# Practice of Public Health Interventions Collaboration and Integrated in Macau SAR and Zhuhai to Response to Pandemic of COVID-19

**Xiling Yin**
Center for Disease Control and Prevention of Zhuhai City
**Songjian Xiao**
Center for Disease Control and Prevention of Zhuhai City
**Xuebao Zhang**
Center for Disease Control and Prevention of Zhuhai City
**Long Chen**
Center for Disease Control and Prevention of Zhuhai City
**Xihe Ni**
Center for Disease Control and Prevention of Zhuhai City
**Sicheng Huang**
Center for Disease Control and Prevention of Zhuhai City
**Wenhua Mei**
Center for Disease Control and Prevention of Zhuhai City
**Feng Ruan** ( fruan@126.com )
Center for Disease Control and Prevention of Zhuhai City

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# Abstract

Background

In 2020, the Guangdong-Hong Kong-Macau Greater Bay Area (GBA) was in proximity to the second epicenter of COVID-19 in China, where Macau and Zhuhai are located. Both cities communicated, cooperated, and coordinated under different backgrounds to play a "cocity" effect in response to the COVID-19 pandemic.

Results

In 2020, Macau and Zhuhai had a total of 46 and 112 confirmed cases of COVID-19, respectively. Ten and 98 confirmed cases in two cities that were imported from mainland China or were the result of local infection caused by imported cases of patients who recovered and were discharged during the first period (January 1 to March 14), respectively. During the second period (March 15 to December 31), both of the cities mainly disposed of imported cases (36 and 14 cases in Macau and Zhuhai) from abroad. In the third period (July 15 to December 31), the two cities gradually returned to normal work and life and economic recovery. Under dynamically adjusted prevention and control measures, the two cities have adopted a series of border control measures based on domestic and abroad changes in the COVID-19 epidemic situation. They had closely cooperated and shared information in terms of epidemic information docking, traffic control, patient care, and material guarantees. The prevention and control policies and measures are basically the same in the two cities and different in the 3 time periods. Health QR code exchange was the basis of mobility of residents between the two cities.

Conclusions

Both cities had zero tolerance for COVID-19 cases and adopted a suppression strategy to accurately grasp the changing epidemic situation at any time. There was no community transmission of local cases, and the control effect with resumption of work and personnel turnover was very obvious in the two cities. These characteristics provide a suitable example for other countries and cities to better understand the effectiveness of control measures to address the possible long-term existence of COVID-19.


# Background

Coronavirus disease 2019 (COVID-19) has continued since the World Health Organization (WHO) announced a COVID-19 pandemic in March 2020.[1] The pandemic has brought a huge burden of disease to the world and has seriously affected the economic development of society and people's normal lives.[2,3] Hubei Province (especially Wuhan), where the first case was found, had the largest number of confirmed cases of COVID-19 in China [4], followed by the Guangdong-Hong Kong-Macau Greater Bay Area (GBA), which was the fourth largest bay area in the world and has a population of 71 million in proximity to the second epicenter where Macau SAR (Macau) and Zhuhai City are located.

Macau is a special administrative region of China. The Chinese government resumed the exercise of sovereignty over Macau 20 years ago. Macau is a successful practice of China's "One Country, Two Political Systems" (Mainland China implements a socialist system, and Macau implements a capitalist system). Macau is connected to Zhuhai, which is attached to Guangdong Province and one of the major frontier cities in the process of China's globalization by land to land, and the two cities have close population flows with each other. Some ports are set up to facilitate 24-hour customs clearance and reach a 1-hour living circle between the two cities, and approximately 24 million passengers entered Macau from Zhuhai in 2019.

Macau and Zhuhai are famous ports and tourist cities where they are located and are facing greater import pressure from the COVID-19 pandemic. During the response to the COVID-19 pandemic, Macau and Zhuhai communicated, cooperated, and coordinated under different frameworks to have a "cocity" effect. For example, fighting together during the imported outbreak, digesting the infected cases that were linked between the two cities, consensus on zero tolerance for COVID-19 cases, economic recovery under normalized prevention and control measures, minimizing the impact of this global pandemic, abandoning different political systems and launching cooperation and integration as the cocity. All these efforts under nonpharmaceutical interventions have been successfully practiced during the COVID-19 pandemic with a background fatality rate of 2.7%-5% [5,6] with a large number of infected patients being at risk of impacting the medical system, and no vaccine available. To date, there are no reports on antiepidemic collaboration as a cocity under different backgrounds. These characteristics provide a suitable example for researchers and decision makers in countries and cities severely affected by the COVID-19 pandemic to better understand the effectiveness of control measures to address the possible long-term existence of COVID-19.[7]

# Results

### *Epidemiological characteristics of COVID-19 outbreaks in Macau and Zhuhai*

In 2020, Macau had a total of 46 confirmed cases of COVID-19. Seven cases were Wuhan-related cases, and 1 case did not have a history of living in Wuhan but had a history of travel to the hospital of Zhuhai. Two cases were potentially local infections, and one of them had a contact history with imported cases, but another source of infection was unclear [8], and 36 cases had a travel history abroad.

A total of 112 confirmed cases were reported in Zhuhai in 2020, of which 14 (12.5%) were locally infected, 84 (75.0%) were imported domestically (79 cases were Wuhan-related cases or related to cities around Wuhan, 3 cases had a history of living in other cities and 2 cases were infected on a cruise ship), and 14 (12.5%) were imported from outside mainland China, including foreign countries (10 cases) and Hong Kong S.A.R. (4 cases). (Figure 2). Of the 112 cases, 25 cases (22.3%) had travel (20 cases), passing-by (3 cases) or work (2 cases) histories in Macau during the incubation period. Among them, 12 cases only entered and exited from Gongbei port, 12 cases passed from Gongbei and Hengqin ports, and 1 case migrated from Cross-border industrial zone port.

### *Characteristics of 3 Time Periods*

Within the first period (January 1 to March 14), the first confirmed case of COVID-19 was reported on January 22 in Macau, and no new cases continued for 39 days after the 10$^{th}$ confirmed case was reported on February 4. Similarly, the first confirmed case was reported on January 20 in Zhuhai, and no new cases increased for 30 days after the 98th confirmed case was reported on February 17. All confirmed cases that were imported from mainland domestically or local infections caused by imported cases in two cities recovered and were discharged before March 14.

During the second period (March 15 to December 31), on March 15$^{th}$, Macau began to report imported cases from abroad. Among them, 32 cases (32/36) entered Macau after entering Hong Kong Airport. Since March 19, Zhuhai has reported 5 imported cases from the UK, 5 imported cases from the Philippines, and 4 imported cases from Hong Kong, China. Among the 14 imported cases, 6 cases entered Zhuhai through the Hong Kong-Zhuhai-Macau Bridge. Five cases were freighter employees stopping at the Zhuhai International Container Terminal, and 3 cases were transferred to Zhuhai after arriving at other cities in Guangdong Province with international airports.

Under dynamically adjusted prevention and control measures, from March 15 to July 14, 2020, the percentage of inbound visitors from mainland China traveling to Macau was 1.0% compared to the same period in 2019. In the third period (July 15 to December 31, 2020), this percentage reached 21.0% compared to the same period in 2019. The percentage of people entering Macau from Zhuhai's main ports compared to the same period in 2019, from March 15 to July 14, 2020, was 1.4% and 20.2% in the third period. (Figure 1)

**Macau: Border control 1**. Airports and border gates conduct temperature screening and health declarations for passengers from Wuhan and mainland China. **Border control 2**. Nonresident employees who have been to mainland China 14 days prior to entry must undergo medical observation for 14 days at a designated location in Zhuhai or Macau. **Border control 3**. From February 24, according to the changing form of the COVID-19 epidemic in other countries, people who had been to South Korea, Italy, Iran and other countries in the 14 days before entry, including Macau residents, tourists and foreign employees, were required to undergo intensive 14-day medical observation**. Border control 4.** All nonlocal residents who had been to a foreign country within 14 days before entry were prohibited from entering. All persons who have been to the Hong Kong S.A.R. or Taiwan within 14 days before entry must undergo 14 days of intensive medical observation**. Border control 5.** Centralized quarantine medical observations will not be implemented for out-of-town employees who live in Zhuhai City. All persons entering Macau from mainland China must hold a 7-day virus nucleic acid test certificate, which can be displayed by the Health QR Code. **Border control 6.** All persons entering Macau from Hong Kong must have a certificate of a negative nucleic acid test for the novel coronavirus within 72 hours and must undergo 14 days of intensive medical observation. Starting on August 4, according to the changing patterns of the epidemic in some cities in mainland China, , people who have been to Dalian, Urumqi, Qingdao and other cities within 14 days before entering must undergo 14 days of intensive medical observation. After the partial

epidemic was over, relevant quarantine measures were cancelled. **Border control 7**. Those entering Macau from Hong Kong must have a negative nucleic acid test certificate within 24 hours and receive 14 days of medical observation. **Border control 8.** For those who had been to a country or region outside mainland China for the past 14 days, the medical observation period for isolation in Macau increased from 14 days to 21 days.

**Zhuhai:Border control 1**. Zhuhai Airport conducted temperature testing on passengers from Wuhan. **Border control 2.** All ports in Zhuhai have launched a health declaration system for entry-exit persons. **Border control 3**. Suspension of endorsement for free travel from mainland China to Macau. **Border control 4**. A comprehensive nucleic acid test for high-risk populations from Hubei Province (especially Wuhan City) to Zhuhai was conducted and required these high-risk people to stay at home for 14 days. **Border control 5**. People who came to Zhuhai from high-risk areas in other cities of mainland China needed to be quarantined for 14 days. **Border control 6.** People from outside of mainland China, including foreign countries, Macau and Hong Kong, needed to be quarantined for 14 days, except for those specially exempted. **Border control 7.** All personnel coming from Macau to Zhuhai were not quarantined for 14 days, and the scope of activities was limited to 9 cities in Guangdong Province. **Border control 8**. The scope of activities for people coming from Macau to Zhuhai was expanded to Guangdong Province. After 14 days, they could move nationwide if the nucleic acid test result was negative. **Border control 9**. Gradually resume processing of visas for residents of Zhuhai City, residents of Guangdong Province, and all mainland residents to travel to Macau. People can pass freely with the negative certificate of nucleic acid within 7 days, and the "green code" logo interchangeable between Macau or Guangdong Health QR Code.

### *Matrix of main strategies and measures in 3 Time Periods*

The two cities have adopted a series of border control measures based on the changes of the COVID-19 epidemic situation of domestic and abroad. They had closely cooperated and shared information in terms of epidemic information docking, traffic control, patient care, and material guarantees. The prevention and control policies and measures are basically the same in the two cities (Figure 1 and Table 1).

| Table 1. Matrix of main strategies and measures in 3 time periods | | | |
|---|---|---|---|
| | The first period (2020/1/1-3/14) | The second period (2020/3/15-12/31) | The third period (2020/7/15-12/31) |
| **Government mobilization and political consensus** | 1.Consensus on zero tolerance for COVID-19 cases. | | |
| | 2.The governments of the two cities communicated and cooperated as soon as possible to mobilize the whole society. | | |
| | 3.Docking of professional technical institutions for disease control, port quarantine institutions, etc., to exchange and sharing epidemic information. | | |
| | 4.Actively control the spread of import cases and local cases. | 5.Under the premise that the epidemic is gradually within control, to increase the communication between the two cities step by step, and to promote cocity operation and economic recovery. | |
| **Source of infection controled** | 1.Port of entry to implement health declaration and dynamically adjusted border control strategies. | | |
| | 2.Timely diagnosis and treatment of confirmed or suspected cases, strict discharge standards, and isolation observation and followup after discharge. | | |
| | 3. Strictly follow up close contacts and give centralized isolation for medical observation (This measure extended to close contacts of close contacts later). | | |
| | 4. Strengthen the monitoring of fever clinics, and the screening of patients by medical institutions, and prevent iatrogenic infection. Strengthen the sensitivity and timeliness of suspicious cases of infection detection, and strengthen multichannel early warning. | | |
| | 5.Zhuhai: Nucleic acid test for people coming to Zhuhai from Hubei Province.<br><br>6.Macau: Civil Aviation cuts international flights. | | 7. The normalized nucleic acid test monitoring (sampling scope includes practitioners, site environment or selling food) in various key places such as medical institutions, railway stations, bus stations, docks, urban vehicles, markets and so on had been initiated.<br><br>8. Regular monitoring of the virus nucleic acid in the environment and personnel of the activities of cross-border truck drivers (exempt from quarantine).<br><br>9.Regular nucleic acid tests and health declaration management were carried out on floating fishermen. |
| **Cut off the transmission route** | 1.Different indoor entertainment venues were closed for half a month or one month. | | |

| | | | |
|---|---|---|---|
| | 2.Implemented a "stay at home" policy for residents in the city for about half a month and cancelled social gatherings. | | |
| | 3.Reduce the frequency of public transportation in the city for about half a month and encourage citizens not to go out unless necessary. | | |
| | 4.Regular sampling and nucleic acid testing of public facilities and the environment such as stations and ports. | | |
| | | 5.Centralized supervision of imported frozen goods and health management of cold chain practitioners | |
| **Protect uninfected people** | 1.It was required to enter public places to wear masks and take body temperature tests. Plan to protect the supply of masks. | | |
| | | 2.The police department pushed population movement data to the community, and the community relies on a three-person team to implement grid management. | |
| | | 3. Specific personnel traveling to and from Macau and Zhuhai have implemented exemption measures (only move in designated areas and receive regular monitoring) | |
| | | 4.The health code recognized each other, and personnel exchanges in low-risk areas between the two cities do not need to be isolated and move freely with a negative nucleic acid certificate within 7 days. | |

## Information exchange and data sharing

### *Health QR code exchange*

Health QR code exchange was the basis of mobility of residents between two cities. The travelers could apply for the Health QR Code through real-name registration and display it on personal portable mobile phones in the cities of residence. On this basis, travelers can apply for the Macau or Guangdong Health QR Code before entering by filling out 3 supplementary questions (whether they have fever or other

symptoms on the day, 14 days of contact history, 14 days of travel history). The travelers could pass the port with the green code after completion. According to changes in epidemic prevention and control or personal situations, the three-color code (red, yellow, and green) assignment rules of the "Health QR Code" were dynamically adjusted and improved (Figure 2).

# Discussion

### *Government deployment and zero tolerance consensus against COVID-19 between two cities with different frameworks.*

Although Macau and Zhuhai belong to the same country, there are several differences in the political systems, legal regulations, and procedures between the two cities. Since the outbreak of COVID-19 in Wuhan, the governments of Macau and Zhuhai have attached great importance and responded quickly. Unlike other cities or countries, such as mitigation strategies[9,10], which aim to slow the spread of COVID-19 in the community and prevent the intensive care unit (ICU) from being unstoppable when dealing with severe cases, Macau and Zhuhai have zero tolerance for COVID-19 cases and adopt suppression strategies to accurately grasp the changing epidemic situation at any time. Under a strong coordination mechanism, the two cities connected closely together, convened multiple emergency meetings as soon as possible, implemented a daily timing and mutual feedback notification system, and discussed and shared the latest epidemic information and control decisions in a timely manner. The prevention and control of the COVID-19 epidemic had achieved positive results, and the resumption of work, production and school education had been effective. Since the COVID-19 pandemic, there has not been such thorough cooperation between two cities. Sharing successful experiences can be used as a reference for cooperation between other areas, regions or countries.[11]

There was no cross-cultural consensus on whether wearing a mask was a physical intervention method to effectively prevent the spread of diseases.[12] However, residents in Macau and Zhuhai had unified support for wearing masks based on extensive publicity, education and promotion in the early stage of the COVID-19 outbreak. When there was a high degree of compliance, wearing masks was the most effective way to reduce the spread of the virus.[13,14] The governments of two cities established a risk-adjusted mask use strategy, scientifically promoted the use of masks, ensured an adequate supply of masks, and cooperated to reduce the unfairness of health resources.

### *Necessary conditions of response to the COVID-19 pandemic in Macau and Zhuhai gradually reached the cocity.*

Macau and Zhuhai, which are geographically adjacent and both tourist and port cities in the GBA, had many similarities in the pressure of the global pandemic. The occurrence and development of the COVID-19 epidemic in Macau and Zhuhai were highly consistent. They processed cases imported mainly from Hubei in the early stage, and in the later stage, they faced cases imported mainly from foreign countries or Hong Kong in China. Macau and Zhuhai strictly implemented management measures for their

respective confirmed cases, suspected cases and close contacts and actively dealt with related cases traveling or working between the two cities. The local cases that were all epidemiologically related to imported cases were less than 20% in both cities; specifically, there were no community spreads.

The prevention and control measures for high-risk people in Macau and Zhuhai were highly consistent. Nonpharmacological interventions, which included avoiding mass gatherings, school closures, case isolation, contact tracing [15], and implementation of infection prevention strategies in medical institutions, were all means to interrupt the pandemic.[16,17] During the first period, both cities implemented strict health quarantine and isolated medical observation for those who had lived in Hubei in the previous 14 days.[18] The timeliness of strategies was very important to address the forms of epidemics in different situations, and timely dynamic adjustments must be made to respond consistently. Starting from the second period when the epidemic situation in mainland China had been well controlled, they shifted to closed management of the entire chain from entry territory to free immigration regardless of nationality and comprehensively strengthening the prevention of foreign or Hong Kong of China imports. Residents from mainland China gradually were not included in the scope of immigration control in the third period. The exchange of the itinerary trajectory of the confirmed cases, close contact tracking information and other information related to epidemic prevention and control. At the same time, mutual recognition of medical isolation measures was implemented for personnel traveling between Zhuhai and Macau.

### *Efforts to achieve a response to the COVID-19 pandemic as a cocity*

The COVID-19 pandemic caused governments to scramble to reduce their vulnerability to the virus by restricting global trade and the movement of people. [19] However, with the closure of borders and the implementation of strict immigration measures, there has been a major disruption in the global supply chain, which has adversely affected employment and poverty. In the long run, strict social distancing measures and long-term lockdown suppression interventions to address the COVID-19 pandemic were unsustainable. These long-term measures would have a significant adverse effect on the economy and health welfare.[20]

Both Macau and Zhuhai are tourist cities with extremely large population flows. Especially for cities that rely on export-oriented economies, it is necessary to consider the balance between social protection plans and epidemic control. Cooperation between the two cities was limited not only to epidemic control but also to basic living security and economic recovery promotion. For example, for cross-border truck drivers, students, etc., exempt quarantine measures, adjustment of strategies in a timely manner based on Health QR Code[21] intercommunication and nucleic acid testing to gradually open tourism and promote consumption, and continue to conduct strict disease monitoring. The common goal of both was to gradually balance the economic and health consequences, that is, "safe reopening"[22], and this effect was gradually reflected.

The COVID-19 pandemic brought severe challenges and provided an opportunity for cooperation between the governments of two cities. Working closely with public health policy experts and medical experts,

feasible and dynamic adjustment plans were designed.[23] Both cities have gradually reached 100% foreign immigrants to implement centralized quarantine and medical observation, 100% nucleic acid testing for travelers of entry, and 100% health code mutual recognition management. The measures were implemented in phases. From providing ordinary citizens with free nucleic acid testing services, implementing mutual recognition of health codes, and gradually expanding those exempted from quarantine, the policy for mainland tourists to Macau was gradually relaxed. After consultation and consensus, the "cocity management" of epidemic prevention and control could be implemented.

### *Health QR code conversion was the basis of the mobility of residents*

The Health QR code generated using the mobile application was based on the user's activity in the previous 14 days, including whether the user had been to a high-risk area and whether he had been in contact with a confirmed or suspected case.[24] According to the specific circumstances involved in epidemic risk and the classification requirements of prohibition, restriction, and normal flow, corresponding management measures should be taken for people with different color codes. The use and intercommunication of the Health QR Code of the two cities indicated that their respective departments of health, public security, communications management, customs, border inspection, transportation and other departments should rely on a unified public data platform to strengthen the timely sharing of epidemic-related data. Comprehensive analysis was carried out to ensure accurate coding, and at the same time, the dynamic adjustment of the "health code" coding rules must be consistent between two cities and provide convenience for the elderly and minors to use the "health code".[25] It was much more time-efficient to show the QR code when required. It has also helped to facilitate traffic and speed up the resumption of work and production, ultimately promoting regional economic recovery.

### *Movement trajectory of cross-border exemption of quarantined people and truck drivers or management of floating fishermen*

For a period of time in the first stage, Macau prohibited all nonlocal residents from entering the territory, except for some mainland Chinese employees whose regular nucleic acid monitoring was carried out. With the gradual resumption of school, students and teachers who live in Zhuhai and attend schools in Macau were also exempted. Zhuhai also implemented quarantine exemptions for certain people. Exempting people from quarantine increased import risk [26], but strict management of the trajectory of actions provided the possibility for necessary work and life.

Cross-border truck drivers, including those from Macau or Hong Kong, were registered and managed. The trucks were equipped with a positioning system and carried out point-to-point transportation from the port of entry to the destination factory (warehouse) according to the declared activity track and did not travel to areas outside the declaration. The traffic node service stations were equipped with a special parking lot, rest area, and toilet for cross-border truck drivers, which scanned QR codes and implemented closed management. Cross-border truck drivers should hold a valid nucleic acid test certificate within 48 or 72 hours of cross-border activities and conduct regular nucleic acid tests.

As the pandemic progressed, disease control responses had become more detailed and targeted. Understanding the fine-grained patterns of how individuals interact was essential to develop an effective public health control plan.[27]The response to the epidemic was not only in the timely treatment of patients or close contacts but also in preventive monitoring and management of risk groups. Some fishermen in the two cities would buy fish from fishing boats at sea. These overseas fishing boats were mainly from countries where the COVID-19 epidemic was more serious. The purchased fishery may be contaminated by the virus and then brought back by cold chain transportation on the fishing boat. At the same time, fishermen may come into contact with people infected with COVID-19 overseas. Regular nucleic acid tests and health declaration management were carried out on fishermen.

### *Response to COVID-19 pandemic as protective barriers to each other*

Macau implemented dynamically adjusted isolation and quarantine measures for foreign immigrants. In key links such as airport transshipment, designated hospital treatment and isolation management, the entire chain of management from border to home door was realized, and the border defense line was strengthened. This border defense line provided a barrier for Zhuhai, which had no international flights. As a tourist city connected to mainland China, Zhuhai quarantined people from high-risk areas in the mainland for the purpose of traveling to Macau, providing a barrier for Macau. For example, in the early stage, a one-time full-coverage nucleic acid test was performed on all personnel from Hubei in Zhuhai to detect suspected cases as soon as possible. Zhuhai established a three-person health management team in the community to conduct grid management for residents in the jurisdiction.

In addition, the two cities strengthened the isolation management of Hong Kong immigrants, timely detection and investigation of patients with fever/cough or patients with travel history in risky areas by medical institutions, and regular nucleic acid inspections of all medical staff. Strictly implemented measures were performed, such as wearing masks, temperature checks, and health QR codes checked for public places and public transportation[28]in densely crowded individuals.

### Limitations

Because the source of infection and transmission chain of some cases were not clear, the judgment of local infection cases may be biased. Adjustment of the measures, especially the details, was very frequent. Due to space limitations, only the representative ones were listed.

## Conclusions

In the prevention and control of the COVID-19 epidemic in Macau and Zhuhai, both had zero tolerance for COVID-19 cases and adopted a suppression strategy. They responded quickly, with measures in place, and cooperated and communicated in a timely manner. There was no community transmission of local cases, and the control effect was very obvious. After the epidemic stabilized and the comprehensive promotion of the resumption of work and production, the two cities implemented unified normalization

measures that were basically consistent and successfully implemented the prevention and control strategy of coccities.

# Methods

### Settings

The average permanent population was 679,600 in 2019 in Macau, and the population density was 20400 people per square kilometer. Macau is one of the most densely populated areas in the world and one of the world's four largest gambling cities, with up to 38 million tourists per year.[29] Macau's economy is highly export-oriented. Its pillar industries are mainly gaming, tourism, hotels and casinos and are closely linked to the international economy.

The permanent population of Zhuhai city was 2,023,700 in 2019, of which floating populations accounted for approximately 34.1%.[30] Xiangzhou District of Zhuhai, as the main urban region, is connected to Macau’s core area by land.

People from Macau and Zhuhai need to apply for endorsement in advance and hold entry and exit passes through cross-border channels, such as Gongbei Port, Hengqin Port, Cross-border industrial zone Port, Wanzai Pier Port, Hong Kong-Zhuhai-Macau Bridge entry and exit ports, to realize working, attending school, shopping or tourism. In addition, Macau and Zhuhai dual-licensed motor vehicles can travel between the two cities. Macau’s consumer supplies, such as food and daily necessities, as well as water supply, partly depend on the supply of mainland China, especially Zhuhai City. The number of nonresident workers in Macau was 196,538 in 2019, and 27.9% of them worked in the hotel and catering industry.[31] A considerable portion of Macau's nonresident workers from mainland China live in Zhuhai and work or live across the two cities every day.

Macau and Zhuhai cross the sea from the Hong Kong S.A.R. (who had reported 8846 COVID-19 cases and was another S.A.R. of China contributing the most to the number of cases in the GBA)[32,33]. The number of reported cases in GBA was 10,782 in 2020, and Hong Kong accounted for 82%. In comparison, Zhuhai and Macau accounted for 1.5% of the reported cases, and there was no continuous community transmission in either city. Except for passenger transport by waterways, railways or highways, after the opening of the Hong Kong-Zhuhai-Macau Bridge in October 2018, they reached each other within half an hour. (Figure 3)

(a) Heat map of cumulative reported cases of COVID-19 in China in 2020. Area A: The number of reported cases in Hubei Province was 68,149 (50,354 in Wuhan); Area B: The number of reported cases in GBA was 10,782. (b) The number of reported cases in Hong Kong was 8846,114 cases in Zhuhai and 46 cases in Macau. There were 1776 cases in the other 8 cities in GBA.

### Data collection

The period for obtaining data was from January 1, 2020, to December 31, 2020. The data of confirmed cases in Macau came from the public announcement of the Health Bureau of Macau.[34] The data of confirmed cases in Zhuhai came from China's infectious disease report information management system. The data on Macau inbound visitors who came from mainland China were obtained from the Macau Statistics Bureau. The prevention and control strategy adopted by Macau came from the official website of the Macau Department of Health. The prevention and control strategy that Zhuhai adopted came from the municipal government's epidemic prevention and control headquarters.

### Analysis

#### *Classification of 3 Periods*

To better reflect the epidemic characteristics of COVID-19 in Macau and Zhuhai and the corresponding coordinated intervention measures, this time was divided into three periods (Figure 2). The first period was the early stage of the COVID-19 epidemic in Wuhan, as the first place of the clustered cases was located and spread outward. Macau and Zhuhai jointly responded to the outbreak caused by the import of mainland China, especially from Wuhan, and curbed the further spread of indigenous infection cases. The second period was the stage of the global pandemic. Macau and Zhuhai cooperated to deal with imported cases outside of mainland China, including foreign countries and Hong Kong, and further improved the normalized prevention and control mechanism. In the third period, which had an overlap with the second period under normalized prevention and control measures, the two places communicated with each other, gradually returning to normal work and life and economic recovery. From the perspective of three periods, we analyzed the characteristics of the epidemic in different periods and the strategies and measures adopted.

#### *Strategy Matrix*

From the three levels of controlling the source of infection, cutting off the route of transmission, and protecting the susceptible population, expounding the collaborative cooperation strategy of Macau and Zhuhai from the perspective of different development period stages.

## Abbreviations

World Health Organization, WHO; Coronavirus Disease 2019, COVID-19; Guangdong-Hong Kong-Macau Greater Bay Area, GBA; Intensive Care Unit (ICU).

## Declarations

### Ethics approval and consent to participate

This study protocol was approved by the Ethics Committee of the Center for Disease Control and Prevention in Zhuhai and followed the tenets of the Declaration of Helsinki.

### Consent for publication

Not required.

### Availability of data and materials

No additional data available.

### Competing interests

None declared.

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### Authors' contributions

Feng Ruan and Wenhua Mei designed the research. Xiling Yin and Songjian Xiao were the main writer of this manuscript. Xuebao Zhang and Long Chen analyzed and interpreted data. Xihe Ni and Sicheng Huang prepared part of this manuscript. All authors reviewed and approved the final version of the manuscript.

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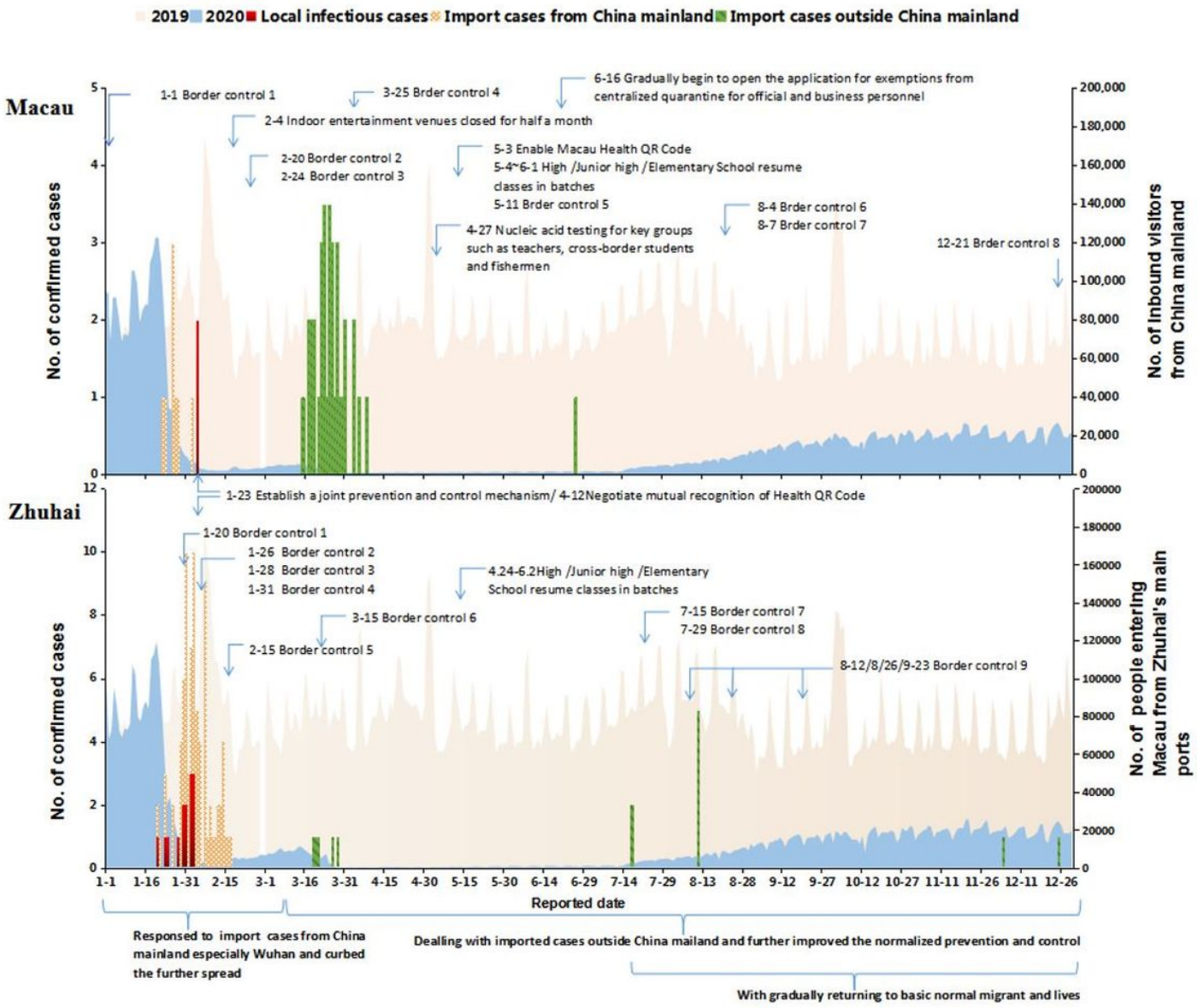
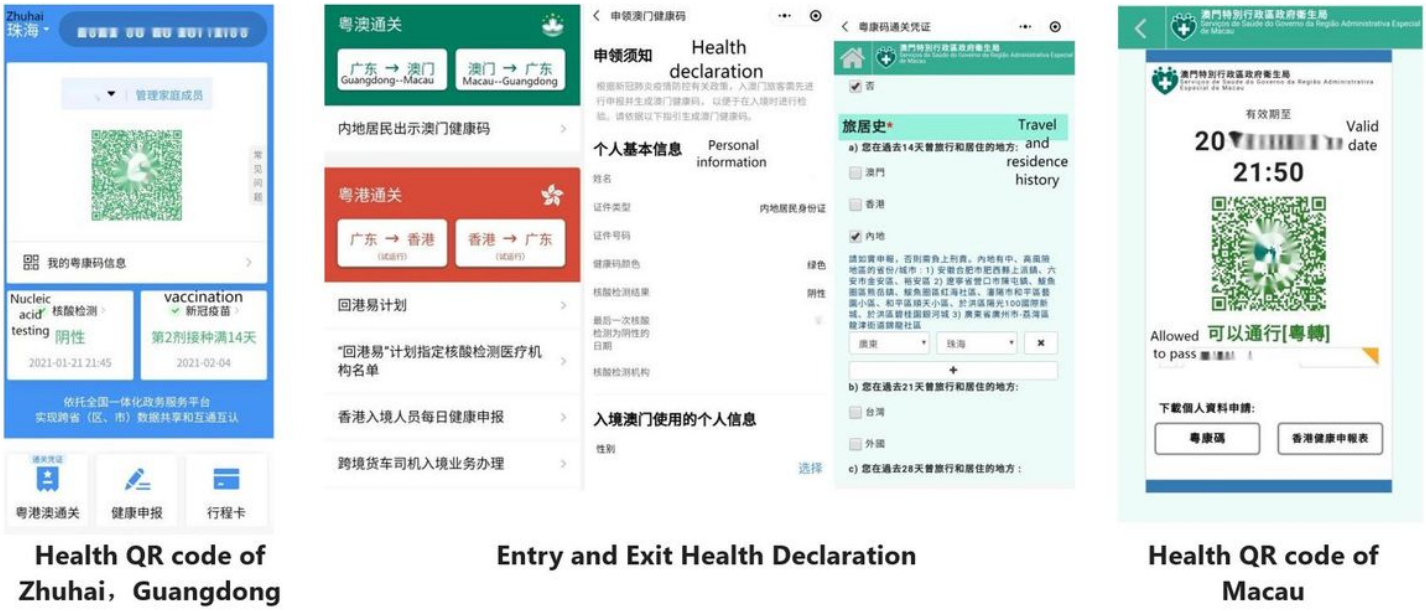
# Figures




## Figure 1

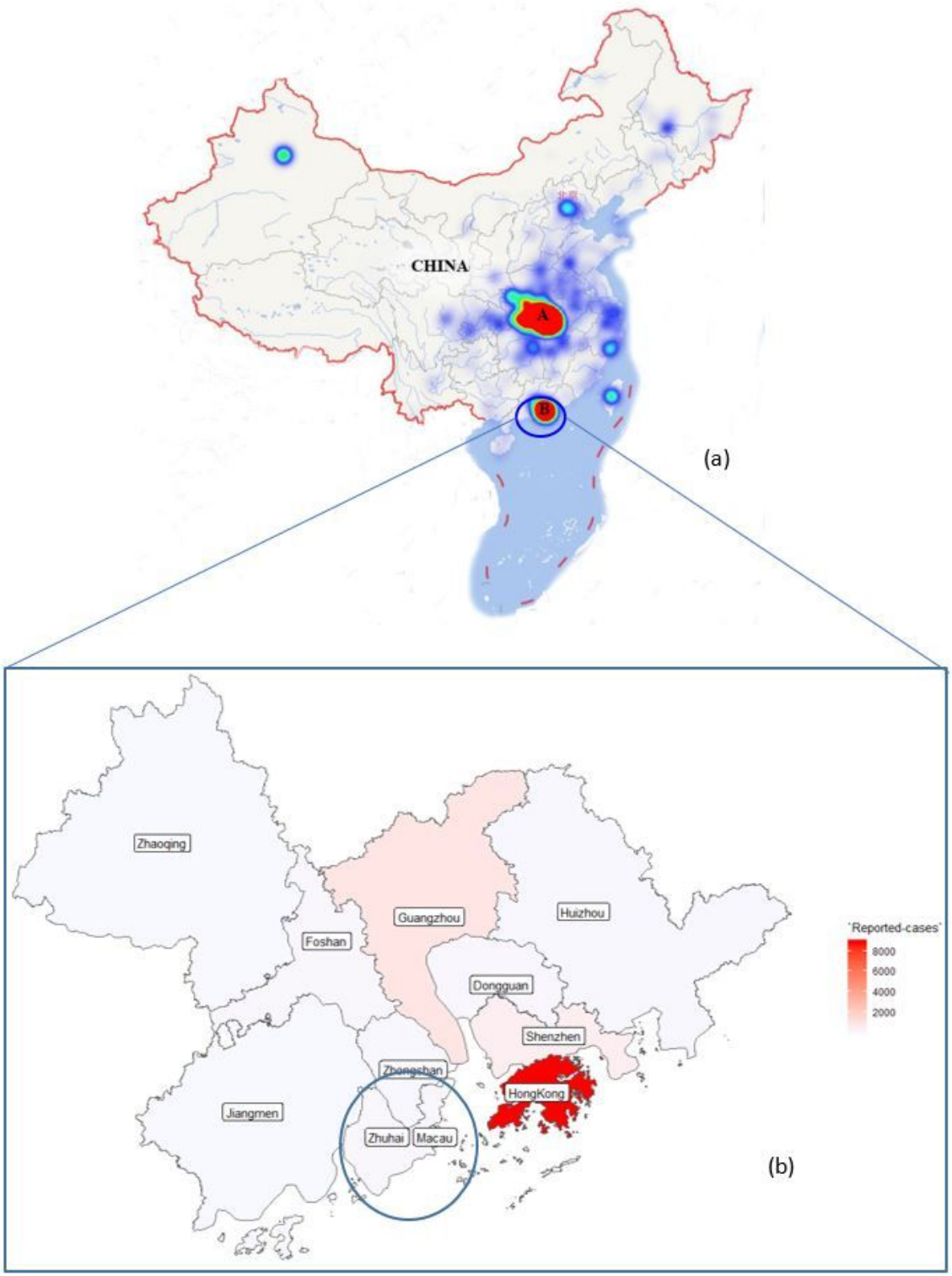
Epidemiological characteristics and main border control strategies of 3 time periods of COVID-19 outbreaks in Macau and Zhuhai




**Health QR code of Zhuhai，Guangdong** **Entry and Exit Health Declaration** **Health QR code of Macau**

## Figure 2

Health QR Code of Zhuhai and Macau The "green code" means that personnel can freely enter and exit public places, and their normal movement will not be restricted by epidemic prevention and control measures. The "yellow code" refers to persons with fever symptoms, persons with a history of living in medium-risk and high-risk areas, and those who are required to undergo nucleic acid testing for the new coronavirus according to regulations. The "red code" refers to confirmed patients, suspected patients, asymptomatic infected persons and their close contacts; persons who have lived abroad in the past 14 days; persons who are required to undergo centralized quarantine or home medical observation according to regulations, etc. The "yellow code" and "red code" were not allowed to pass through the customs gate.




## Figure 3

Map of cumulative reported cases of COVID-19 in China and GBA in 2020 (a) Heat map of cumulative reported cases of COVID-19 in China in 2020. Area A: The number of reported cases in Hubei Province was 68,149 (50,354 in Wuhan); Area B: The number of reported cases in GBA was 10,782. (b) The number of reported cases in Hong Kong was 8846,114 cases in Zhuhai and 46 cases in Macau. There were 1776 cases in the other 8 cities in GBA.