative Region, China. CDARS includes the patients' demographics, deaths, diagnoses, procedures, drug prescriptions, dispensing history and laboratory results from all public hospitals and clinics in Hong Kong. It represents inpatient and outpatient data of around 80% of the 7.47 million population in Hong Kong[2323]. Full-scale emergency medicine services providing 24-hour emergency physician-led care are only available in the EDs of 18 public hospitals. In 2019 the total number of attendees at 18 EDs was 2.2 million that was equivalent to a total attendance rate of 290 per 1 000 population. [24]

*Patient and setting*

All patients attending the EDs of 18 public hospitals in Hong Kong between the pre-pandemic period of January 1st, 2019 and August 31st, 2019 (denoted as '2019') and between the pandemic period of January 1st, 2020 and August 31st, 2020 (denoted as '2020') were included. For year-to-year comparison, ED data recorded on February 29th, 2020 were excluded from the analysis. Data extraction was undertaken on October 10th, 2020, so all patients were follow-up for at least 28 days. The first case in Hong Kong was confirmed on January 23rd, 2020. With the implementation of active and enhanced surveillance with progressively wider screening criteria during the evolution of this epidemic, Hong Kong has recognized most of the confirmed cases upon hospitalization, and have achieved zero nosocomial transmission between healthcare workers and patients within the first 6 months.[25] The corresponding period in 2020 covered the pre-pandemic, first, second and third waves of the pandemic. As of midnight September 1st, 2020, there are 4,823 confirmed cases of COVID-19 in Hong Kong, leading to 88 (1.2%) fatalities.[26]

*Outcome measures*

The primary outcome was all-cause, 28-day mortality in patients attending the ED or admitted to hospital through the ED. Secondary outcomes were weekly attendance to ED and diagnosis-specific mortality.

*Structured covariates*

Data including sex, age, race, comprehensive social security assistance (CSSA) recipients, residential districts, discharge destination (death in ED, left without being seen, hospital admission or discharge) triage category (1-critical; 2-emergency; 3-urgent; 4-semi-urgent; and 5-non-urgent), ambulance utilization, institutional residents, and the diagnoses. The diagnoses included lower respiratory tract infection, airway disease, coronary heart disease, cerebrovascular disease, sepsis, trauma, cancer, diabetes mellitus, chronic kidney diseases, epilepsy, deliberate self-harm, mental disorders and poisoning. Diagnoses defined by International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) diagnosis codes recorded in each episode were listed at Supplemental Table 1. The social deprivation index (SDI) for each residential district was calculated by taking the average of six selected variables from by-census 2016 in Hong Kong, namely unemployment, monthly household income < US$250, no schooling at all, one-person household, never-married status, and sub-tenancy. It has been validated and was adopted as a measure of the socioeconomic status of patients.[28]

*Definitions*

ED mortality was defined as any death certified in the ED. Hospital mortality was defined as any death occurring after admission to the hospital ward from the ED up to 28 days. '28-day mortality' covers all deaths, i.e. ED mortality and Hospital mortality up to 28-days.

*Statistical analysis*

Descriptive statistics were used to show the distributions of baseline covariates and outcomes of ED attendances in 2019 and 2020. A complete-case analysis was performed, and missing data was noted. In the categories selected for this study data was missing in less than 0.8% cases leaving data available for analysis in 99.2 – 100% cases. To minimize potential confounding biases due to discrepancy in baseline covariates of ED attendances between years, propensity score covariate adjustment was applied to account for covariate imbalances for ED attendances in 2019 and 2020. A logistic regression model was performed to estimate the propensity score for each ED attendance that included the sex, race, age group, residential region, ED arrival time,

attendance period, ambulance utilization, institutional residents, comprehensive social security assistance (CSSA) recipients, social deprivation index (SDI) and triage category.

Study outcomes were compared between the pandemic COVID-19 outbreak period in 2020 and the same pre-pandemic period in 2019 overall and by covariates as mentioned above. The percentage drops in ED attendances from 2019 to 2020 in overall and by other covariates were calculated. Weekly ED attendances during the different phases of the pandemic period in 2020 *vis-á-vis* corresponding period in 2019 were visualized in overall and by attendance characteristics and disease subgroups. Natural cubic splines with 95% confidence interval (CI) and equally spaced knots were fitted through the weekly attendance by disease subgroup and the weekly attendance yearly percentage change by triage category. Odds ratios (OR) of COVID-19 effect in 2020 on 28-day mortality were estimated by multivariable logistic regression models adjusted propensity score as covariate, with generalized estimating equations specifying an exchangeable correlation structure. Correlations of outcomes between ED attendances belonging to the same patient repeating attendances were accounted for in generalized estimating equations. To assess heterogeneity of COVID-19 effects, repeated analyses considering subgroups based on different levels of covariates above were conducted. Interaction effects between the COVID-19 and covariates on mortality outcome were tested.

All the statistical analyses and figure generations were performed by using Stata version 16.0 (College Station, TX: StataCorp LLC). A P<value of less than 0.05 was considered statistically significant.

## RESULTS

*Demographics*

A total of 1,047,805 ED attendances occurred in the pandemic period (January 1st to August 31st, 2020) compared with 1,441,319 attendances during the equivalent pre-pandemic period in 2019, a 27.4% reduction.

*Comparison of Mortality between 2019 and 2020*

**Table 1** shows the characteristics and mortality outcomes of ED attendees during the two periods. In 2019 there were 29,400 deaths (3,899 ED certifications and 25,501 hospital certifications) compared with 30,531 deaths in 2020 (4,983 ED certifications and 25,548 hospital certifications), a 3.8% increase in overall mortality, a 27.8% increase in ED mortality and a 0.2% increase in hospital mortality. Of the 1,131 excess deaths, 1,084 (95.8%) were ED mortality and none were due to COVID-19. Significant differences between 2019 and 2020 occurred in all categories assessed except for the age 18 to <35 year group several diagnostic categories (dementia, poisoning, bronchiectasis and Parkinson's Disease). The small (0.2%) increase in hospital mortality was attributable solely to COVID-19.

*Comparison of ED attendance between 2019 and 2020*

The reduction in ED attendance (supplementary table 2) occurred in both sexes, across all age groups, in all regions of the territory, in both Chinese and non-Chinese and across all triage categories (critical -2%; emergency -13.2%; urgent -25.5%; and urgent/semi-urgent -29.5%) and social class. Whilst most marked during the waves of COVID-19 infection it persisted during the inter-wave periods (wave: -31.5% versus non-wave: -22.8%). However, associated with this reduction in attendance was a 30% increase in death certifications in the ED.

**Figure 1** shows the variation in weekly ED attendance associated with 16 diagnostic categories. There were significant reductions in ED attendance during the first two waves across all diagnostic groups except for domestic violence. The first inter-wave period was brief with no return to 2019 levels except for domestic violence. During the second inter-wave period reductions in ED attendances persisted for lower respiratory tract infection, airway diseases, sepsis, diabetes mellitus, coronary heart disease, epilepsy and dementia. The third wave period saw persistent reductions in ED attendance except for cerebrovascular disease, cancer and

Parkinson's Diseases that trended to 2019 levels. The major change was in deliberate self-harm that significantly increased.

**Table 2** shows that the overall percentage death rate and incidence rate ratio increased between the pre-pandemic and pandemic periods. The increase in percentage death rate was mostly due to hospital mortality and is most marked because of the decrease in the denominator i.e. ED attendance. The highest incidence rate ratio occurs in ED mortality.

*Excess deaths certified in the ED between 2019 and 2020*

**Figure 2** shows the dynamic changes in actual weekly count of certified deaths in the emergency departments. Apart from early January and a short period in late June there was a significant increase in overall ED death certification between the cubic spline and weekly counts throughout the period. The dynamic changes, ebbs and flows, in weekly count were similar in both pre-pandemic and pandemic periods.

*Odds ratios for 28-day (ED and hospital deaths) mortality between 2019 and 2020*

**Figure 3** shows the dynamic relationships between the number of new COVID-19 cases reported to the Centre for Disease Control in Hong Kong and the adjusted weekly mortality odds ratios of COVID-19 and non-COVID-19 cases attending EDs. The odds ratios of 28-day all-cause mortality was highest during the first wave despite extremely few COVID-19 cases and reflects a change in the balance of absolute number of deaths (increased) and a reduction in ED attendances (decreased) compared with 2019. Apart from a few isolated weeks during the second inter-wave and early third wave period, the odds ratios remained significantly elevated throughout the pandemic.

**Figure 4** shows the adjusted odds ratio and 95% confidence interval of 28-day, all-cause, COVID-19 and non-COVID-19 mortality among patients attending EDs in 2020 compared with 2019. The adjusted odds ratios for 28-day mortality for all parameters was significantly increased in 2020 compared with 2019 except for aged 45 years or less, dementia, poisoning, bronchiectasis, Parkinson's disease and deliberate self-harm. There was no significant difference between the odds ratios of low, middle and high SDI and the odds ratio for mortality. The increase in mortality risk is more prominent in women (OR 1.92; $P < 0.001$) even though the proportion of mortality from male patients was higher in both years (1.1% in 2019; 1.6% in 2020; OR 1.43; $P < 0.001$).

## DISCUSSION

### *The Rise of Population Mortality in COVID-19*

This is the first territory-wide study from Hong Kong showing the reduction of emergency patients and rise of ED-related population mortality across multiple waves of COVID-19 in a low-mortality region with few cases of COVID.[29] This is evidenced by the increase in death count compared with the preceding year, the increased odds ratio for 28-day, all-cause mortality, the exceptionally low number of COVID deaths and the stable population. The overall increase in ED-related all-cause mortality (i.e., ED mortality and Hospital ward mortality in patients admitted through the ED) of 3.8% during the pandemic is significant. Over 95% of these excess deaths were not related to COVID-19 but occurred in the ED classified either as dead before arrival or dead after arrival.

Others have reported an alarming increase in non-COVID-19 mortality numbers and rates during the pandemic, but these have all been in settings where COVID-19 numbers and mortality rates have been extremely high. Overseas and local reports suggest that the fear of COVID-19, the perception that hospitals are dangerous places and the phobia of being stigmatized have resulted in delays in patients seeking medical care until their condition is critical.[30-32] The reduction in ED attendance (-27.6%) over the first eight months of the pandemic in Hong Kong is consistent with the trend in the US (-42%) and UK (-35%) although not so extreme.[10, 11] While the public fear of infection in the ED may have driven some patients away, the proximity of ED to densely populated habitats in Hong Kong, higher sense of urgency among the general public,[33] less well-developed primary care system, convenient and affordable ED services and high standard of emergency care may explain the difference with the US and UK.

The pattern of decrease in different conditions is consistent with another single-centered report from US. [34] While patients in more severe conditions were less affected by the fear, yet those affected may present to the health system with more severe conditions that may lead to further morbidity or even mortality.[34] Reports have suggested the similar delay in presentation for myocardial infarction and stroke.[35, 36] Our findings confirm this with reductions in ED attendance for myocardial infarction and stroke. However, we also showed that this reduction applied across a broad range of conditions including cancer, poisoning, mental disorders, deliberate self-harm, diabetes mellitus, chronic kidney disease, trauma, epilepsy, dementia and Parkinson's disease.

Reductions in ED attendance may not always be adverse. The reduction in lower respiratory tract infection, airways disease and sepsis may not be surprising as Hong Kong residents donned face masks and applied rigorous personal protective equipment and good hygiene from an early stage. The reduction in trauma Thus a reduction in ED attendance for some cases may not always reflect poor decision-making. Rather, they are positive effects of the pandemic.

Hong Kong is different in that the pandemic has been brought largely under control quickly, effectively and efficiently – at least to date. The overall absolute increase in ED-related, all-cause mortality in Hong Kong may not be striking compared to other reports. However, the 95% excess ED deaths that were not related to COVID-19 suggest that the pandemic has had a huge and adverse impact. Even where there are few cases of COVID-19 and the territory-wide COVID-19 mortality rate is 0.6%, the reduced ED attendance and high ED mortality suggest that the critically ill public may have been unnecessarily fearful of seeking timely emergency care. Hospitals in Hong Kong have remained safe places throughout the pandemic but the public health message may not have reflected this to the detriment of the public. It is hard to get the balance right.

In Hong Kong, contrary to our initial expectation, mortality risk did not vary significantly with socioeconomic status such as residential regions and SDI.[37-41] The health system in Hong Kong provides equitable access, physically and financially, for all walks of life in different locations in Hong Kong. However, health and social care disruption affected the patients who need long-term care and rehabilitation. In this connection, odds ratio increased to 1.6 during the first wave when all specialist outpatient clinics and community health care service were suspended. With more planning in contingency measures the service disruption was then more limited in subsequent waves, contributing less to the increase in OR. The increase in mortality risk that is more prominent in women even though the proportion of mortality from male patients was higher in both years is consistent with the health inequity by sex.[29]

The increase in fatalities among attendees is a concern that the public is suffering from excess death due to delayed care for medical problems outside COVID-19. The 28-day mortality risk for attendees during the waves is higher than non-wave periods. The early implementation of public health interventions helped control and mitigate surge of COVID-19, nevertheless, the general public has underestimated the importance of early medical advice for medical emergencies, contributing to the increase of 28-day mortality[42].

While Hong Kong has adopted universal masking since the early stage of the pandemic and the public has high health literacy and good practice of protective behavior,[43] possibly due to the impact of Severe Acute Respiratory Syndrome in 2003 and frequent local epidemics of seasonal influenza. The public health intervention may be accountable for the drop of attendance for lower respiratory tract infections, but its increased number of death and OR for 28-day mortality also suggests the possibility of delayed presentation, as the health system has not been overwhelmed by COVID-19 waves. This may inform the administrators the possibility of increased demand for service from patients with more severe conditions when the disease is more controlled.

Our results showed a persistent excess death in ED in 2020 should be a wakeup call to the general public and health authority. On one hand this is an alarm to emergency physicians and hospitals about increased prehospital deaths and potential of receiving patients with acute and severe conditions upon arrival; on the other hand, hospital management are liable to explain to the public the infection control measures in place so as to address their concern, as well as the development of alternative access to care such as diversion of less severe patients to primary care providers such as private doctors, community nurses, and advanced care practitioners.

Hong Kong is one of the most densely populated regions in the world but, comparing with epicenters around the world, Hong Kong has small case number and low mortality for COVID-19. This study provides a new perspective outside epicenters to evaluate the change on emergency morbidity and mortality in the region. It demonstrates the concept that the reduction of medical care seeking behavior due to the public fear of contraction of virus at hospitals is associated with increased risk of mortality.

***Personal and Family Crises***

While not the focus of the study, atypical variation in domestic violence and deliberate self-harm was noted. Even though Hong Kong did not implement containment measures such as curfew, lockdown and stay home order, the city operation has been severely disrupted by public health interventions such as gathering restrictions and social distancing, home office and school suspension, leading to reduction of economic activities. The effect of the social unrest since second half of 2019 and the social stabilization measures from government complicated the interpretation of this phenomenon further.

***Strength and limitations***

The strength of the study is the electronic data capture on >99.9% patients attending EDs in Hong Kong. As the system is universal in Hong Kong, data abstraction could be efficiently done without encountering specific procedures to each ED. Data enabled us to quantify the effects that the COVID-19 pandemic has had on current and prospective emergency conditions in the Hong Kong Special Administrative Region, China.

Limitations of this study are threefold. This is a retrospective cohort study and may include inaccurate and incomplete documentation, as well as variance in the quality of the information recorded by physicians. However, owing to the territory-wide data obtained in this study, the overall validity and reliability of the study findings are enhanced. Secondly, the findings may not be generalizable beyond as this is a Hong Kong based study and the interpretation of the data was limited by low rates of diagnostic coding among general patients (58.6%), compared with 82.8% among emergency patients. Thirdly, the attendance data in two-third of 2019 may not represent the usual picture because of the large-scale social unrest.

***Implications to practice***

The number of visits for cerebrovascular disease, coronary heart disease, airway diseases, lower respiratory tract infection, sepsis, trauma and mental conditions decreased, suggesting that some persons could be delaying care for conditions that might result in more severe and critical illnesses at presentation and additional mortality if delayed or left untreated. Hence, alternatives to visiting ED should be explored, for example, telenursing triage service [44]. Through protocol-driven approach nurses may help identify the high-risk patients and refer them to ED accordingly, mild patients may benefit by timely health advice so that they know how to monitor their own health condition before seeking medical advice in ED. Also, public health education should not only focus on infection containment and prevent but health messages in primary care should also reinforce the importance of seeking medical care if symptoms arise are necessary.

## CONCLUSION

Our findings indicated that compared with an equivalent period in the previous year the COVID-19 pandemic is associated with a significant decline in ED attendances and an increase in ED and 28-day mortality. The delay in seeking care may be associated with more advanced pathology at ED presentation and an increased demand for acute critical care in the future. Public health education should not only focus on infection containment and prevention during a pandemic but address factors that hinder patients seeking timely emergency care. Provision must be made to encourage patients with alarming symptoms, mental health conditions and co-morbidities to seek timely emergency care, regardless of the pandemic.

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**Competing conflicts of interests**

All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: The authors report no potential conflicts of interest.

**Ethical approval**

The Institutional Review Board of University of Hong Kong/ Hospital Authority Hong Kong West Cluster (Reference No approved ethics approval of this study. UW 20-112).

**Contributor and guarantor information**

AW, JW, OC and CW reviewed the literature, designed statistical analysis, conducted analyses, wrote the manuscript; AW, OC, and CW collected and compiled data. CW, JW, MT and TR provided critical input to the statistical analyses and design. AW acted as guarantor for the study. All authors contributed to the interpretation of the analysis, critically reviewed and revised the manuscript, and approved the final manuscript as submitted. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

**Data sharing**

The data that support the findings of this study were extracted from the Hospital Authority database. Restrictions apply to the availability of these data, which were used under license for this study. Analysis codes are available upon request from OC and CKHW, yet data sharing is prohibited by the Hospital Authority. The codes used to produce and analyze the data are available upon request to the corresponding author.

**Transparency statement**

The manuscript's guarantor affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted;

and that any discrepancies from the study as originally planned (and, if relevant, registered) have been explained.

**Dissemination declaration**

We plan to disseminate the results to patients, clinicians, academics, members of the public through press release, institutional websites, and social media.

**Figure Legend**

**Figure 1. Weekly emergency department attendances by diagnoses**

The figures show the matched actual number of weekly attendance for the months of January through to August between 2019 (ringed circles) and 2020 (crosses). Cubic spline has been used to smooth the trends. The blue shaded area shows the 95%CI for 2019 whilst the red shaded area shows the 95%CI for 2020. The grey shaded areas correspond with the three waves. The first confirmed COVID-19 case in Hong Kong was announced on 23rd January 2020: first wave from 23rd January to 29th February; inter-wave period from 1st March to 16 March; second wave from 17th March to 21st April; inter-wave period from 22nd April to 4th July; third wave from 5th July to 31st August, 2020. The diagnostic groups are lower respiratory tract infection (Fig 1a), airway disease (Fig 1b), sepsis (Fig 1c), cancer (Fig 1d), poisoning (Fig 1e), mental disorder (Fig 1f), domestic violence (Fig 1g), deliberate self-harm (Fig 1h), diabetes mellitus (Fig 1i), chronic kidney disease (Fig 1j), cerebrovascular disease (Fig 1k), coronary heart disease (Fig 1l), trauma (Fig 1m), epilepsy (Fig 1n), dementia (Fig 1o), and Parkinson's disease (Fig 1p). Note that the last week of August is not fitted to cubic spline.

**Figure 2 Dynamic changes in actual weekly count of certified deaths in the emergency departments.**

The figure shows the matched actual number of certified deaths per week in the emergency department of periods before the pandemic (1st January to 31th August, 2019; ringed circles) and during the COVID-19 pandemic (1st January to 31th August, 2020; crosses). Cubic spline (95%CI) has been used to smooth the trends. The blue shaded area shows the 95%CI for 2019 whilst the red shaded area shows the 95%CI for 2020. The grey shaded areas correspond with the three waves. Note that the last week of August is not fitted to cubic spline.

**Figure 3 Dynamic relationships between number of new COVID-19 cases and adjusted weekly mortality odds ratios of COVID and non-COVID cases attending EDs**

Panel A shows the number of weekly new cases of COVID-19 recorded in Hong Kong. Panel B shows the adjusted odds ratios of ED and 28-day hospital mortality among all patients (COVID

and non-COVID) attending EDs in 2020 compared with 2019. Odds ratios are adjusted for sex, age, race, residential region, triage category, institutional residents, CSSA, ambulance case, attendance time (eight hour period) and attendance period (month of year). Note that Panel A shows COVID cases, not COVID deaths.

**Figure 4. Adjusted odds ratio and 95% confidence interval of 28-day, all-cause, COVID and non-COVID mortality among patients attending EDs in 2020 compared with 2019.**

Odds ratios are adjusted for sex, age, race, residential region, triage category, institutional residents, SDI and attendance period. Note that Panel A shows COVID cases, not COVID deaths. Estimations by logistic regression have been adjusted by propensity score as covariate both overall and by attendance characteristics and disease groups.

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