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Epidemiology of imported infectious diseases, China, 2014–18

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Abstract

Background: The frequent movement of population between countries brings an increasing number of travel-related infections. This study aims to define the spectrum and dynamics of imported infections observed from international travel in the Chinese mainland.

Methods: Sick travellers were screened by inbound sentinel surveillance and post-travel clinic visits from 2014 to 18. The infections were classified as respiratory, gastrointestinal, vector-borne, blood/sexually transmitted and mucocutaneous. The analysed variables included the place of origin of the travellers (Chinese or foreign) and the time when travel-related infection was present (at the time of return, during travel and post-travel visits to the clinic).

Results: In total, 58 677 cases were identified amongst 1 409 265 253 travellers, with an incidence of 41.64/million, comprising during-travel incidence of 27.44/million and a post-travel incidence of 14.20/million. Respiratory infections constituted the highest proportion of illnesses during travel (81.19%, 31 393 of 38 667), which mainly came from Asian countries and tourists; with influenza virus and rhinovirus infections being mainly diagnosed. Vector-borne diseases constituted the highest proportion of post-travel illnesses (98.14%, 19 638 of 20 010), which were mainly diagnosed from African countries and labourers; with malaria and dengue fever being mainly diagnosed. The differential infection spectrum varied in terms of the traveller's demography, travel destination and travel purpose. As such, a higher proportion of foreign travellers had blood/sexually transmitted diseases (89.85%, 2832 of 3152), while Chinese citizens had a higher prevalence of vector-borne diseases (85.98%, 19 247 of 22 387) and gastrointestinal diseases (79.36%, 1115 of 1405). The highest incidence rate was observed amongst travellers arriving from Africa, while the lowest was observed amongst travellers arriving from Europe.

Conclusions: The findings might help in preparing recommendations for travellers and also aid in primary care or other clinics that prepare travellers before trips abroad. The findings will also help to identify locations and the associated types of infections that might require attention.

Key words: Travel, malaria, dengue, influenza, COVID-19, yellow fever, HIV

Background

The global population moves frequently in an increasingly globalized world, with international tourist arrivals reaching 1.4 billion in 2018.[1] But with increasing international travel, the number of travellers falling ill during or after travel has also increased,[2–4] particularly with travel to tropical regions and low-income countries that are associated with a high risk of acute illnesses and hospitalization.[5–9]

Surveillance, risk assessment and travel advisories are of strategic importance to prevent the introduction and further indigenous spread of imported infectious diseases.[2–10] Over the past three decades, several large-scale studies have evaluated health issues encountered during and after travel.[2–5] A survey of US travellers found that 38% of 9624 imported infectious diseases were to be found in tourists, while 45% sought pre-travel advice and 7% required hospitalization.[11] Several studies based on GeoSentinel, a worldwide network of specialized tropical and travel medicine clinics, reported the most commonly encountered disorders to be gastrointestinal, systemic febrile illness, dermatologic and respiratory problems.[3,7,9] The travel destination could greatly affect infection types, e.g. the most common and specific diagnosis amongst travellers arriving from West Africa was malaria (310 of 770, 40.3%),[12] while travellers to northern Africa commonly reported gastrointestinal illnesses.[13]

China was not a participating member of GeoSentinel, and most of the travel-related disease data were derived from screening at international entry-exit ports. A surveillance study on international travellers who had fallen ill was undertaken by both customs screening and post-travel clinic visits. We, thus, sought to describe the spectrum of imported infection through international travel, to assess the changing pattern of the infection spectrum and its impacting factors.

Methods

Data collection

Sick travellers were screened by inbound sentinel surveillance and post-travel clinic visits from 2014 to 18. Illness during travel data were obtained from the entry–exit sentinel network of customs,[14] and post-travel illness data were obtained from the National Notifiable Infectious Disease Reporting System (NNIDRS) of the Chinese CDC[15] (Figures S1–S4, Tables S1–S4 available as Supplementary data at *JTM* online). The analysed variables included the origin of travellers (Chinese or foreign) and the time when travel-related infection was present (at the time of return as during travel and post-travel visits to the clinic). The infections were classified as respiratory, gastrointestinal, vector-borne, blood/sexually transmitted and mucocutaneous (detailed in Supplemental Materials and Methods).

Data usage and statistical analysis

All the data were extracted from two anonymous, delinked databases and underwent data sorting and redundant clearance (Figure S5 available as Supplementary data at *JTM* online). Diseases with long incubation periods, e.g. hepatitis B virus, hepatitis C virus and tuberculosis, were excluded from the analysis because of the uncertainty regarding the infection of individuals was at home or abroad (Table S5). The five syndromic diseases (respiratory, gastrointestinal, vector-borne, blood/sexually transmitted and mucocutaneous diseases) were defined using the same criteria as previously described.[16]

Descriptive statistics were used for all variables. Continuous variables were summarized as medians and ranges. Proportions were calculated regarding various disease categories. Incidence rates were calculated as the case number divided by the total number of arriving passengers. The chi-square test was used to assess the difference in proportions amongst subgroups.

Results

Demographic characteristics of the recruited patients

During 2014–18, a total of 58 851 travel-related episodes were recorded amongst 1 409 265 253 arrivals, including 38 667 sick travellers with a single infection and 174 with co-infection (Figure S6 available as Supplementary data at *JTM* online), screened at 272 international entry-exit ports and 20 010 records were extracted from the NNIDRS. Altogether, 58 677 single infections were used in the final analysis, corresponding to an overall incidence rate of 41.64 per million, comprising 27.44 per million during-travel infections and 14.20 per million post-travel infections (Table 1). The patients with during-travel infection were younger and had a lower proportion of males than the patients with post-travel infection (both $P < 0.0001$). The frequency of Chinese travellers who had been to Asian and African destinations and who had vector-borne diseases was higher in post travel than in during travel ($P < 0.0001$) (Table 1). Additionally, there was no significant difference in gender proportion between Chinese and non-Chinese travellers, but the non-Chinese travellers were slightly younger ($P < 0.0001$) (Table S6). Asia was the most preferred destination continent, and respiratory infection was the most common disease type in both Chinese citizens and non-Chinese travellers (Table S6).

The infection spectrum of imported illnesses

For during-travel illnesses, respiratory infection was the most common (81.19%, 31 393 of 38 667), significantly higher than blood/sexually transmitted diseases and vector-borne diseases (Table 1). The highest number of cases were found amongst travellers returning from travel to Asian countries, followed by travellers from the countries of Europe, Africa, North America, Oceania and South America. Sick travellers returning from Africa had a significantly higher frequency of vector-borne diseases compared with travellers from the other continents (Figure 1A and B).

As regards post-travel illnesses, vector-borne diseases were the most commonly observed (98.14%, 19 638 of 20 010), followed by blood/sexually transmitted diseases and respiratory,

Table 1. The characteristics of imported cases during and post travel in Chinese mainland, 2014–18

	Overall ($n = 58\,677$)	Cases during travel ($n = 38\,667$)	Cases post travel ($n = 20\,010$)
Sex			
Male	42 621 (72.64)	25 751 (66.60)	16 870 (84.31)
Female	16 056 (27.36)	12 916 (33.40)	3140 (15.69)
Age, years (median, IQR)	34 (24–46)	32 (21–46)	38 (29–46)
≤9	6547 (11.16)	6144 (15.89)	403 (2.02)
10–19	3423 (5.83)	2677 (6.92)	746 (3.73)
20–29	12 649 (21.56)	8191 (21.18)	4458 (22.28)
30–39	13 115 (22.35)	7890 (20.41)	5225 (26.11)
40–49	12 109 (20.63)	6007 (15.54)	6102 (30.49)
50–59	6945 (11.84)	4371 (11.3)	2574 (12.86)
≥60	3889 (6.63)	3387 (8.76)	502 (2.51)
Citizenship			
Chinese mainland	44 294 (75.49)	26 976 (69.76)	17 318 (86.55)
Foreigner	13 528 (23.05)	10 849 (28.06)	2679 (13.39)
Hong Kong, Macau, or Taiwan of China	855 (1.46)	842 (2.18)	13 (0.06)
Destination continent			
Africa	13 340 (22.74)	1505 (3.89)	11 835 (59.15)
Asia	27 701 (47.21)	20 139 (52.08)	7562 (37.79)
Europe	1804 (3.07)	1785 (4.61)	19 (0.09)
North America	1165 (1.99)	1128 (2.92)	37 (0.19)
Oceania	1132 (1.93)	1024 (2.65)	108 (0.54)
South America	190 (0.32)	122 (0.32)	68 (0.34)
Unknown	13 345 (22.74)	12 964 (33.53)	381 (1.90)
Disease type			
Respiratory	31 460 (53.62)	31 393 (81.19)	67 (0.34)
Gastrointestinal	1405 (2.39)	1340 (3.46)	65 (0.33)
Vector-borne	22 387 (38.15)	2749 (7.11)	19 638 (98.14)
Blood/sexually transmitted	3152 (5.37)	2937 (7.6)	215 (1.07)
Mucocutaneous	273 (0.47)	248 (0.64)	25 (0.12)
Number of infections			
2014	5261 (8.97)	1902 (4.92)	3359 (16.79)
2015	8540 (14.55)	4427 (11.45)	4113 (20.55)
2016	10 157 (17.31)	6277 (16.23)	3880 (19.39)
2017	20 019 (34.12)	15 196 (39.3)	4823 (24.10)
2018	14 700 (25.05)	10 865 (28.1)	3835 (19.17)

gastrointestinal and mucocutaneous diseases (Table 1). The highest number of infections was recorded in travellers from African countries (59.15%), followed by travellers from Asian countries (37.79%). Sick travellers from Europe and North America had a significantly higher frequency of blood/sexually transmitted diseases than those from the other continents (Figure 1C and D).

Characteristics of travellers with various types of infection

The during-travel and post-travel infections were compared to explore the characteristics that differed amongst various infection types (Table S7). A significantly higher proportion of males (84.36%), older in age (median: 38, IQR: 28–46), and a higher frequency amongst those travelling to Africa (58.42%) were observed in the patients with vector-borne diseases. A significantly higher proportion of foreign travellers were observed in blood/sexually transmitted diseases, while a higher proportion of Chinese citizens were observed as having vector-borne diseases and gastrointestinal diseases. Gastrointestinal diseases were also most frequently seen amongst travellers returning from Asian countries. Travel purpose also had an impact on the disease spectrum. With regard to during-travel illnesses, respiratory illnesses were more likely to occur in tourists, while vector-borne diseases were more likely to occur in labourers for both during-travel illnesses (Table S8) and post-travel illnesses (Table S9).

The aetiological diagnosis of imported infection

In total, 58 677 patients were diagnosed with 67 specific agents (Table S10), including 38 667 during-travel patients who were diagnosed with 52 agents and 20 010 post-travel patients diagnosed with 37 agents (Figure 2).

For the during-travel illnesses, 7 aetiological agents with an incidence >0.5/1 million travellers were determined, namely influenza, dengue fever, HIV infection, syphilis, rhinovirus infection, norovirus infection and malaria, collectively accounting for 93.27% of the total diagnoses (Figure 2A). Amongst the post-travel illnesses, three agents were diagnosed with an incidence >0.1/1 million travellers, namely malaria, dengue fever and HIV

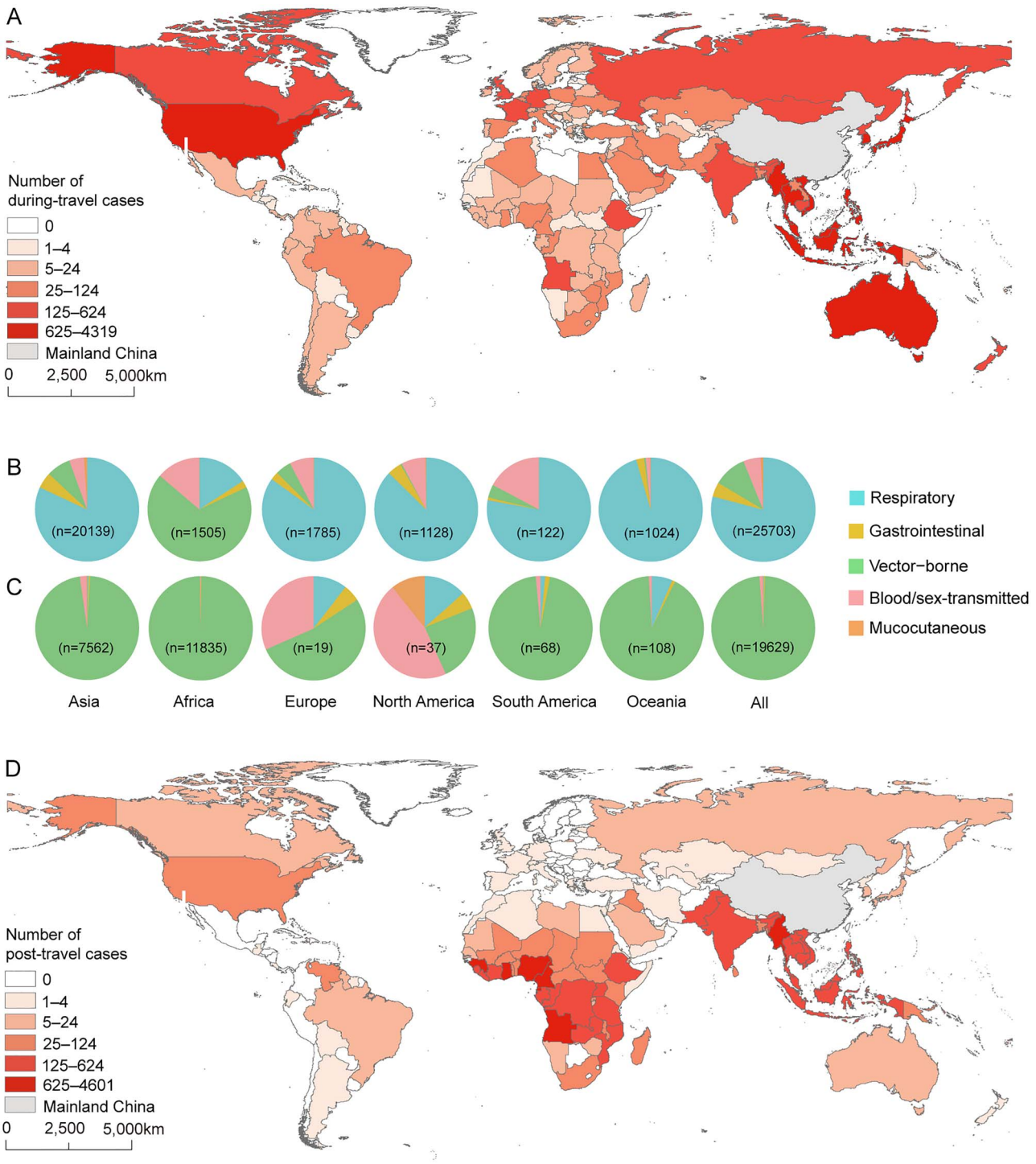

Figure 1. The case number and disease spectrum of during-travel infection (A, B) and post-travel infection (C, D) in relation to the original countries/continents, 2014–18

infection, which collectively accounted for 98.30% of the total diagnoses (Figure 2B).

The baseline characteristics differed amongst travellers with specific aetiological diagnoses. A significantly higher proportion of males was observed for all of the infections except for several gastrointestinal infections (Figure 2C). Adenovirus, rotavirus and enterovirus infections were associated with significantly lower age (Figure 2D). Vector-borne infections, including malaria, Zika, schistosomiasis, loiasis, yellow fever and haemorrhagic fever, were more frequently diagnosed in those travelling to or from African countries (Figure 2E). The most frequent diagnoses amongst travellers of Chinese citizenship were influenza and malaria, followed by dengue virus, rhinovirus and norovirus infections (total 94.86%, 42 828 of 45 149). Compared to Chinese travellers, foreign travellers were more frequently diagnosed with HIV infection, *Neisseria*

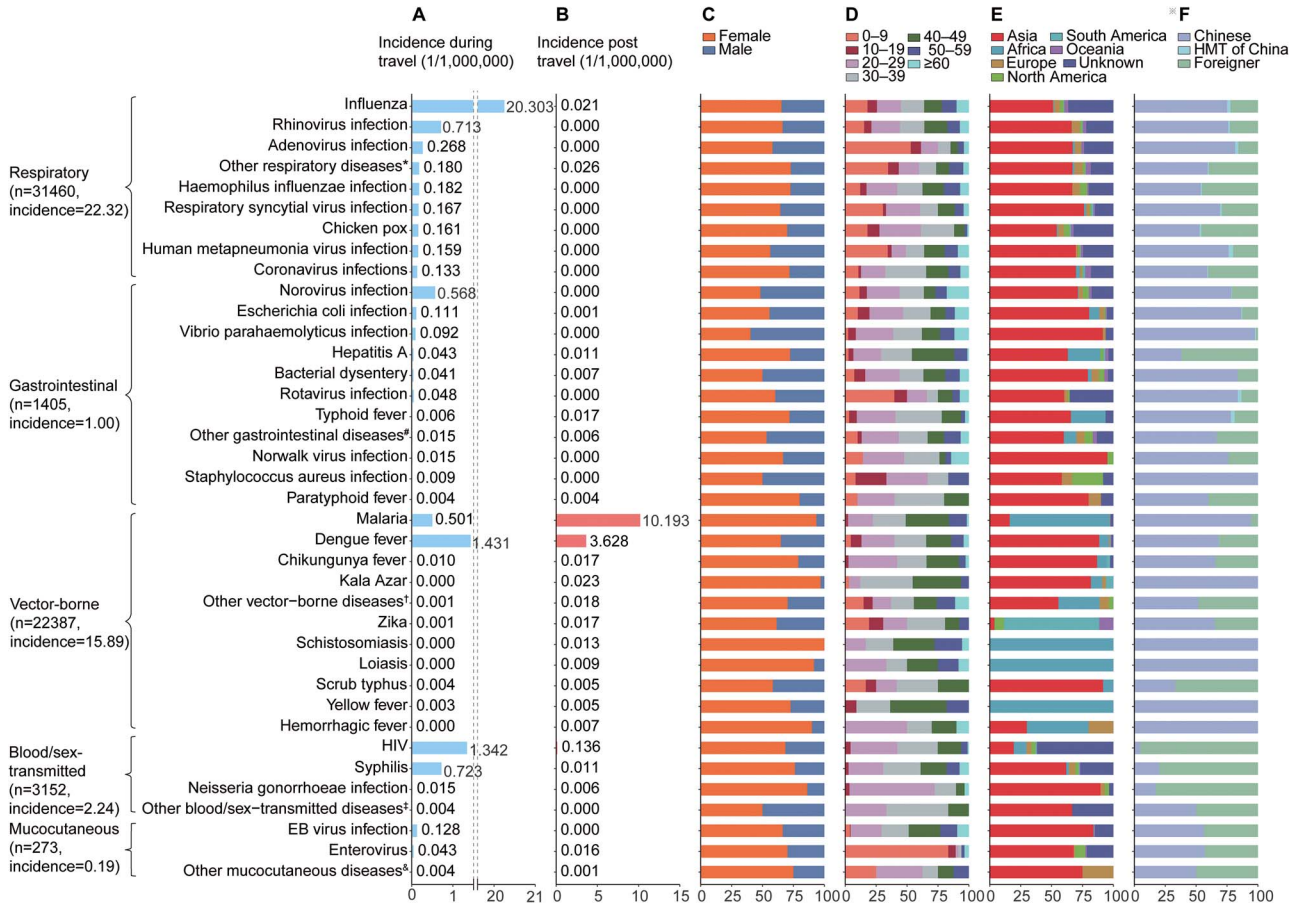

Figure 2. The incidence of 67 imported infectious diseases according to during-travel infection (A), post-travel infection (B), sex (C), age (D), destination continent (E) and citizenship (F). The incidence rate was expressed as the case number/1 million travellers. Other respiratory diseases: parainfluenza virus infection, pneumococcal infection, measles, epidemic mumps, *Mycoplasma pneumoniae* infection, *Legionella* disease, streptococcal infection, Boca virus infection, rubella, scarlet fever, *Chlamydia pneumoniae* infection, pertussis, infectious atypical pneumonia, Middle East respiratory syndrome and *Streptococcus pneumoniae* infection. Other gastrointestinal diseases: hepatitis E, amebic dysentery, cholera, Proteus infection, astrovirus infection, pin worm disease. Other vector-borne diseases: encephalitis B, brucellosis, rabies, epidemic and endemic typhus, trypanosomiasis, echinococcosis, clonorchiasis, *acute Toxoplasma gondii* infection, Rift Valley fever, forest encephalitis. Other blood/sex-transmitted diseases: *Chlamydia* infection of the genitourinary tract, trichomoniasis. Other mucocutaneous diseases: trachoma, neonatal tetanus. Chinese: Chinese citizen from the mainland of China; HMT: Chinese citizen from the Hong Kong, Macau or Taiwan regions of China; Foreigner: Non-Chinese citizenship

gonorrhoeae infection, syphilis, scrub typhus and hepatitis A infection (Figure 2F).

Annual trends and the seasonal pattern of imported infection

The analysis based on the annual number of cases and incidence rate revealed a similar temporal trend between the post-travel and during-travel illnesses, both increasing from 2014 to a peak level in 2017, with a slight reduction in 2018 (Table 1 and Figure 3). When the five disease types were separately analysed, all their incidence rates showed an increasing trend from 2014 to 18, particularly with a sharp increase for respiratory illnesses in 2017 (Figure 3A). Influenza virus infection was responsible for a major part of the increased incidence of respiratory illnesses (Figure 3B). The incidence of gastrointestinal diseases increased from 2014 to 18, mainly due to the increase in patients with norovirus, *Escherichia coli*, *Vibrio parahaemolyticus*, and rotavirus infections and bacterial dysentery (Figure 3C).

A slight increase in the incidence of vector-borne diseases was also observed in 2017, mainly due to the dengue virus and chikungunya virus infections; in contrast, malaria displayed a decreasing trend throughout the surveillance years. Zika and yellow fever peaked, notably in 2016, with incidences of 0.085 and 0.039 per 1 million respectively (Figure 3D). Although the general incidence of blood/sexually transmitted diseases remained at a comparable level across the surveillance years, HIV infection displayed a rapid increase during the study period (Figure 3E). Amongst all the mucocutaneous diseases, only the Epstein–Barr (EB) virus infection demonstrated an elevated incidence in 2017, while all the others changed steadily (Figure 3F).

The originating countries of imported infections

The major originating areas of imported diseases differed amongst the infection types (Figure S7 available as Supplementary data at *JTM* online). Although respiratory infections were widely imported from six continents, a dramatically high number

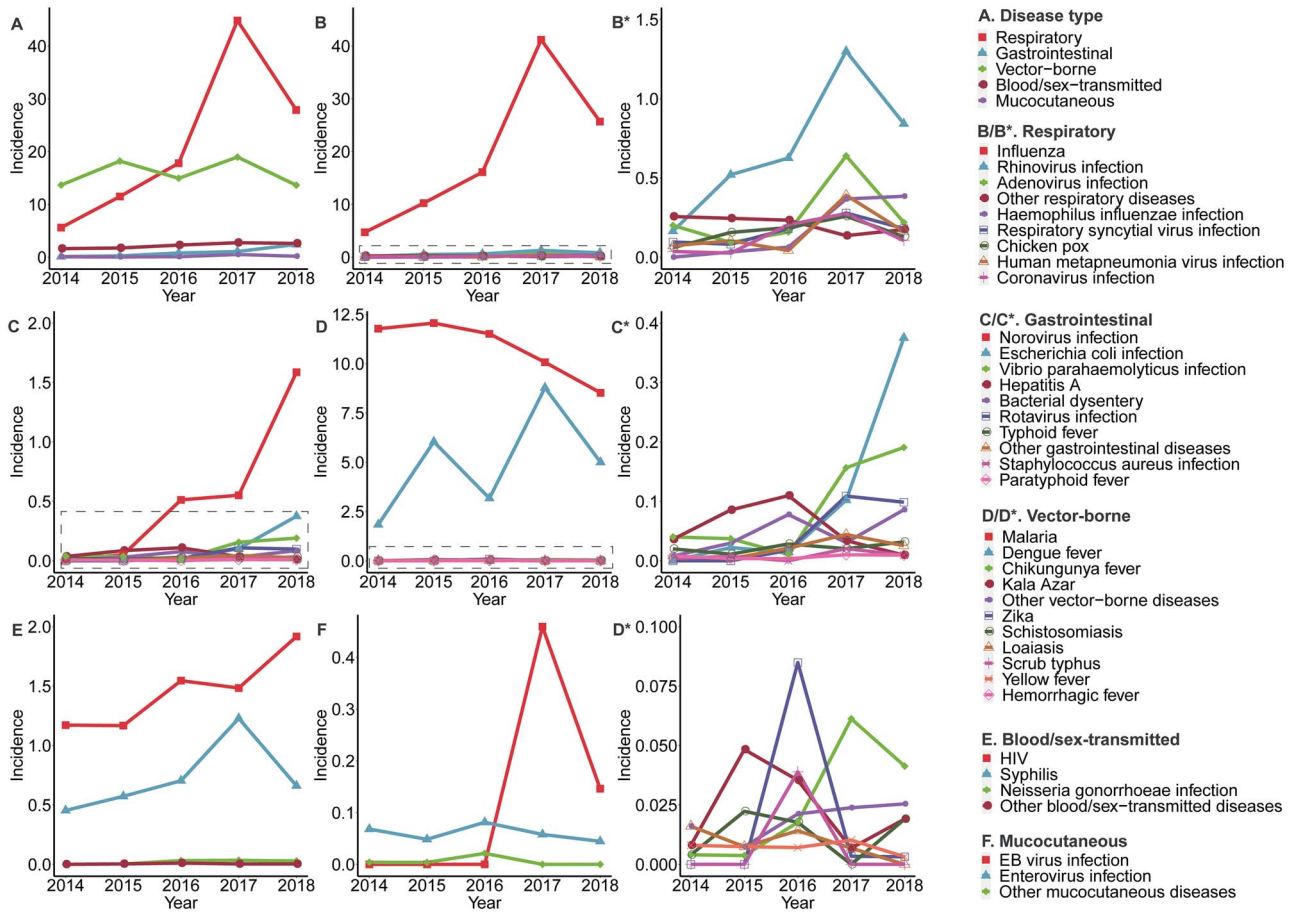

Figure 3. The temporal dynamics of travel-related illnesses in Chinese mainland, 2014–18. Five types of infectious diseases (A), respiratory diseases (B), gastrointestinal diseases (C), vector-borne diseases (D), blood/sex-transmitted diseases (E) and mucocutaneous diseases (F). The incidence was calculated as case number/1 million travellers. B*/C*/D* are an extension of the B/C/D graph in the dashed box, respectively

of cases were imported from Asia; imported from 40 Asian countries into 30 Chinese provinces, particularly the coastal or developed provinces (Figure S8A available as Supplementary data at *JTM* online). The influenza virus infection showed characteristics similar to those of respiratory diseases as a whole (Figure S9 available as Supplementary data at *JTM* online). Gastrointestinal diseases were mainly imported from Asian and African countries to Shanghai, Guangdong, Zhejiang and other provinces; provinces similar in characteristics to those that suffered from respiratory infections (Figure S8B available as Supplementary data at *JTM* online). The majority of the vector-borne diseases were imported from Africa and Asia; specifically imported from Asian countries to the Yunnan and Guangdong provinces, and from African countries to the Henan, Shandong, Jiangsu, Sichuan and Guangxi provinces (Figure S8C available as Supplementary data at *JTM* online). Two of the most frequently occurring diseases—malaria, mainly originating from Africa, and dengue, mainly originating from Southeast Asia—were imported to most provinces in the Chinese mainland (Figure S9 available as Supplementary data at *JTM* online). The blood/sexually transmitted diseases were mainly imported from Southeast Asia to Yunnan and from Mongolia and Russia to Inner Mongolia, which could be attributed to their close borders and resultant frequent human movement (Figure S8D available as Supplementary data at *JTM* online). Mucocutaneous diseases were mainly imported from Asian countries into the coastal provinces of the Chinese mainland (Figure S8E available as Supplementary data at *JTM* online).

We further calculated the incidence rate of imported infection, with the total number of arriving passengers as the denominator. When all these infections were added, the highest incidence rate was observed in travellers returning to the Anhui province, followed by the Qinghai and Gansu provinces (Figure S10 available as Supplementary data at *JTM* online). For the during-travel infections, the highest incidence rate was observed amongst travellers returning to the Qinghai Province, followed by the Jiangsu, Zhejiang, Liaoning, Henan and Hunan provinces (each having an incidence rate > 100/1 million). For post-travel infections, the highest incidence rate was observed amongst travellers returning to the Anhui province, followed by the Gansu, Hebei, Henan, Jiangxi, Hunan, Jiangsu, Sichuan, Hubei and Guizhou provinces (each having an incidence rate > 100/1 million) (Figure S11 available as Supplementary data at *JTM* online).

Table 2. The case number and incidence rate (one case per million persons) of predominant imported infectious diseases amongst non-Chinese citizenship arrivals from each continent and selected countries, 2014–18

	Overall	Influenza	Dengue	HIV	Malaria	Syphilis	Rhinovirus	Norovirus
Overall [a]	13 528 (96.48)	6353 (45.31)	2250 (16.05)	1979 (14.11)	835 (5.96)	826 (5.89)	228 (1.63)	173 (1.23)
Asia	8417 (95.53)	4105 (46.59)	2173 (24.66)	345 (3.92)	343 (3.89)	508 (5.77)	158 (1.79)	101 (1.15)
North Korea	236 (241.38)	84 (85.92)	0 (0.00)	0 (0.00)	0 (0.00)	5 (5.11)	37 (37.84)	0 (0.00)
India	325 (82.80)	173 (44.07)	52 (13.25)	4 (1.02)	23 (5.86)	5 (1.27)	6 (1.53)	23 (5.86)
Indonesia	262 (83.43)	175 (55.72)	33 (10.51)	11 (3.50)	4 (1.27)	3 (0.96)	8 (2.55)	1 (0.32)
Japan	853 (64.72)	672 (50.99)	3 (0.23)	9 (0.68)	1 (0.08)	13 (0.99)	20 (1.52)	32 (2.43)
Malaysia	461 (78.19)	353 (59.88)	52 (8.82)	10 (1.70)	1 (0.17)	6 (1.02)	7 (1.19)	4 (0.68)
Mongolia	317 (45.05)	6 (0.85)	0 (0.00)	0 (0.00)	0 (0.00)	310 (44.05)	0 (0.00)	0 (0.00)
Philippines	494 (90.14)	377 (68.79)	27 (4.93)	14 (2.55)	1 (0.18)	9 (1.64)	18 (3.28)	9 (1.64)
Singapore	421 (89.19)	315 (66.73)	17 (3.60)	13 (2.75)	2 (0.42)	10 (2.12)	14 (2.97)	4 (0.85)
South Korea	1044 (48.65)	855 (39.84)	1 (0.05)	17 (0.79)	0 (0.00)	61 (2.84)	27 (1.26)	2 (0.09)
Thailand	345 (95.35)	230 (63.57)	46 (12.71)	29 (8.02)	3 (0.83)	8 (2.21)	5 (1.38)	9 (2.49)
Africa	823 (268.15)	111 (36.17)	28 (9.12)	193 (62.88)	448 (145.97)	18 (5.86)	1 (0.33)	1 (0.33)
Europe	860 (30.87)	606 (21.75)	16 (0.57)	78 (2.80)	5 (0.18)	49 (1.76)	34 (1.22)	18 (0.65)
Britain	66 (22.15)	39 (13.09)	0 (0.00)	13 (4.36)	0 (0.00)	10 (3.36)	0 (0.00)	3 (1.01)
Germany	63 (19.75)	44 (13.79)	2 (0.63)	7 (2.19)	0 (0.00)	3 (0.94)	0 (0.00)	6 (1.88)
France	65 (25.98)	34 (13.59)	7 (2.80)	10 (4.00)	1 (0.40)	6 (2.40)	0 (0.00)	2 (0.80)
Italy	34 (25.66)	25 (18.87)	0 (0.00)	9 (6.79)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Netherlands	46 (48.31)	33 (34.66)	0 (0.00)	4 (4.20)	0 (0.00)	3 (3.15)	2 (2.10)	1 (1.05)
Portugal	3 (10.98)	2 (7.32)	0 (0.00)	1 (3.66)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Sweden	10 (16.73)	5 (8.37)	0 (0.00)	1 (1.67)	0 (0.00)	2 (3.35)	0 (0.00)	2 (3.35)
Switzerland	8 (21.53)	6 (16.15)	1 (2.69)	0 (0.00)	1 (2.69)	0 (0.00)	0 (0.00)	0 (0.00)
Russia	242 (23.32)	177 (17.06)	2 (0.19)	5 (0.48)	1 (0.10)	7 (0.67)	30 (2.89)	0 (0.00)
Latin America	151 (76.79)	69 (35.09)	8 (4.07)	27 (13.73)	2 (1.02)	7 (3.56)	2 (1.02)	2 (1.02)
North America	634 (42.35)	496 (33.13)	2 (0.13)	57 (3.81)	0 (0.00)	17 (1.14)	12 (0.8)	32 (2.14)
Canada	237 (63.30)	212 (56.62)	0 (0.00)	8 (2.14)	0 (0.00)	4 (1.07)	0 (0.00)	7 (1.87)
The United States	397 (35.36)	284 (25.30)	2 (0.18)	49 (4.36)	0 (0.00)	13 (1.16)	12 (1.07)	25 (2.23)
Oceania	505 (119.75)	431 (102.2)	5 (1.19)	8 (1.90)	5 (1.19)	1 (0.24)	12 (2.85)	17 (4.03)
Australia	363 (104.58)	307 (88.45)	0 (0.00)	7 (2.02)	0 (0.00)	0 (0.00)	12 (3.46)	17 (4.90)
New Zealand	118 (173.84)	112 (165.00)	1 (1.47)	1 (1.47)	0 (0.00)	1 (1.47)	0 (0.00)	0 (0.00)

[a]The travel destination was available for partial patients, so the number of all patients is larger than the sum of six continents

The incidence rate of imported infection for non-Chinese travellers

In total, 13 528 sick travellers of non-Chinese citizenship were recorded, resulting in an incidence rate of 96.48 per million amongst non-Chinese arrivals (Table 2). The highest incidence rate was observed in travellers from Africa (268.15 per million travellers), followed by Oceanian, Asian and Latin American travellers.The travellers from Europe had the lowest incidence rate. The specific infections that were diagnosed with an incidence rate >1 per million travellers included influenza, followed by dengue, HIV, malaria, syphilis, rhinovirus and norovirus. This result was similar to the spectrum when all patients were considered (Figure 2). The incidence of influenza was the highest ranking in almost all originating continents, except in Africa, where malaria (145.97 per million) and HIV (62.88 per million) were the leading infection types.

Discussion

In the current study, and the only one of its kind, we have provided a complete spectrum of imported infectious diseases in the Chinese mainland. By combining data that were obtained from inbound screening and post-travel reports, an overall incidence of 41.64/million was identified amongst 1 409 265 253 travellers. Different spectra were determined between inbound screening and post-travel reports, with respiratory infections and vector-borne diseases most frequently diagnosed amongst illnesses during travel and post-travel, which actually reflected their differences in incubation periods. Our study has also provided an important supplement to a previous study when only the international entry-exit ports from 2014 to 16 were analysed,[16] which accounted for only 38.15% of the total travel-related infection, according to the current results. It was observed that since the travellers who were infected with vector-borne pathogens could

still be in the incubation period when arriving at the entry–exit ports, these travellers/patients could be easily neglected if we were to depend only on inbound custom screening.

Our study reveals that some destinations or travel purposes are more frequently associated with some specific causes. For example, the highest number of cases of respiratory infections was imported from Asian countries and tourists, primarily comprising the influenza virus and rhinovirus infections. The highest number of cases of vector-borne disease was imported from African countries and through labourers, mainly comprising malaria and dengue fever.

Amongst the imported infections, most of the causative pathogens for the respiratory, gastrointestinal, blood/sexually transmitted and mucocutaneous diseases were already epidemic in mainland China, and thus, the imported diseases could be a source of onward transmission, although they could not exert a high impact on the epidemic situation in China. However, for those intensively encountered infections that were preventable by vaccines, such as influenza, an improved approach towards educating the population about risks and prophylaxis needed to be developed.[17]

Malaria remained the leading imported vector-borne disease, which mainly originated from Africa.[18] Malaria has now proved to be a rare diagnosis amongst native Chinese, after the implementation of the 'Action plan of China malaria elimination (2010–2020)' in 2010, with a plan to achieve the goal of malaria elimination by 2020.[19] However, competent vectors for malaria were sustained, along with suitable ecoclimatic conditions in provinces like Yunnan, Zhejiang and Hubei.[20–22] Therefore, imported malaria can still present the likelihood of onward transmission in the local population, once introduced into an environment that is receptive to the sustenance and spread of *Plasmodium*. Dengue is another major vector-borne disease, secondary only to malaria, with the imported disease mainly originating from Southeast Asia.[23] We , however, precisely determine the source of infection of this so-called travel-related dengue, as the indigenous epidemic has been widely reported from Guangdong, Yunnan, Guangxi, Zhejiang, Fujian and other southern provinces in China.[24,25] The high risk of onward transmission in these provinces should result in these provinces being put on high alert, especially since this has been illustrated by the recent dengue outbreak in Guangzhou which could be attributed to imported cases.[26] Unexpectedly, rare diagnoses of Ebola virus disease (EVD) or other severe zoonotic viral haemorrhagic fever (VHF) were recorded during the epidemic period, even from EVD-endemic African countries.[27,28] Travel-acquired zoonotic VHFs are rarely encountered, mostly because these diseases typically occur during epidemics and are notifiable diseases, which are associated with international travel restrictions.[29–31]

The disease spectrum has been highly dependent on travel destination, inbound provinces, and purpose of travel. Compared with travellers who had other travel purposes, labourers were more likely to acquire vector-borne diseases, while tourists were more likely to acquire respiratory infections. Although tourists accounted for a substantial part of all during-travel imported infections, the labourers returning to the Chinese mainland were the main importers of vector-borne diseases.[16,18] Migrant workers often live in crowded conditions that are conducive to the spread of infections and are particularly vulnerable to disease acquisition as a consequence of low coverage of pre-travel vaccinations and poor adherence to preventive behaviours.[20,32] Therefore, migrant workers are highly likely to spread disease upon return to China. The importation of yellow fever cases from Angola into China provides a vivid example.[32,33] Travellers returning from Asia showed the highest proportion of gastrointestinal diseases, and norovirus is one of the most common causes of travellers' diarrhoea, especially amongst those returning from low-income countries. For example, foreign travellers from India had the highest incidence rate of norovirus infection, which was an indicator of the hygienic conditions of the traveller's or immigrant's environment. Studies from other countries also show similar results—that of norovirus being the frequent cause of traveller's diarrhoea,[34] and indicating that norovirus infection should be considered a priority for prevention during international travel. Furthermore, the highest prevalence of blood/sexually transmitted infections was found to be imported from Southeast Asia to Yunnan and from Mongolia and Russia to Inner Mongolia, mostly via foreign travellers, which could be due to their close borders, frequent human movement and resultant intimate or sexual contacts with the native population, but we lack precise data on this hypothesis.[35]

A particularly laudable aspect of the study is that, for the first time, a denominator of inbound travellers has been provided, enabling the calculation of an incidence rate that gives clues as regards the high-risk countries that transmit a disease. The overall incidence for importing infectious disease was highest amongst African travellers and lowest amongst European travellers. The provinces with high incidence rates were economically less well-off, such as Qinghai, Anhui and Gansu, as compared to the coastal/developed provinces with a high number of cases. The possible reason could be that the patients with imported infection from these provinces were predominantly migrant labourers—the population with a higher risk of infection from vector-borne diseases as mentioned before. This information has provided accurate knowledge of the priority to be given to target populations and countries, based on which healthcare providers could make evidence-based health recommendations and educate international travellers.

Although this study lasted for almost 5 years, we disclosed the yearly trends of disease epidemics. The increase in imported cases in 2017 could obviously be attributed to the increased importation of influenza infection, possibly due to the outbreak of events that might have occurred during long-distance travel, with the exact reason unexplored in the current research. As influenza occupied the most significant proportion of imported infectious diseases, non-pharmaceutical interventions such as frequent hand-washing, maintaining social distancing and wearing a face mask should be advocated during travel when appropriate. The efficiency of non-pharmaceutical interventions in reducing the cases of influenza has been observed during the coronavirus pandemic of 2019–20 (COVID-19).[36] Also, the recent increase in imported vector-borne diseases has been no surprise, due to the increasing number of such cases recorded in endemic countries. As has been observed in Europe, global warming could play a critical part in facilitating this increase and spread.[37,38] Another prominent example of increased importation has been the HIV infection, with its overall increase in incidence worldwide.[39] A similar study from Paris, France, found that there is a broad

and different spectrum of blood/sexually transmitted diseases amongst travellers with HIV-positive and HIV-negative, which indicates the importance of pre-exposure prophylaxis in high-risk travellers.[40]

We also acknowledge that the current data only reflect the trends of imported infectious diseases in China prior to the emergence of COVID-19. Due to the central role of travellers in rapidly dispersing the virus,[41] travel restrictions and lockdown have been widely administered, which have had a major impact on the reduction of air passengers worldwide. As a result, the importation of infectious diseases will be lower in 2020 and possibly in the near future as well. This phenomenon had been demonstrated in other countries such as Switzerland.[42] Currently, with the domestic epidemic of COVID-19 being brought under control in China, centralized medical quarantine for imported COVID-19 has been administered to reduce the onward transmission of COVID-19 as a result of importation.[43]

We have noticed that the post-travel disease spectrum was largely similar to those from other countries where either malaria or dengue is the most common cause of hospitalization.[44] Indeed, traveller's diarrhoea is the leading syndrome in studies of most other countries, especially for travellers originating from the tropics and subtropics.[45,46] However, we have found a lower incidence of diarrhoea compared with respiratory infections in the current research. Previous studies on imported infectious diseases in China have also reported similar results as mentioned in the current study.[16] This is likely due to the wider geographical scope of travel destinations rather than simply the tropical and subtropical regions of China. And this is also likely due to the flaws inherent in case-finding approaches in the surveillance system, since diarrhoea patients are unlikely to be picked for medical inspection, and diarrhoea is also rarely reported by the travellers themselves. All these disadvantages have resulted in an underreporting of traveller's diarrhoea in China.

In the current research, some vaccine-preventable diseases such as yellow fever have also been reported. None of the 11 imported yellow fever patients in this study had been vaccinated before travelling to the known endemic countries. The lack of pre-travel advice, such as vaccination, was particularly notable in labourers. This puts a major population at risk and calls for targeting an improved, educational effort at building awareness.

Our study has, however, been subjected to several limitations. First, we have had no access to the total number of incoming travellers who could be grouped for their country of origin, age or gender; therefore, the incidence rate could not be calculated according to these characteristics due to the lack of a denominator. For travellers with several destinations before entering the country, the exact location where the infection was acquired could not be determined, especially when the time of visit to both destinations was within the incubation period of the infection. For example, the importation of malaria or dengue cases from France, Germany or Switzerland, where no endemic diseases exist, was doubtful. Moreover, the current study did not record the data on the frequency of clinical visits before an international travel. Hence, we could not identify those travellers who might have acquired infection domestically before the start of their travel, but only those who turned symptomatic after returning from the trip, especially for diseases with wide-range incubation periods. However, we did set well-defined criteria to define the post-travel patients, and diseases with long incubation periods were excluded from our analysis. On the other hand, we have apparently missed out on data from sick travellers from at least three sources: (i) those who were sick while travelling overseas but recovered by the time they returned, (ii) those infected travellers who refused to be investigated and sampled and (iii) those who had developed post-travel illness but did not seek medical care or failed to be recognized as patients of travel-related illnesses even if they had sought medical care; therefore, the reported incidence of most travel-related illnesses is substantially lower than the destination-based incidence or the actual incidence. There was also no information about the pre-travel preparation and exposure time of each patient included, so we could not calculate the risk but have only reported the proportion in most cases.

Despite these limitations, the current work has implications for understanding the burden of imported infections into China, and in pinpointing the major diseases, regions and populations that should be targeted with education and pre-travel vaccinations. The findings might help in recommendations for travellers regarding the potential risk of infection and self-treatment, according to their travel destinations and travel purposes. The findings might also assist clinics to prepare for primary care and tips for travellers before they travel abroad, mostly through pre-travel vaccination, education, provision of malaria chemoprophylaxis, etc., as well as the ability to make medical risk assessments after travel, according to their travel-related information.

Supplementary data

Supplementary data are available at *JTM* online.

Author contributions

L.Q.F., W.L., Y.W. and L.P.W. conceived and designed the study. M.Y.L., J.L.W., H.Y.Z., Y.S., Y.Y., S.X.Z., Y.X.W., Z.B.W., Y.X.Z., Y.H., M.M.L., W.M.L., L.P.W. and X.H.G. performed data collation, data sorting and database establishment. M.Y.L., J.L.W., H.Y.Z., Y.S., Y.Y., S.X.Z., Y.X.W., Z.B.W., Y.X.Z., Y.H. and M.M.L. conducted the analyses. Y.W., W.M.L., L.P.W., X.H.G., W.L. and L.Q.F. helped with the analyses. W.L., L.Q.F. and M.Y.L. wrote the draft of the manuscript. All authors contributed to and approved the final version of the manuscript.

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Conflict of Interest

We declare no competing interests.

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