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A review of epidemiology and public health control measures of COVID-19 variants in Hong Kong, December 2020 to June 2021

Ho Yeung LAM*, Cheong Chi Andrew LAU, Chi Hong WONG, Ka Yin Karen LEE, Sum Lisa YIP, Ka Lun Alan TSANG, Kwok Chu Peter CHENG, Ka Wing Albert AU, Ho Leung Ken NG, Shuk Kwan CHUANG, Man Kin Ronald LAM

Centre for Health Protection, Department of Health, Hong Kong Special Administrative Region

ARTICLE INFO

Keywords:

COVID-19
SARS-CoV-2
variants
public health intervention
quarantine
contact tracing
surveillance
Hong Kong

ABSTRACT

Background: The emergence of coronavirus disease 2019 (COVID-19) variants posed considerable threats to the global public health. We reviewed the epidemiology of variant cases and control measures implemented in Hong Kong.

Methods: The epidemiological characteristics and the temporal trend of the COVID-19 variant cases and local clusters in Hong Kong, and the corresponding public health control measures were reviewed.

Results: Between December 2020 and June 2021, 393 variant cases were reported, including 153, 59 and 79 cases of Alpha, Beta and Delta variants with no Gamma variant. The vast majority (378, 96.2%) were imported cases. Since early June 2021, Delta variant had taken over Alpha as the dominant strain. Public health control measures, including risk-stratified quarantine and testing requirements for inbound travellers, banning of flights from extremely high-risk areas, enhanced contact tracing and quarantine, were implemented. Among the 3 clusters involving local transmissions, 2 were linked to imported cases while the source of the remaining one was unknown.

Discussion: Amid the global surges of COVID-19 variants, Hong Kong had continued to limit and prevent the occurrence of community-wide outbreak. Ongoing control strategies should be constantly reviewed and adjusted in response to the global and local COVID-19 situation.

Introduction

The COVID-19 pandemic caused by SARS-CoV-2 has so far led to more than 186 million cases and 4 million deaths around the world (World Health Organization, 2021a). With time, an increasing number of SARS-CoV-2 variants was reported globally. Some, being of public health significance, were classified by the World Health Organization (WHO) as Variants of Concern (VOCs), Variants of Interest (VOIs), and Alerts for Further Monitoring (AFMs) (World Health Organization, 2021b). VOCs drew most attention for their associations with increased transmissibility and virulence, and decreased effectiveness of vaccines, diagnostics, and therapeutics.

Hong Kong reported its first COVID-19 case on 23 January 2020. The ensuing epidemic was characterized by a continuous stream of imported cases with several distinct waves of local transmissions. As of early July 2021, despite having reported more than 11920 COVID-19 cases (equivalent to around 0.16% of the population), its multipronged containment strategy had managed to prevent a sustained outbreak at the community level (Lam et al., 2020).

Following WHO's designation of the first VOC (B.1.1.7) on 18 December 2020, the Centre for Health Protection, Department of Health of Hong Kong (CHP) started retrospective variant analysis on the clinical specimens of COVID-19 cases imported from the United Kingdom (UK) since early December 2020 where there was a prevailing B.1.1.7 surge. The coverage of the analysis was gradually expanded to include all confirmed cases from early January 2021 onwards.

This study was performed to review the epidemiology of confirmed COVID-19 variant cases reported in Hong Kong and the public health measures implemented.

Methods

Case definition

Under CHP's case definition (Centre for Health Protection, 2020), confirmation of a COVID-19 case required the detection (e.g., by reverse transcription polymerase chain reaction (RT-PCR)) of SARS-CoV-2 in a clinical specimen as confirmed by CHP.

* Corresponding author: Dr LAM Ho-yeung, 3/F, Centre for Health Protection, 147C Argyle Street, Kowloon, Hong Kong. Tel.: (852) 2125 2340.
E-mail address: smo_epi4@dh.gov.hk (H.Y. LAM).

<https://doi.org/10.1016/j.ijregi.2021.11.002>

Received 7 September 2021; Received in revised form 4 November 2021; Accepted 4 November 2021

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Identification of variant strain

Specimen of COVID-19 cases would undergo initial tests for specific mutations suggestive of variant strains, including N501Y, E484K and L452R (Planas *et al.*, 2021; Xie *et al.*, 2021). For those with mutation(s) detected, the virus strain would be determined by whole genome sequencing (see supplementary materials for methodology).

Variant cases classified as either VOCs, VOIs, or AFMs reported by CHP from 1 December 2020 to 30 June 2021 were included in this analysis.

Source of case information

Relevant epidemiological and clinical data collected from CHP's epidemiological investigations were extracted from the CHP electronic databases.

Descriptive epidemiology and public health measures

The epidemiological profiles of the variant cases were described and compared between different strains.

Cases were classified based on the history of travel during the incubation period (IP, defined as 21 days before symptom onset) and epidemiological investigation as –

- (1) an imported case (travelled to a place with local COVID-19 transmission during the IP);
- (2) a local case (absence of travel history during the IP);
- (3) epidemiologically linked with imported case; or
- (4) epidemiologically linked with local case.

The temporal trend of COVID-19 variants was described using the weekly proportion of different variants detected among all imported cases and the number of variant cases from different countries of origin.

The public health measures implemented by the government in response to the COVID-19 variant situation were reviewed (HKSAR Government, 2021a). For clusters of variant cases involving local transmission, their epidemiology, phylogenetic analysis (see supplementary materials for methodology) and corresponding control measures were discussed in further details.

To illustrate the overall trend of COVID-19 situation in Hong Kong, an epidemic curve of all daily reported COVID-19 cases was constructed. Data from the School of Public Health of the University of Hong Kong was used to construct a curve of daily effective reproductive number (R_t) of local COVID-19 cases (School of Public Health of the University of Hong Kong, 2021). The methodology of the derivation of R_t was discussed elsewhere (Tsang *et al.*, 2021).

Results

Descriptive epidemiology

Overall summary

5609 confirmed COVID-19 cases were reported between 1 December 2020 and 30 June 2021 in Hong Kong. Sequencing was attempted for variant characterization on 468 cases, with 401 successfully sequenced. 393 cases belonged to VOCs (291, 74%), VOIs (73, 18.6%) or AFMs (29, 7.4%). There were 153, 59 and 79 cases of Alpha, Beta and Delta variants, with no Gamma variant case. Of note, there were 52 (13.2%) cases of Kappa variant (Table 1).

Overall, there were 147 males and 246 females (male-to-female ratio, 1:1.67) whose age ranged from 4 months to 79 years (median: 33; mean: 33.1). 31% of cases were symptomatic. One death was reported (overall case fatality: 0.25%), which involved a sea crew who was found dead on board an incoming marine vessel. Except the deceased case and

one other case who had already left Hong Kong by the time his specimen was confirmed positive, all cases were hospitalised for isolation and treatment. As of mid-July 2021, 389 cases (99.5%) had been discharged.

174 (44%) and 203 (52%) cases were identified on arrival at the airport and during compulsory hotel quarantine respectively. 7 (2%) were identified during quarantine as close contacts of confirmed cases and 9 were identified in the community (from Community Testing Centres and general practitioners).

A majority (378, 96.2%) were imported cases. The top five countries of origin were the Philippines (89), India (85), Indonesia (46), Pakistan (38) and the UK (27).

12 VOC cases (1 Alpha, 9 Beta and 2 Delta) were classified as epidemiologically linked to imported cases. There was only one local case (Alpha variant) and 2 cases were epidemiologically linked to this local case.

Public health control measures

Throughout the COVID-19 epidemic, a containment strategy was adopted in Hong Kong with the ultimate aim of achieving “zero infection” (HKSAR Government, 2020a). With the emergence of COVID-19 variants, additional measures were implemented to mitigate the overall public health risk. Moreover, a total of nine new subsidiary regulations under the Prevention and Control of Disease Ordinance had been enacted to provide legal basis for implementation of the public health measures, and ensure public compliance (HKSAR Government, 2020b).

Preventing importation of cases

Since end-March 2020, all inbound travellers were required to undergo COVID-19 testing upon arrival at the airport. Those who tested positive would be immediately hospitalised for isolation. Previously, those tested negative would undergo quarantine at their homes or hotels. To further limit the contact between the community and imported cases who became infectious during quarantine, starting from 22 December 2020, they were conveyed by designated transportation to one of the designated hotels solely used for quarantine. These hotels had to observe the strict infection control requirements issued by the government.

Furthermore, as the IP of some COVID-19 cases could reach up to 21 days (Dhouib *et al.*, 2021), since 24 December 2020, the quarantine duration for inbound travellers had been extended from 14 to 21 days. They also needed to undergo additional COVID-19 testings (3 to 4 times depending on the countries of origin) during and after quarantine.

Since 23 January 2021, different countries and regions were categorised into different risk levels based on their local COVID-19 epidemiology. Inbound travellers had to observe the corresponding set of boarding, quarantine, and testing requirements. Banning of flights and inbound travellers from extremely high-risk areas with COVID-19 variants transmissions were implemented to limit introduction of cases. As of mid-July 2021, the bans for Brazil, India, Indonesia, Nepal, Pakistan, the Philippines, South Africa, and the UK were in effect (HKSAR Government, 2021b).

Enhanced contact tracing and quarantine measures for cases

Since the start of the epidemic, CHP had been conducting epidemiological investigation, contact tracing, and implementing control measures for every notified COVID-19 case. Contact tracing and quarantine of close contacts were considered crucial in limiting further spread but resource-intensive and time-sensitive (Centers for Disease Control and Prevention, 2020). To strengthen the capacity and timeliness, CHP established the Contact Tracing Office in early January 2021. Staffed by law enforcement officers, it was responsible for ascertaining the movement of each case and identifying close contacts for quarantine.

The tracing period was also extended to cover the period from 21 days before symptom onset or the day of collection of the positive spec-

Table 1
Epidemiological profiles of the 393 COVID-19 variant cases in Hong Kong reported between 1 December 2020 and 30 June 2021.

	VOCs (n = 291)				VOIs (n = 73)					AFMs (n = 29)			Total
	Alpha (B.1.1.7)	Beta (B.1.351)	Gamma (P.1/P.1.1/P.1.2)	Delta (B.1.617.2)	Eta (B.1.525)	Iota (B.1.526)	Kappa (B.1.617.1)	Epsilon (B.1.427)	Theta (P.3)	B.1.466.2	C.36.3	B.1.621	
Reporting date of first identified case	6 Dec 2020	29 Dec 2020	NA	27 Mar 2021	12 Feb 2021	29 Mar 2021	24 Mar 2021	26 Feb 2021	23 Jan 2021	12 Mar 2021	9 Apr 2021	8 Jun 2021	-
Age (year)													
Range	8m – 67	4m – 67	NA	2 – 78	31 – 67	28	4m – 60	50 – 59	25 - 53	21 – 79	19 – 67	19 – 22	4m to 79
Mean	32.8	33.7	NA	20.5	40.0	28	30.0	54.5	34.8	35.5	51.8	20.5	33.1
Median	32	33	NA	32	34.5	28	34	54.5	32	34	60.5	20.5	33
Sex													
Male (%)	64 (42%)	8 (14%)	NA	36 (46%)	5 (83%)	1 (100%)	25 (48%)	1 (50%)	2 (17%)	1 (4%)	3 (75%)	1 (50%)	147 (37%)
Female (%)	89 (58%)	51 (86%)	NA	43 (54%)	1 (17%)	0 (0%)	27 (52%)	1 (50%)	10 (83%)	22 (96%)	1 (25%)	1 (50%)	246 (63%)
Clinical features													
%Symptomatic	29%	14%	NA	24%	50%	100%	25%	0%	33%	13%	75%	50%	31%
%Deceased	0%	0%	NA	1.30%	0%	0%	0%	0%	0%	0%	0%	0%	0.25%
Case classification													
Imported case (%)	149 (97%)	50 (85%)	NA	77 (93%)	6 (100%)	1 (100%)	52 (100%)	2 (100%)	12 (100%)	23 (100%)	4 (100%)	2 (100%)	378 (96%)
Epidemiologically linked with imported case (%)	1 (1%)	9 (15%)	NA	2 (3%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	12 (3%)
Local case (%)	1 (1%)	0 (0%)	NA	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (0%)
Epidemiologically linked with local case (%)	2 (1%)	0 (0%)	NA	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (1%)
Mode of detection													
At arrival in airport (%)	81 (53%)	22 (37%)	NA	34 (43%)	1 (17%)	0 (0%)	6 (12%)	2 (100%)	5 (42%)	17 (74%)	4 (100%)	2 (100%)	174 (44%)
During quarantine for inbound travelers (%)	69 (45%)	28 (47%)	NA	41 (52%)	5 (83%)	1 (100%)	46 (88%)	0 (0%)	7 (58%)	6 (26%)	0 (0%)	0 (0%)	203 (52%)
During quarantine for close contacts (%)	2 (1%)	4 (7%)	NA	1 (1%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	7 (2%)
In the community (%)	1 (1%)	5 (8%)	NA	3 (4%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	9 (2%)
Top 5 countries of origin for imported cases	Pakistan (37)	Philippines (44)	NA	Indonesia (19)	UAE (4)	USA (1)	India (52)	USA (2)	Philippines (10)	Indonesia (23)	Egypt (4)	Colombia (2)	Philippines (89)
	Philippines (35)	Bangladesh (2)		Nepal (18)	Togo (1)				USA (1)				India (85)
	India (17)	South Africa (1)		India (16)	Lebanon (1)				Indonesia (1)				Indonesia (46)
	UK (13)	Pakistan (1)		UK (14)									Pakistan (38)
	UAE (8)	Kenya (1)		Bangladesh (4)									UK(27)
Total	153	59	0	79	6	1	52	2	12	23	4	2	393

*NA: Not applicable; UAE: the United Arab Emirates; UK: the United Kingdom; USA: the United States.

imen to the day of isolation in hospital. All close contacts identified, and household members of symptomatic close contacts would be arranged for quarantine at quarantine centres.

To maximize case detection, the government would issue a compulsory testing notice (CTN) for the entire block of residential building and workplace of the case, as well as premises visited during the tracing period. Anyone present in these premises during the time of visit by the case would be legally required to undergo COVID-19 testing. More than a dozen Community Testing Centres were established throughout the territory to offer free COVID-19 testing (HKSAR Government, 2021c).

In November 2020, the government launched LeaveHomeSafe, a mobile application which allowed users to record their visits by scanning the QR codes posted at different public premises. An alert for testing would be sent to users who had logged their visit at the premises visited by a COVID-19 case.

For local variant cases with unknown source, the government would also conduct restriction-testing declaration (RTD) operations. A restricted area would be delineated around the case's residential building. All personnel present within the area would receive mandatory COVID-19 testing and were prohibited from leaving the area until all test results were available.

In view of the higher transmissibility of COVID-19 variants, CHP initially adopted the practice to evacuate all residents of the residential building of a variant case for quarantine as they were potentially at risk of contracting COVID-19 through sharing of common facilities within the building. In view of the absence of such transmission observed in the initial few cases of COVID-19 variants, this practice was later relaxed and replaced with CTN for the entire building.

Continuation of on-going social distancing measures

The social distancing measures implemented since the start of the epidemic, including mandatory mask-wearing in public areas, restrictions on restaurant operations, prohibition of group gatherings and closure of premises like bars and fitness centres, were continued with different degrees of relaxation.

Trend of variant cases

Before mid-February 2021, less than one-quarter of imported cases were fully genetically sequenced. Thereafter, the proportion gradually increased to 100% after mid-June 2021 (Figure 1).

From early December 2020 to early February 2021, most successfully-sequenced imported cases were of Alpha variant. Its proportion increased to almost half during March and gradually decreased afterwards, followed by a brief surge in the latter half of May.

The proportion of Beta variant cases started to rise in early February 2021 and fluctuated between 5% and 25% in the weeks that followed, finally experiencing a gradual fall towards early May.

Cases of Delta variant emerged in late March 2021 and soon caused a surge during the latter half of April, followed by a further surge to 80% in mid-June. Delta became the only VOC reported during June.

There was a brief surge of Kappa variant cases during mid-April 2021.

Countries of origin of variant cases

The first wave of the Alpha variant cases during December 2020 and early January 2021 was imported mainly from the UK, while the subsequent waves between March and May 2021 were from the Philippines, Pakistan, and India (Figure 2).

Most Beta variant cases were from the Philippines between February and early May 2021.

The first wave of Delta variant in April 2021 was from India and Nepal. Of note, 10 out of the 18 Delta variant cases were passengers of a single flight arriving from Nepal on 20 April 2021. The second wave starting from the latter half of May mainly comprised of cases from the UK and Indonesia.

All 52 Kappa variant cases were from India. 46 cases (88%) were passengers of the same flight from India arriving on 4 April 2021. Of note, 59 passengers of that flight were tested positive for COVID-19 (with Alpha, Delta, and Kappa variants) after arrival.

The number of imported cases from the above countries dropped to zero after the implementation of banning of flights and inbound passengers. (It should be noted that cases reported after the ban were all confirmed during quarantine).

Clusters of variant cases with local transmission

3 clusters of variant cases involving local transmission were identified during the study period.

(a) Beta variant cluster (Figure 3a)

On 16 April 2021, CHP received notification of a preliminary positive COVID-19 case involving a 29-year-old male (the index). He travelled from Dubai to Hong Kong on 19 March 2021. He underwent quarantine at a designated hotel from 19 March to 8 April 2021 and was tested negative three times during hotel quarantine on 25 March, 30 March and 6 April 2021. After completing quarantine, he moved to stay with a female friend since 9 April 2021. He received testing on 15 April 2021 in a Community Testing Centre and was tested positive for Beta variant. The female friend was also later tested positive during quarantine.

It was found that 2 previously confirmed COVID-19 Beta variant cases were also residing on the same floor of the hotel as the index was undergoing hotel quarantine. Both were foreign domestic helpers (FDHs) from Indonesia and tested positive during hotel quarantine. Genetic sequencing revealed that all 3 cases carried 5 unique mutations and were similar phylogenetically, which was indicative of transmission within the hotel.

As there was no contact between the 3 cases in the hotel, on-site investigation revealed that hotel staff used S-shaped door hooks to hang meal boxes outside the guest rooms for collection by the guests under quarantine. One of the possibilities was that transmission might have occurred through contamination of the hooks by one of the cases, followed by contamination of other hooks by the hotel staff. However, swabs taken from all available hooks on 17 April were all tested negative for SARS-CoV-2. As a precautionary measure, all designated quarantine hotels were advised to cease the use of door hooks for meal deliveries.

On 29 April 2021, CHP received notification of another preliminary positive case involving a FDH with no recent travel history. She had symptom onset on 23 April 2021, underwent testing at a Community Testing Centre and tested positive for Beta variant.

In view of the possibility of silent transmissions within the FDH community in Hong Kong, the government issued a CTN on 30 April 2021 which required all FDHs to undergo COVID-19 testing. Two FDHs with Beta variant were subsequently identified on 4 May 2021.

Further investigation revealed that all these cases were in fact epidemiologically linked: The index and his female friend attended a family gathering on 13 April 2021. Five days later, some of the attendants attended another gathering with the 3 FDHs above. Consequently, 4 attendants of the family gathering and 2 household members of one of the FDHs tested positive for Beta variant during quarantine.

There were in total 13 cases in this cluster, involving 4 generations of transmission. Eight cases which had been successfully sequenced were found to be nearly identical phylogenetically. For each of the 13 cases, CHP conducted thorough epidemiological investigation and extensive contact tracing. All close contacts were arranged for quarantine. CTNs were issued for the venues visited by each case. Four RTD operations and evacuation of all residents were conducted for the residential buildings of the index case and the three FDHs. No further case related to this cluster was identified.

(b) Alpha variant cluster (Figure 3b)

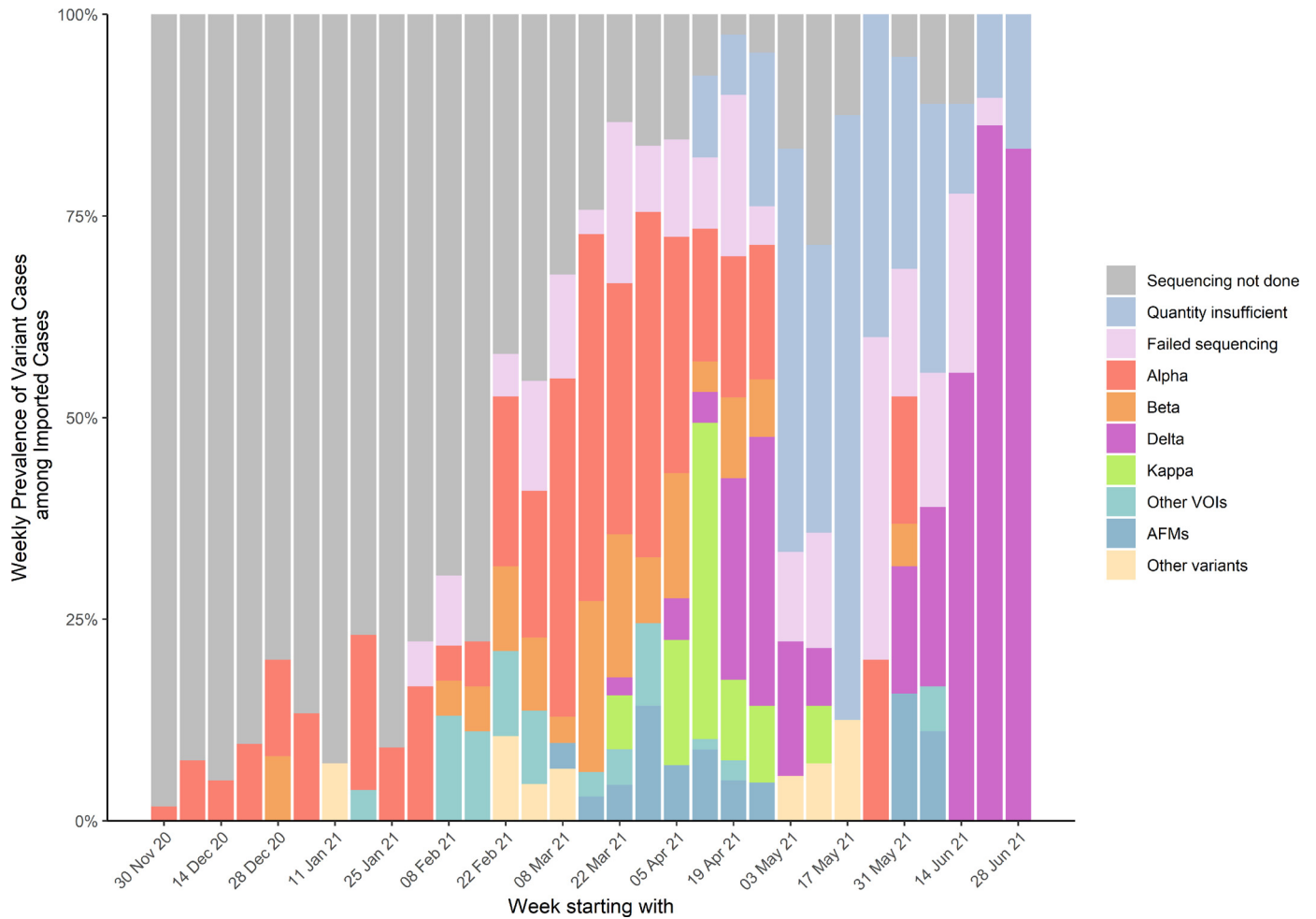


Figure 1. Weekly prevalence of variant cases among all imported cases.

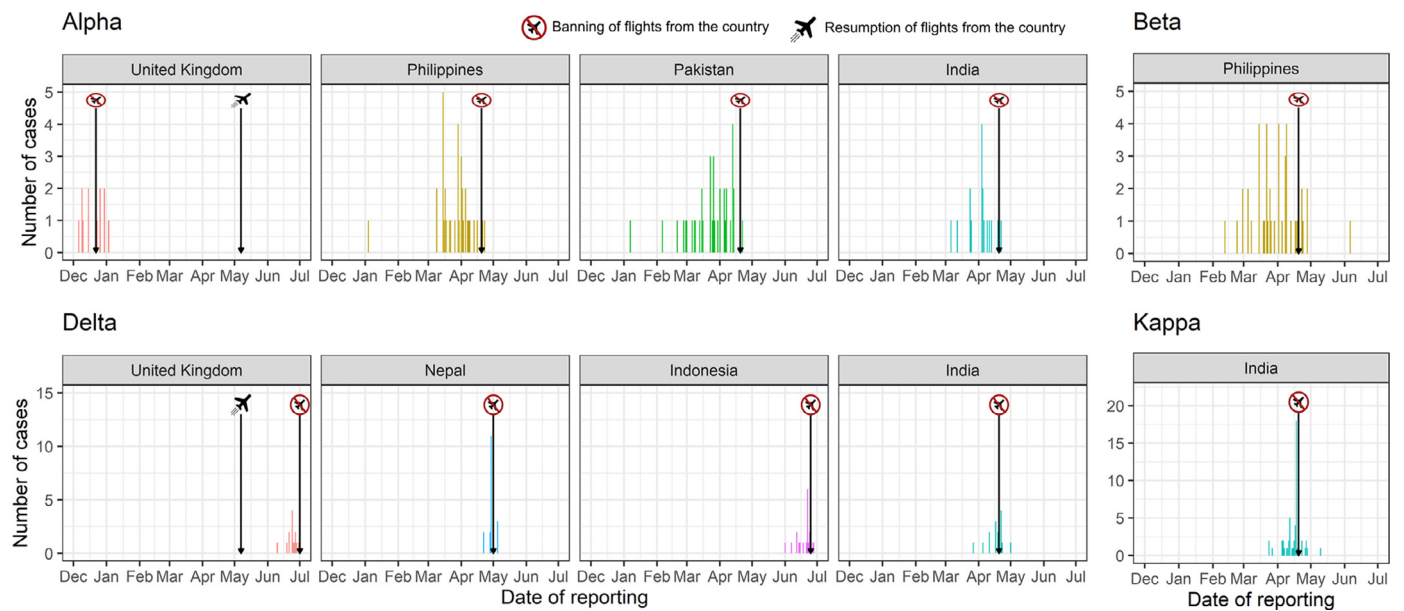


Figure 2. The daily number of imported cases with VOCs and Kappa variant from different countries by date of reporting. For each variant, only countries with more than 10 cases are displayed. The "No flight" and "Flight" symbols indicate the day of banning and resumption of flights from the corresponding country. Note the different scale of the y-axes.

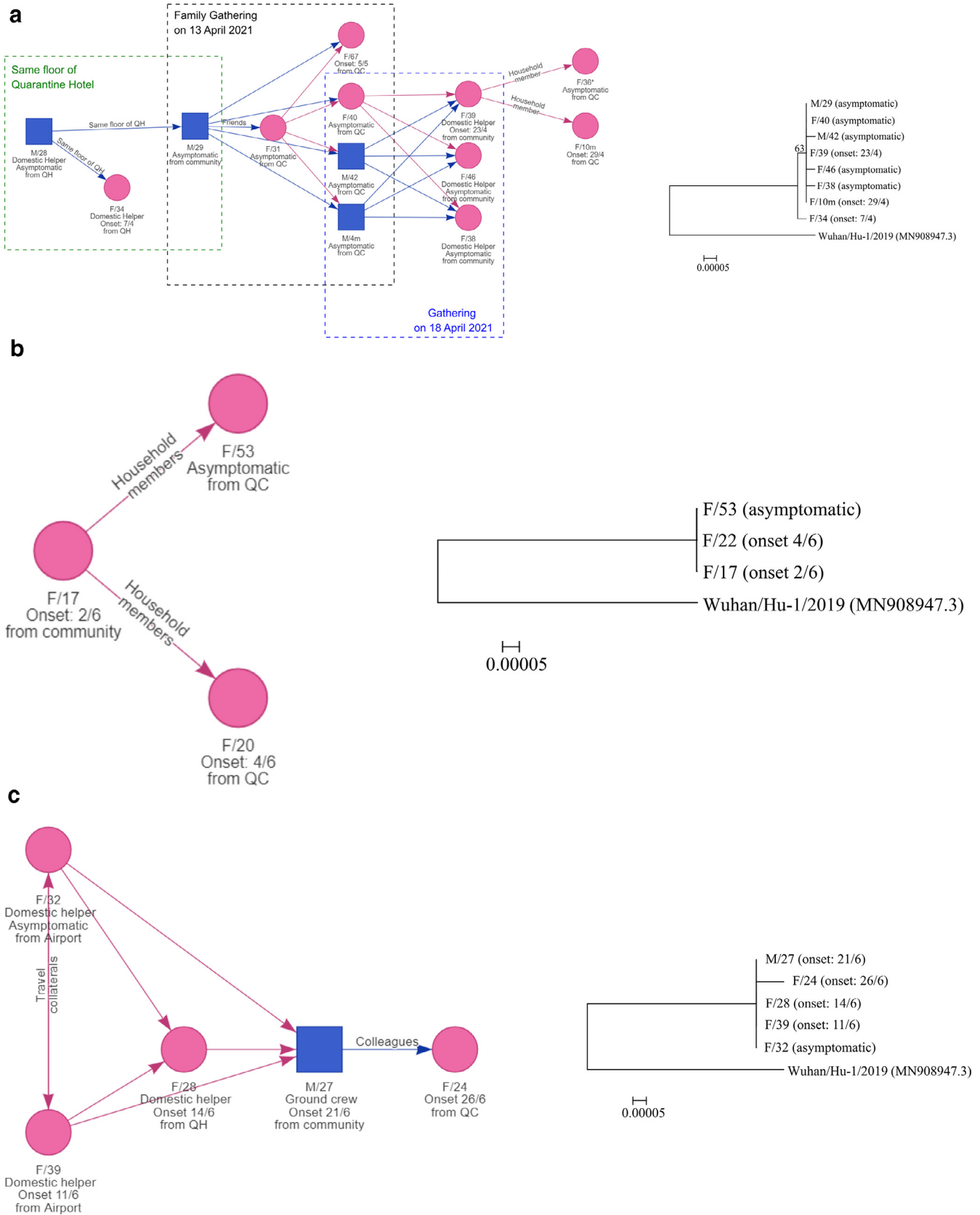


Figure 3. Transmission chains and phylogenetic diagrams of the 3 clusters of variant cases with local transmission. (a) The Beta variant cluster involving 13 cases; (b) The Alpha variant cluster involving 3 cases, with unknown source; (c) The Delta variant cluster involving 5 cases. (Square: male sex; Circle: female sex; Arrow: direction of transmission; QC: quarantine centre (for close contact of cases); QH: quarantine hotel (for inbound travellers); Airport: COVID-19 testing on arrival at the airport; Community: COVID-19 testing in the community, e.g., Community Testing Centres, primary care clinics; *: variant result not available)

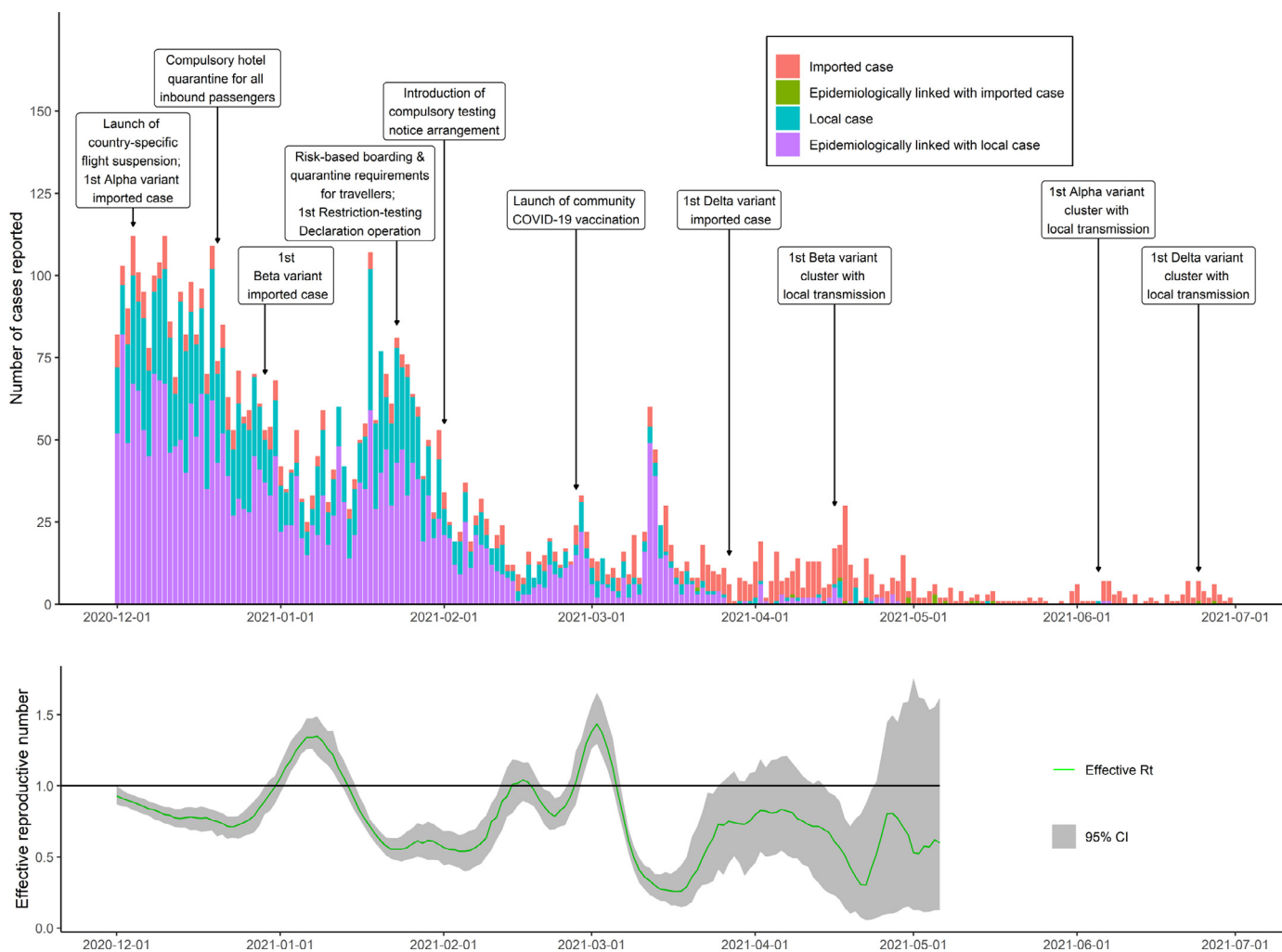


Figure 4. Epidemic curve of all COVID-19 cases (including both non-variant and variant cases) and the trend of effective local reproductive number of COVID-19 in Hong Kong between 1 December 2020 and 30 June 2021. Key public health measures and events were indicated in the curve. The effective local reproductive number beyond early May 2021 was unavailable due to the paucity of local cases.

The index case involved a 17-year-old female who developed symptoms on 2 June 2021. She attended an outpatient clinic and tested positive for COVID-19 with Alpha variant. She had no recent travel history.

Extensive contact tracing identified about 130 close contacts for quarantine. Two of her household members were subsequently tested positive for Alpha variant during quarantine. Phylogenetic analysis showed that the genetic sequence of the three cases were identical. Genetic analysis of the specimen from the index case showed at least 17 nucleotide differences from any previously reported COVID-19 cases.

CTNs were issued for the venues visited by each case and an RTD operation was conducted at her residential building. No further Alpha variant case was identified from the community. The exact source of this cluster remained unidentified.

(c) Delta variant cluster (Figure 3c)

On 24 June 2021, CHP was notified of a preliminary positive COVID-19 case involving a 27-year-old male (the index). He developed symptoms on 21 June 2021, sought treatment from a general practitioner and was subsequently tested positive as a Delta variant case.

He worked both as a ground crew in the airport responsible for receiving inbound aircrews and a customer service staff in a local shopping mall.

Extensive contact tracing was conducted. His household members and colleagues at both workplaces (~170) were quarantined. One of

his colleagues at the shopping mall was subsequently tested positive, with nearly identical sequence phylogenetically. CTNs were issued for the places he had visited and a RTD operation was conducted for his residential building. No further cases were identified.

Whole genome sequencing revealed that the case was identical to 3 previous imported Delta variant cases, involving 3 FDHs who arrived at the airport on 11 June 2021 from Indonesia. Although both sides could not recall any contact, review of surveillance footage revealed that the index walked past the 3 FDHs when the latter were waiting for COVID-19 testing in the airport. Besides, one FDH might have had touched the handrail of an escalator which was subsequently touched by the index about 20 minutes later without disinfection in between. It was possible that the transmission might have occurred during the brief encounter or through environmental contamination.

Overall trend of the COVID-19 situation

There were several waves of local COVID-19 cases between December 2020 and March 2021, as reflected by the corresponding rises of R_t . No COVID-19 variant cases were identified from these local clusters. The R_t remained below one during the rest of the study period (Figure 4).

Starting from mid-March 2021, the number of local cases sharply declined. Since early April 2021, most cases reported were imported cases. The absence of local community transmission was supported by

the below-one R_t . Of note, the R_t values beyond early May 2021 were unavailable due to the paucity of local cases.

Discussion

The overall epidemic of COVID-19 variants in Hong Kong during the study period had several distinctive characteristics. One was the absence of mortality among hospitalised cases, attributable to a younger case population and the high-quality healthcare system in Hong Kong.

Another feature was the high proportion of imported cases. This was not surprising as Hong Kong was receiving around 1500 inbound travellers from different countries (excluding mainland China) every month (Hong Kong Tourism Board, 2021) despite the drastic reduction in international travel. It also means that Hong Kong was under the constant threat of invasion by different COVID-19 variants.

However, unlike other countries which saw surges of COVID-19 variants following their introduction (Callaway, 2021; Kirby, 2021; Noureddine *et al.*, 2021), no widespread community outbreak of variant cases was observed in Hong Kong. Local transmission of COVID variants was largely absent, as supported by the low R_t value.

We suggest that this success could be attributed to the timely implementation of the various control measures. Under border control, the requirement of pre-departure and on-arrival COVID-19 testing ensured that positive cases could either not board the flight or be detected upon arrival at the airport. For those who were still incubating at the time of arrival, the 21-day compulsory hotel quarantine (c.f. 10- to 14-day duration in other countries (NSW Government, 2021; UK Government, 2021)) and the multiple testing during and after quarantine, could limit the risk of community spreading. Indeed, an overwhelming majority of cases were identified through these two ways.

Banning of flights and passengers from extremely high-risk areas further limited the introduction of COVID-19 variants. The notable absence of Gamma variant among the reported cases might be partially due to the pre-emptive banning of flights and passengers from Brazil on 23 January 2021 when the surge of Gamma variants was still developing there.

The availability of free COVID-19 testing with quick turn-around-time (within 1-2 days) facilitated early detection of local cases. All index cases in the three local clusters discussed were detected at the community level. The enhanced operational capacity and the readiness of quarantine facilities made thorough epidemiological investigation and timely quarantine of close contacts possible. Nearly half of the cases in the three local clusters were identified during quarantine, a testament to the importance of quarantine in limiting disease spread. The use of whole genome sequencing was also pivotal in identifying the sources of the clusters.

Lastly, the public of Hong Kong had maintained a high level of vigilance towards COVID-19, with continuous practice of mask-wearing, hand hygiene, and environmental hygiene. Following the launch of the community COVID-19 vaccination programme on 26 February 2021, more than 40% of the population had received at least 1 dose of vaccine as of mid-July 2021 (HKSAR Government, 2021d). The public's contribution to the control of COVID-19 could not be overstated.

This study had several limitations. Variant analysis was not conducted for all confirmed COVID-19 cases reported during the study period. Variant information was unavailable for some cases due to technical reasons including insufficient viral load and failed sequencing. The total burden of variant cases might thus be underestimated but nevertheless allowed analysis of the overall trend.

In addition, as a descriptive study, causal relationships between the public health measures and the epidemic situation could not be established. Due to the overlapping nature of the measures, it was not feasible to assess their individual effects. In addition, the effect of potential confounders was not measured. Further studies, including modelling studies, are warranted to investigate the effect of these public health measures on limiting the community spreading of COVID-19 variants.

Furthermore, the role of COVID-19 vaccination against variants was not explored in this report, as the community vaccination programme was still ongoing. The evaluation of vaccine effectiveness would also be limited by the absence of community-wide transmission of COVID-19 in Hong Kong.

While the world strives to bring this pandemic to an end, the future trajectory of COVID-19 remains unclear (Skegg *et al.*, 2021). Hong Kong's experience in combating COVID-19 variants demonstrated that the virus could be contained using a combination of public health control measures. This strategy should also be constantly reviewed and adjusted amid the ever-changing global and local COVID-19 situation.

Conflict of Interest

None.

Funding source

This study did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Ethical Approval statement

Approval was not required.

Acknowledgments

The authors would like to thank the staff members of the Centre for Health Protection and Hospital Authority for their dedications and contributions to the control of COVID-19 in Hong Kong.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ijregi.2021.11.002.

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