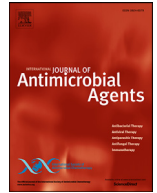




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## Global epidemiology of coronavirus disease 2019 (COVID-19): disease incidence, daily cumulative index, mortality, and their association with country healthcare resources and economic status

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## ABSTRACT

It has been 2 months since the first case of coronavirus disease 2019 (COVID-19) was reported in Wuhan, China. So far, COVID-19 has affected 85 403 patients in 57 countries/territories and has caused 2924 deaths in 9 countries. However, epidemiological data differ between countries. Although China had higher morbidity and mortality than other sites, the number of new daily cases in China has been lower than outside of China since 26 February 2020. The incidence ranged from 61.44 per 1 000 000 people in the Republic of Korea to 0.0002 per 1 000 000 people in India. The daily cumulative index (DCI) of COVID-19 (cumulative cases/no. of days between the first reported case and 29 February 2020) was greatest in China (1320.85), followed by the Republic of Korea (78.78), Iran (43.11) and Italy (30.62). However, the DCIs in other countries/territories were <10 per day. Several effective measures including restricting travel from China, controlling the distribution of masks, extensive investigation of COVID-19 spread, and once-daily press conferences by the government to inform and educate people were aggressively conducted in Taiwan. This is probably the reason why there was only 39 cases (as of 29 February 2020) with a DCI of 1 case per day in Taiwan, which is much lower than that of nearby countries such as the Republic of Korea and Japan. In addition, the incidence and mortality were correlated with the DCI. However, further study and continued monitoring are needed to better understand the underlying mechanism of COVID-19.

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### 1. Global epidemiology of coronavirus disease 2019 (COVID-19)

Since the first reported case of COVID-19 in Wuhan, China, at the end of 2019, COVID-19 has rapidly spread throughout China and has also involved many other countries despite global efforts to prevent its spread [1–4]. According to a report of the World Health Organization (WHO), COVID-19 has affected 85 403 pa-

tients in 57 countries/territories and has caused 2924 deaths as of 29 February 2020, of which approximately 92.9% of cases and 97.1% of deaths have been in China [1]. Among these 57 countries/territories, cases reported in 20 countries/territories were attributed to local transmission of COVID-19, whilst those in 37 countries/regions were imported cases. However, the incidence and mortality of COVID-19 varied in different countries//territories. The incidence ranged from 61.44 per 1 000 000 people in Republic of Korea to 0.0002 per 1 000 000 people in India (Table 1).

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**Table 1**

Characteristics of 57 countries/territories with reported cases of coronavirus disease 2019 (COVID-19) as of 29 February 2020 [1]

Country/territory	Cumulative case no.	No. of deaths	Mortality rate (%)	Incidence per 1 000 000 population	Deaths per 1 000 000 population	DCI	GDP (\$US)	HCI [5]	Days since last reported case	Local transmission
Asia										
China	79 251	2835	3.58	55.06	1.97	1320.85	10 098	64.48	0	Yes
Republic of Korea	3150	17	0.54	61.44	0.33	78.78	31 430	81.97	0	Yes
Japan	230	5	2.17	1.82	0.04	5.11	40 846	81.14	25	Yes
Singapore	98	0	0.00	16.75	0.00	2.72	63 987	70.84	0	Yes
Hong Kong SAR	94	2	2.13	12.54	0.27	2.54	49 334	66.08	0	Yes
Thailand	42	0	0.00	0.60	0.00	0.89	7791	77.95	0	Yes
Taiwan	39	1	2.56	1.64	0.04	1.03	24 827	86.71	0	Yes
Australia	24	0	0.00	0.94	0.00	0.69	50 022	77.38	0	Yes
Malaysia	24	0	0.00	0.74	0.00	0.71	11 136	68.10	2	Yes
Vietnam	16	0	0.00	0.16	0.00	0.44	2740	57.70	16	Yes
Macau SAR	10	0	0.00	15.40	0.00	0.27	81 151	NA	25	No
Philippines	3	1	33.33	0.03	0.01	0.10	3294	67.47	33	No
India	3	0	0.00	0.00	0.00	0.10	2171	67.13	0	Yes
Cambodia	1	0	0.00	0.06	0.00	0.03	1620	NA	26	No
Nepal	1	0	0.00	0.03	0.00	0.03	1047	56.88	47	No
Sri Lanka	1	0	0.00	0.05	0.00	0.03	3946	72.53	33	No
New Zealand	1	0	0.00	0.21	0.00	1.00	40 634	73.81	1	No
Subtotal	82 988	2861	3.45							
America										
USA	62	0	0.00	0.19	0.00	1.68	65 111	69.27	0	Yes
Canada	14	0	0.00	0.37	0.00	0.42	46 212	71.58	0	No
Brazil	1	0	0.00	0.00	0.00	0.50	8796	56.29	3	No
Mexico	2	0	0.00	0.02	0.00	NA	10 118	70.12	0	No
Subtotal	79	0	0.00							
Europe										
Italy	888	21	2.36	14.69	0.35	30.62	32 946	66.59	0	Yes
Germany	57	0	0.00	0.68	0.00	1.78	46 563	73.32	0	Yes
France	57	2	3.51	0.87	0.03	1.63	41 760	79.99	0	Yes
Spain	32	0	0.00	0.68	0.00	1.14	29 961	78.88	0	Yes
UK	20	0	0.00	0.29	0.00	0.71	41 030	74.46	0	Yes
Sweden	12	0	0.00	1.19	0.00	0.43	51 241	69.23	0	No
Switzerland	10	0	0.00	1.16	0.00	3.33	83 716	72.44	0	No
Norway	6	0	0.00	1.11	0.00	3.00	77 975	74.36	0	No
Israel	5	0	0.00	0.58	0.00	0.71	42 823	73.29	0	No
Austria	5	0	0.00	0.56	0.00	1.67	50 022	78.73	0	No
Croatia	5	0	0.00	1.22	0.00	1.67	14 949	62.68	0	Yes
Greece	3	0	0.00	0.29	0.00	1.50	19 974	56.21	2	No
Romania	3	0	0.00	0.16	0.00	1.50	12 482	55.06	0	No
Russian Federation	2	0	0.00	0.01	0.00	0.07	11 162	57.59	29	No
Finland	2	0	0.00	0.36	0.00	0.07	48 868	75.79	3	No
Denmark	2	0	0.00	0.35	0.00	1.00	59 795	80.00	0	No
Georgia	2	0	0.00	0.50	0.00	1.00	4289	51.24	0	No
Netherlands	2	0	0.00	1.17	0.00	2.00	52 367	74.65	0	No
Estonia	1	0	0.00	0.75	0.00	0.50	23 523	72.67	2	No
Belgium	1	0	0.00	0.09	0.00	0.04	45 175	74.34	0	No
North Macedonia	1	0	0.00	0.48	0.00	0.50	6096	56.38	3	No
Belarus	1	0	0.00	0.11	0.00	1.00	6603	59.04	1	No
Lithuania	1	0	0.00	0.37	0.00	1.00	19 266	69.49	1	No
San Marino	1	0	0.00	29.47	0.00	NA	47 279	NA	0	Yes
Subtotal	1119	23	2.06							
Eastern Mediterranean region										
Iran	388	34	8.76	4.62	0.40	43.11	5506	51.70	0	Yes
Kuwait	45	0	0.00	10.54	0.00	9.00	29 266	56.21	0	No
Bahrain	38	0	0.00	22.33	0.00	9.50	25 273	NA	0	No
United Arab Emirates	19	0	0.00	1.92	0.00	0.61	37 749	67.04	2	Yes
Iraq	8	0	0.00	0.20	0.00	2.00	5738	41.36	2	No
Oman	6	0	0.00	1.17	0.00	1.50	17 791	58.15	2	No
Lebanon	2	0	0.00	0.29	0.00	0.29	9654	64.38	3	No
Pakistan	2	0	0.00	0.01	0.00	1.00	1388	60.59	3	No
Afghanistan	1	0	0.00	0.03	0.00	0.25	513	NA	5	No
Egypt	1	0	0.00	0.01	0.00	0.07	3046	45.84	15	No
Subtotal	510	34	6.67							
Africa										
Algeria	1	0	0.00	0.02		0.33	3980	54.86	0	No
Nigeria	1	0	0.00	0.00		1.00	2222	51.59	0	No
Subtotal	2	0	0.00							
International conveyance	705	6	0.85			29.38			3	Yes
Total	85 403	2924	3.42							

DCI, daily cumulative index (cumulative cases/no. of days between the first reported case and 29 February 2020); GDP, gross domestic product; HCI, Health Care Index; NA, not applicable.

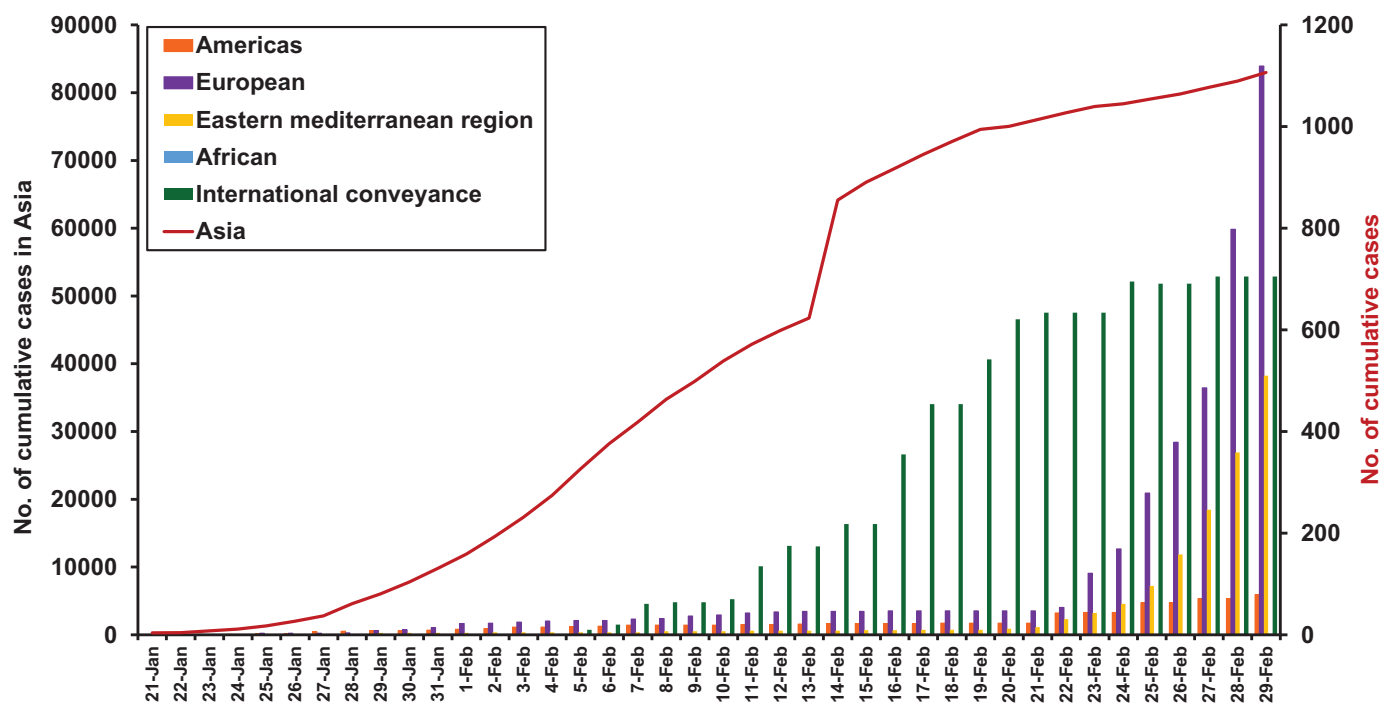


Fig. 1. Daily cumulative case number of patients with coronavirus disease 2019 (COVID-19) in five main geographical regions and the international conveyance (Diamond Princess cruise ship) as of 29 February 2020.

## 2. COVID-19 in different geographical regions of the world

To date, five regions have observed COVID-19 cases, including Asia, Eastern Mediterranean region, Europe, America and Africa. Of course, the highest incidence of COVID-19 was reported in Asia ( $n = 82\,988$ ), followed by Europe ( $n = 1119$ ), Eastern Mediterranean region ( $n = 510$ ), America ( $n = 79$ ) and Africa ( $n = 2$ ) (Fig. 1). Within the last week of February, the number of new cases was highest in Asia ( $n = 5019$ ), followed by Europe ( $n = 998$ ) and the Eastern Mediterranean region ( $n = 467$ ). The overall mortality rate was highest in the Eastern Mediterranean region (6.67%;  $n = 34$ ), followed by Asia (3.45%;  $n = 2861$ ) and Europe (2.06%;  $n = 23$ ). In contrast, there had been no deaths in America or Africa as of 29 February 2020.

## 3. Disease incidence, mortality rate and daily cumulative index of COVID-19 by country

The incidence (cases per 1 000 000 population) of COVID-19 cases was highest in the Republic of Korea (61.44), followed by China (55.06), San Marino (29.47), Bahrain (22.33), Singapore (16.75), Macau Special Administrative Region (SAR) (15.40), Italy (14.69), Hong Kong SAR (12.54), Kuwait (10.54) and Iran (4.62). In the other 47 countries, the incidence of COVID-19 cases was  $<2$  per 1 000 000 population. Only nine countries had observed COVID-19-associated deaths, and the mortality rate ranged from 33.33% (1/3) in the Philippines to 0.54% (17/3150) in the Republic of Korea.

The daily cumulative index (DCI) of COVID-19 cases is defined as the cumulative cases/no. of days between the first reported case and 29 February 2020. The DCI was greatest in China (1320.85), followed by the Republic of Korea (78.78), Iran (43.11), Italy (30.62), Bahrain (9.50), Kuwait (9.00) and Japan (5.11). The DCI in other countries/SARs was  $<4$  per day.

### 3.1. China

China has the highest number of COVID-19 cases in the world ( $n = 79\,251$ ), with an incidence of 55.06 per 1 000 000 people. Among these cases, 2835 patients died, with an overall mortality rate of 3.58%. Despite the increasing trend of daily new cases in the early stage, the trend of daily new cases appeared to decline with time since late February 2020. Moreover, the number of daily new cases in China has been lower than outside of China since 26 February 2020. According to the Chinese Center for Disease Control and Prevention [5], 81% of patients with COVID-19 had a mild case and 87% were aged 30–79 years. In addition, 3.8% of those with COVID-19 were healthcare personnel. The case fatality rate was higher in those with critical cases (49%) and patients aged  $\geq 80$  years (14.8%) [5].

### 3.2. International conveyance (Diamond Princess)

Until the end of February 2020, 705 of the 3700 passengers on the Diamond Princess cruise ship had confirmed COVID-19 and 6 died, with a mortality rate of 0.85%. The basic reproduction rate ( $R_0$ ) was initially four times higher on-board than the  $R_0$  in Wuhan. However, implementation of isolation and quarantine procedures helped to prevent the spread of COVID-19 in more than 2000 passengers and lowered the  $R_0$  to 1.78 [6]. Although the experience of this cruise ship provided a good model for understanding the behaviour of COVID-19 spread, the spread of disease could have been prevented if all passengers and crew were evacuated early.

### 3.3. Countries/territories with more than 100 cumulative cases

In addition to China, four countries (Republic of Korea, Japan, Italy and Iran) had  $\geq 100$  COVID-19 cases. Besides Japan, which showed slowly increasing cases, the other three countries had a rapid increase in COVID-19 incidence since late February (Fig. 2A).

Among these four countries, Iran had the highest mortality ( $n = 34$ ), with a mortality rate of 8.76%. Although these countries had more COVID-19 cases than other sites except China, the number of cases appeared to increase with time.

3.4. Countries/territories with 10–99 cumulative cases

Five countries/territories had 50–99 cumulative cases, including Hong Kong SAR, Singapore, USA, Germany and France. Al-

though the first COVID-19 case reported in these five sites occurred in late January 2020, the number of cases continued to increase at the end of February (Fig. 2B). Seven countries had 20–49 cumulative cases, including Taiwan, Australia, Malaysia, the UK, Spain, Bahrain and Kuwait. Except the five countries whose first cases were reported in late January 2020, the first COVID-19 cases in Bahrain and Kuwait were reported on 25 February and 29 February 2020, respectively (Fig. 2C). Six countries/territories had 10–19 cumulative cases, including Switzerland,

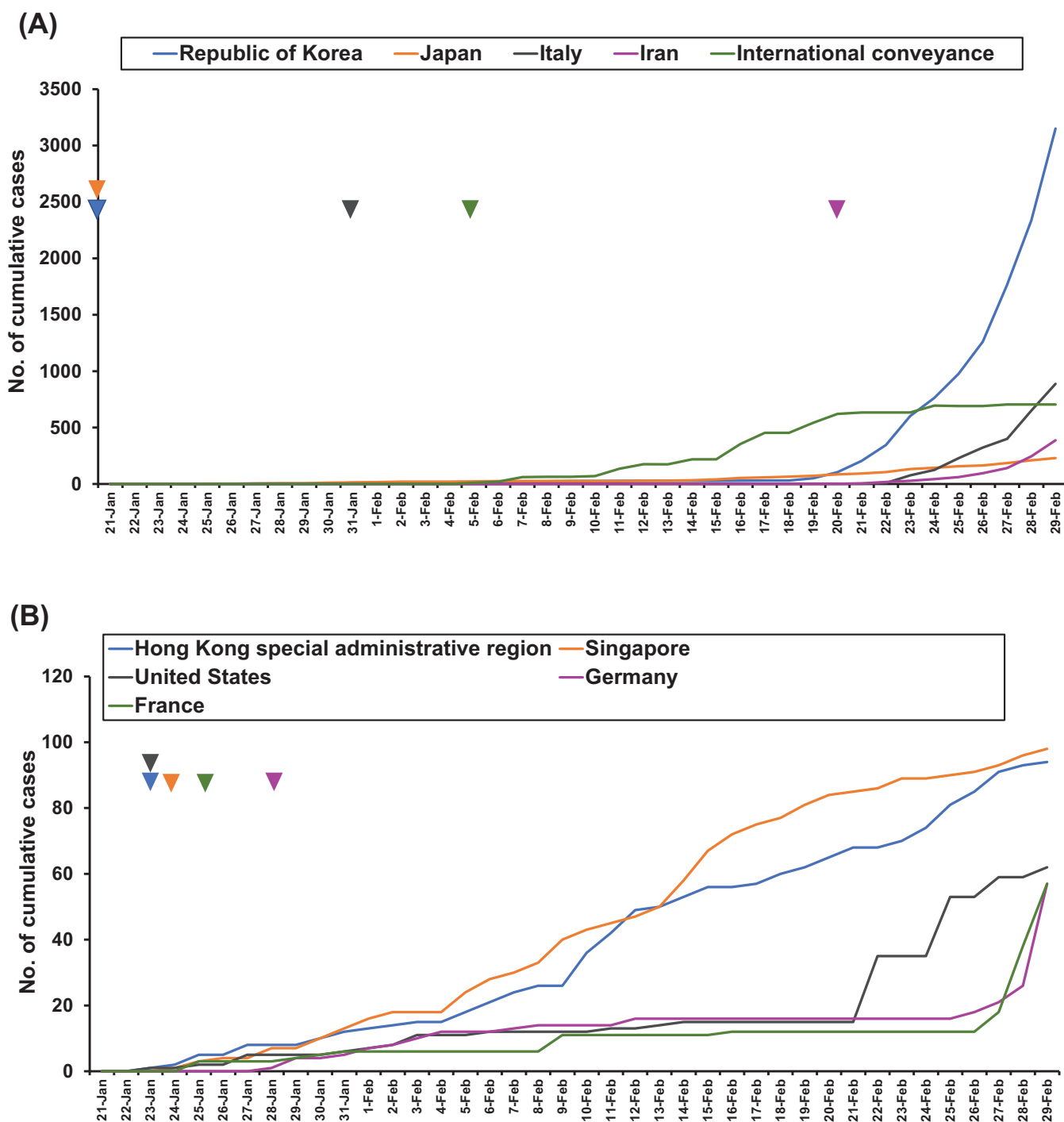


Fig. 2. Daily cumulative case number of patients with coronavirus disease 2019 (COVID-19) in four different categories of countries according to number of reported cases as of 29 February 2020: (A)  $\geq 100$  reported cases; (B) 50–99 reported cases; (C) 20–49 reported cases; and (D) 10–19 reported cases. Inverted triangles with different colours denote the date of the first reported case in each indicated country.

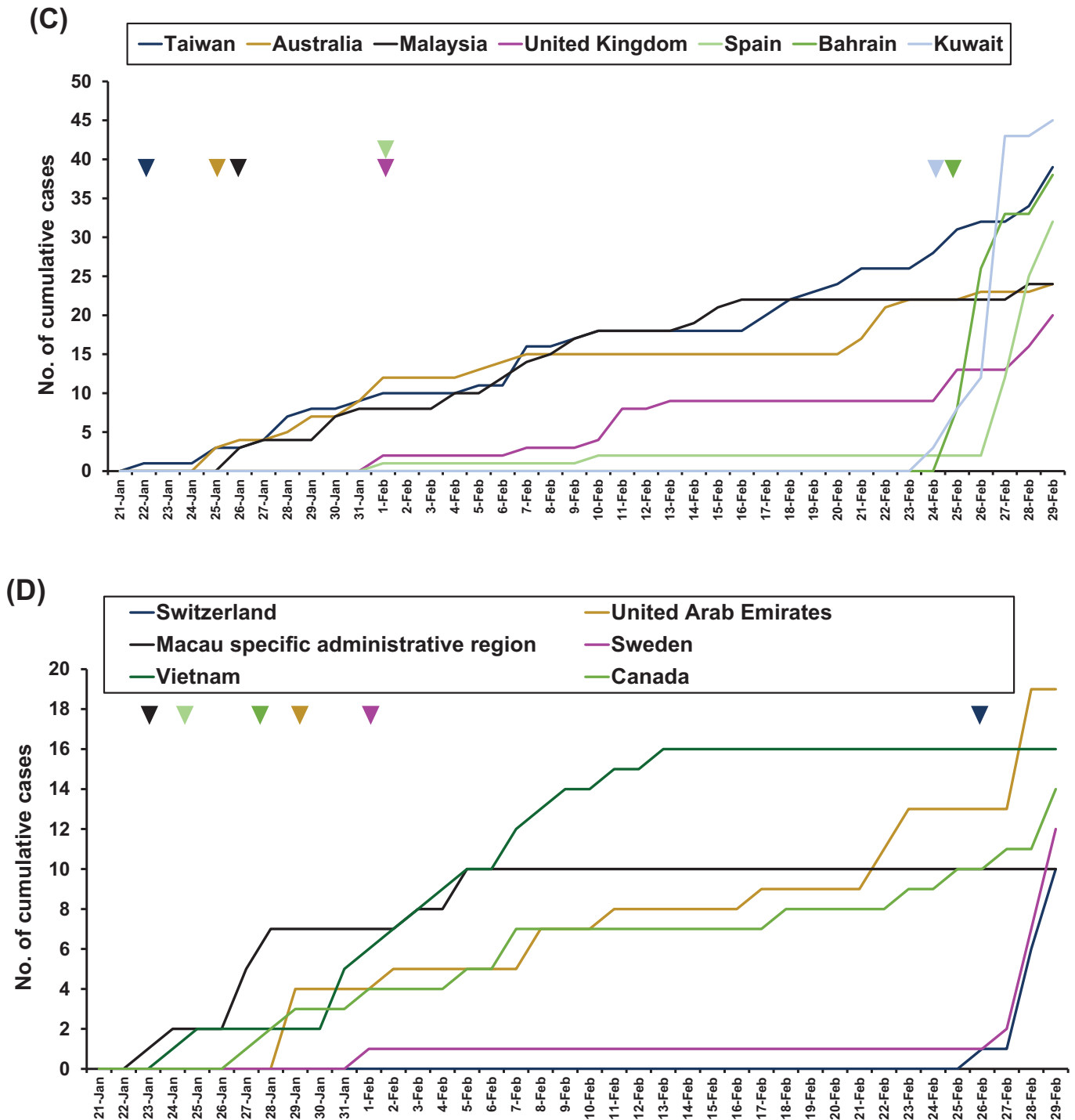


Fig. 2. Continued

United Arab Emirates, Macau SAR, Sweden, Vietnam and Canada. Except Switzerland, all of the other five reported the first cases before February (Fig. 2D). In addition, no new cases were reported in Macau SAR and Vietnam for 25 days and 16 days, respectively.

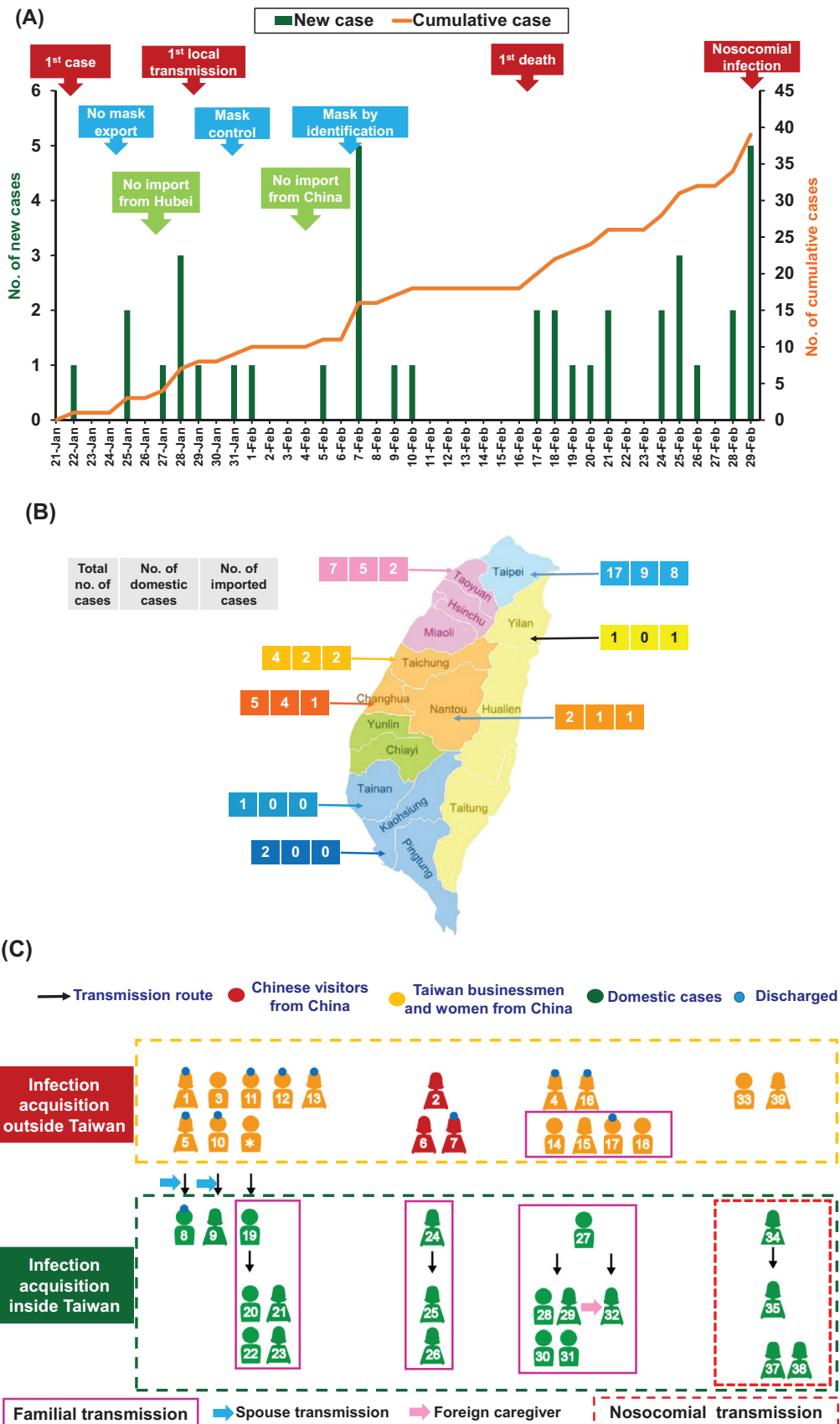
3.5. Countries/territories with a stable number of COVID-19 cases

Ten of fifty-seven countries/regions had stable numbers of COVID-19 cases for  $\geq 15$  days, including Nepal, Cambodia, Sri Lanka, Russian Federation, India, Macau SAR, the Philippines, Belgium,

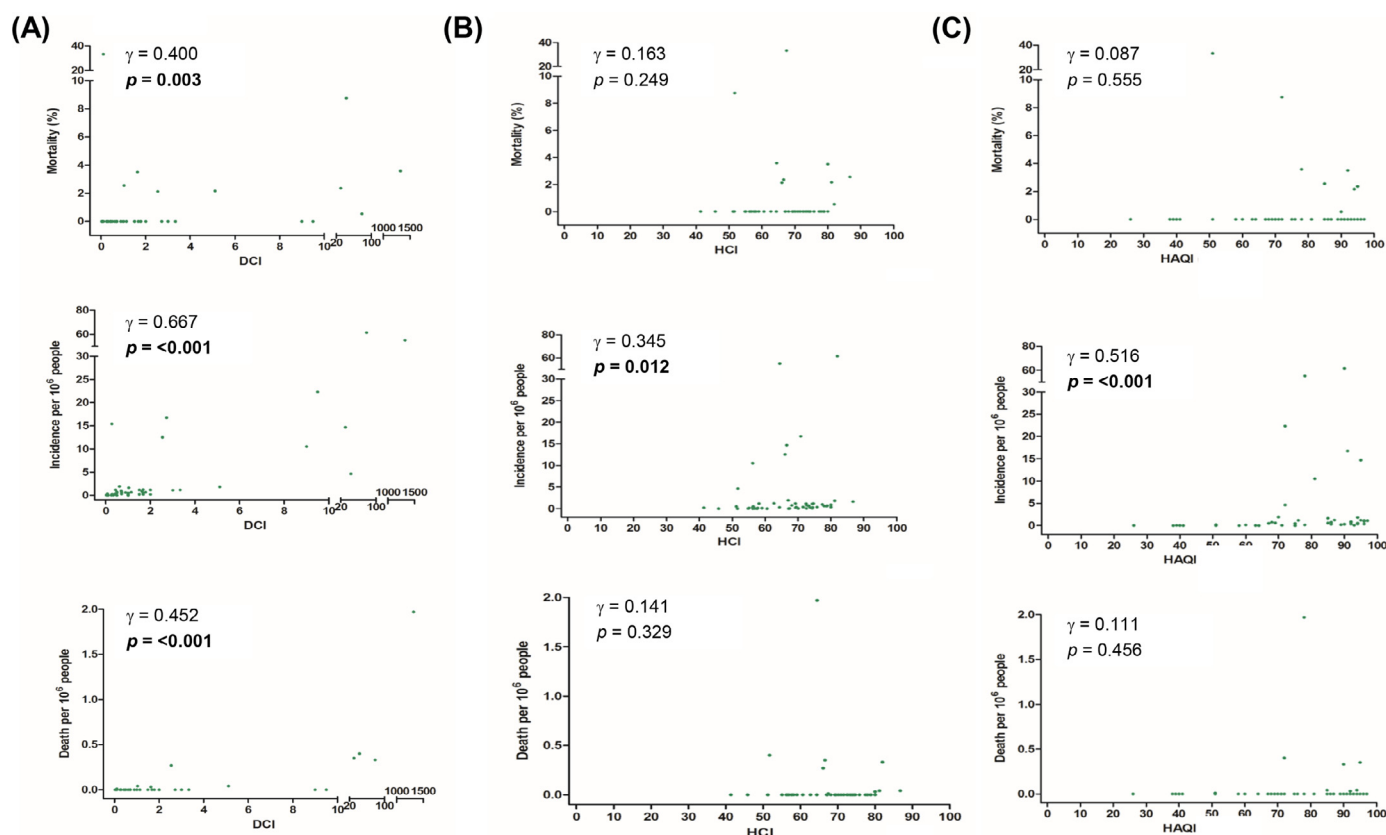
Vietnam and Egypt. The days since last reported case was highest for Nepal ( $n = 47$ ), followed by Sri Lanka ( $n = 33$ ) and Cambodia ( $n = 26$ ). Except Vietnam and Macau SAR (which had 16 and 10 COVID-19 cases, respectively), the other eight countries had a total of  $\leq 3$  cases. In addition to the Philippines, none of them reported any COVID-19-related deaths.

3.6. Taiwan

Taiwan is a country geographically near China and that has a close contact with China, making it more susceptible to COVID-19



**Fig. 3.** (A) Epidemic curve ('epicurve') of the 39 patients with coronavirus disease 2019 (COVID-19) and implementation of primary control measures in Taiwan from 21 January to 29 February 2020. (B) Geographical distribution of the 39 patients with COVID-19 and (C) the possible modes of transmission [https://www.cna.com.tw/news/ahel/202003010211.aspx; accessed 2 March 2020]. \* Taiwanese businesswoman returning from China who had negative real-time RT-PCR for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in the respiratory tract but positive anti-SARS-CoV-2 antibody in the serum.



**Fig. 4.** Incidence (per 1 000 000 population), mortality rate (%) and deaths per 1 000 000 population of patients with coronavirus disease 2019 (COVID-19) and their association (Spearman's rank-order correlation) with (A) daily cumulative index (DCI), (B) Health Care Index (HCI) and (C) Healthcare Access Quality Index (HAQI) by country.

spread. To manage this challenge, infection control measures including prohibiting travel from China, controlling the distribution of face masks, extensive investigation of COVID-19 spread, and a once-daily press conference by the government to inform and educate people were aggressively conducted in Taiwan (Fig. 3A). Under these interventions, Taiwan has a total of 39 cases with a DCI of 1 case per day, which was much lower than that of the nearby countries such as the Republic of Korea and Japan (Fig. 3B). Among the 39 patients, 18 acquired the COVID-19 infection outside of Taiwan, of whom 3 were Chinese visitors from China, whilst the other 21 developed the infection in Taiwan (<http://midss.cdc.gov.tw/ch/SingleDisease.aspx?dc=1&dt=5&disease=19CoV>). Four familial cluster transmissions and one nosocomial transmission were reported. To date, 11 patients were discharged (Fig. 3C). Several important actions and responses conducted by the National Health Command Center of Taiwan, including border control, resource re-allocation, case identification (using new data and technology), quarantine of suspicious cases using big data analytics, reassurance and education of the public, mask control and hand hygiene, and formulation of policies toward schools and childcare, have so far successfully alleviated the crisis and contained the epidemic in Taiwan [7].

#### 4. Association between mortality and disease incidence

Based on the earlier experience in China, Ji et al. found a significant correlation between mortality and healthcare resource availability ( $r = 0.61$ ) [8]. We wonder whether the association between mortality and healthcare burden can be demonstrated outside of China and whether there are other confounding factors, such as the level of health care. Therefore, we used two indexes to represent the level of healthcare: Health Care Index (HCI) [9] and

**Table 2**

Disease incidence (per 1 000 000 population), mortality rate (%) and deaths per 1 000 000 population of patients with coronavirus disease 2019 (COVID-19) and their association with daily cumulative index (DCI)<sup>a</sup>, Health Care Index (HCI) and Healthcare Access Quality Index (HAQI) by country according to transmission route

	Countries with local transmission		Countries with imported cases only	
	<i>r</i>	<i>P</i> -value	<i>r</i>	<i>P</i> -value
Disease incidence (per 1 000 000 population)				
DCI	0.737	<b>&lt;0.001</b>	0.524	<b>0.001</b>
HCI	-0.050	0.835	0.384	<b>0.030</b>
HAQI	0.307	0.201	0.628	<b>&lt;0.001</b>
Mortality rate (%)				
DCI	0.642	<b>0.002</b>	-0.171	0.327
HCI	0.000	1.000	0.010	0.958
HAQI	0.161	0.510	-0.215	0.263
Deaths (per 1 000 000 population)				
DCI	0.747	<b>&lt;0.001</b>	-0.168	0.351
HCI	-0.073	0.760	-0.011	0.955
HAQI	0.177	0.468	-0.215	0.273

<sup>a</sup> DCI = cumulative cases/no. of days between the first reported case and 29 February 2020).

Healthcare Access and Quality Index (HAQI) [10]. The HCI is based on surveys from visitors of one open website and questions for these surveys are similar to many similar scientific and government surveys [9]. The HAQI uses 32 scaled cause values, providing an overall score of 0–100 of personal healthcare access and quality by location over time [10]. First, we found that the mortality rate, incidence and death per 1 000 000 people were correlated with the DCI (Spearman's rank-order correlation, all  $P < 0.05$ ) (Fig. 4A) and this association was more prominent in countries with local transmission (Table 2). This finding is consistent with the findings of Ji et al. [8] and suggests that rapidly increasing cases in

a short time can result in more cases and even more deaths. Second, the incidence was associated with life expectancy ( $r = 0.613$ ,  $P < 0.001$ ). This could be because countries with more older adults were more likely to acquire COVID-19. Finally, the incidence was found to be correlated with both HAQI ( $r = 0.516$ ,  $P < 0.001$ ) and HCI ( $r = 0.345$ ,  $P < 0.012$ ), but mortality and deaths per 1 000 000 people were not associated with the level of health care (Fig. 4B,C). This finding may be explained by the fact that countries with more advanced healthcare systems have better diagnostic ability to identify more cases. By contrast, no death cases were reported in most countries; thus, no significant correlation could be found. However, further study is warranted to clarify these findings.

## 5. Conclusion

Between 31 December 2019 and 29 February 2020, COVID-19 has affected more than 80 000 patients in 57 countries/territories and caused 2924 deaths in 9 countries. Although China had higher morbidity and mortality rates than other sites, the number of daily new cases has been lower in China than outside of China since 26 February 2020. Seven countries had a DCI of  $>5$  cases per day, but the DCI of the other fifty countries/territories was  $<4$  cases per day. The incidence and mortality rates were correlated with DCI, especially in countries with local transmission. Overall, this preliminary report shows us the initial epidemiological findings of COVID-19, but continuous monitoring of patients with this disease is still warranted.

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**Competing interests:** None declared.

**Ethical approval:** Not required.

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