Outbreak, Surveillance, Investigation & Response (OSIR) Journal
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Department of Disease Control, Ministry of Public Health, Thailand
Tel: +6625903894, Fax: +6625903845, Email: osireditor@osirjournal.net, http://www.osirjournal.net

Risk Factors of COVID-19 Infection and the Effectiveness of Pre-flight Screening from an Investigation of an International Flight to Thailand, 2020

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Received: 11 Oct 2022; Revised: 24 Mar 2023; Accepted: 27 Mar 2023
https://doi.org/10.59096/osir.v16i1.262039

Abstract

Thailand implemented pre-flight screening (reverse transcription polymerase chain reaction test for SARS-CoV-2 within 72 hours before departure) to mitigate the importation of COVID-19 during the early phase of the pandemic. We conducted a cross-sectional study to identify factors associated with COVID-19 infection and assess the effectiveness of pre-flight screening among passengers on an India-to-Thailand flight in August 2020. Logistic regression was used to determine the association between the possession of COVID-Free Certificate (CFC) and a positive SARS-CoV-2 test result upon arrival. Twenty-three of 209 passengers (11.0%) had a positive SARS-CoV-2 test. Among 142 CFC holders, 10 (7.0%) tested positive, while 13 of 58 (22.4%) passengers without a CFC tested positive upon arrival (*p*-value 0.003), equivalent to a case reduction of 68.8%. CFC possession yielded an adjusted odds ratio (AOR) of 0.04 (95% CI 0.01–0.44). Being a massage therapist (AOR 17.04, 95% CI 2.37–122.37) and using public transportation in India (AOR 5.30, 95% CI 1.49–18.77) were significantly associated with COVID-19 infection. With the unavailability of vaccines, people should be mindful of taking local public transportation during a pandemic, particularly when planning to travel abroad. Pre-flight screening is an effective method in reducing positive cases from international travel.

Keywords: COVID-19, pre-flight screening, SARS-CoV-2

Introduction

In January 2020, Thailand was the first country outside of China to report a case of coronavirus disease 2019 (COVID-19). Soon thereafter the country experienced widespread community transmission.[1] By late August 2020, there were more than 3,400 cases, 16% of which involved international air travel.[2] Air travel has played a critical role in the spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) worldwide.[3,4] Strategies to prevent and manage imported cases can be challenging as approximately 80% of infected persons are asymptomatic, yet contagious.[5–9] The spread of SARS-CoV-2 by infected travelers has been previously reported.[10–12] However, there is still limited evidence demonstrating the effectiveness of protective measures for air travel to mitigate SARS-CoV-2 transmission.

Preventive measures amongst air travelers vary from country to country.[13] The World Health Organization has recommended that countries introduce public health measures proportionate to public health risks and conduct up-to-date systematic risk assessments.[14,15] To decrease the number of infected air travelers, many countries have implemented pre-flight screening and testing measures, including screening for COVID-19 signs and symptoms, temperature scanning at airports, requiring proof of a negative reverse transcription polymerase chain reaction (RT-PCR) test from nasopharyngeal or throat swabs before boarding, or a negative rapid-test result upon arrival.

Thailand implemented pre-flight passenger screening for all international flights in March 2020. The measure demanded that all foreign inbound passengers undertake a RT-PCR test 72 hours before departure. Those with a negative RT-PCR test would be provided a COVID-Free Certificate (CFC) before travel as proof of the absence of disease.[16] Thai passengers did not need to undergo this test but were required to undergo a general physical examination by a physician and show flight officers a medical certificate, namely a Fit-to-Fly paper, before boarding as proof of the absence of symptoms.[17] After arrival, all travelers were required to be quarantined at government-regulated quarantine centers, or at government-certified private hotels, for 14 days.[18] After over a year, there was still limited information about the effectiveness of the CFC in preventing SARS-CoV-2 infection during the early stages of the pandemic.

On 8 Aug 2020, the Department of Disease Control (DDC) of the Thai Ministry of Public Health was notified of COVID-19 cases among passengers on a direct flight from India to Thailand. A comprehensive examination of factors related to COVID-19 infection in the context of international traveling was undertaken. The investigation provided an opportunity to examine whether having a CFC was associated with COVID-19 infection upon arrival in Thailand.

Methods

Study Design

During 8–25 Aug 2020, we conducted an investigation of all passengers on an international flight from India to Thailand. We used a cross-sectional study to examine the epidemiological characteristics of the passengers and factors associated with COVID-19 infection, particularly pre-flight screening. We also conducted a brief environmental survey to assess adherence to COVID-19 hygiene regulations on the airplane and at the designated quarantine center.

Operational Definitions

A COVID-19 case was defined as any passenger on the aforementioned flight, 8 Aug 2020, with a positive COVID-19 RT-PCR test result for at least two genes (cycle threshold <40) upon arrival in Thailand.[19] As per the national guideline, specimens were collected twice from passengers during their stay in the quarantine center (days 4–5 for the first round and days 10–14 for the second round). A high-risk contact was defined as any passenger interacting with a confirmed COVID-19 case within a one-meter distance for at least five minutes without proper protective personal equipment (PPE) or sitting within two rows of a COVID-19 case while on board.[20] As all cabin crew members, including flight attendants and pilots, reported wearing proper PPE throughout the flight and tested negative for SARS-CoV-2, they were excluded from this study.

Data Collection and Analysis

Using structured data abstraction and interview forms, we reviewed medical records and conducted phone interviews to collect demographic, clinical, and laboratory information of all passengers on the flight. Additionally, we examined the flight manifest to determine the seating arrangements of all passengers. Data collected included age, gender, nationality, occupation, religion, clinical profile, and laboratory results. More detailed information about risk and protective factors related to COVID-19 infection was collected during follow-up phone interviews. Information on pre-flight history, in-flight history, and seat location on the flight were also collected. Thai or English was used, depending on the language preference of the passenger. Cycle threshold values were assessed to measure the concentration of viral genetic material in the samples by RT-PCR.

The dependent variable was the presence (or absence) of SARS-CoV-2 by RT-PCR test upon arrival in Thailand, in either the first or the second round of testing. The main independent variable was the acquisition of pre-flight screening, a CFC. Other covariates included pre-flight history, in-flight history, and demographic characteristics, as described above. Frequency and proportion were calculated for categorial variables, while median with interquartile range (IQR) was used for continuous variables. Wilcoxon's rank sum test was used to compare the distribution of age between the two groups. Fishers' exact test was used to test for differences in proportions. The Wald test was applied to categorical variables with more than two strata. Independent variables with a p-value <0.1 in the univariable analysis were included in the initial multivariable logistic regression model. Crude odds ratios (OR), adjusted odds ratios (AOR), and 95% confidence intervals (CI) were used to measure the association between CFC and COVID-19 test results upon arrival. All statistical analyses were performed using Stata v14.2 (serial number: 401406358220). Statistical significance was assessed against alpha value 0.05. Multicollinearity was checked using variance inflation factors.

For the environmental survey, we assessed the COVID-19 management in the most populated quarantine facility where the passengers stayed. We also interviewed staff in the quarantine facilities and systematically observed how they performed their routine duties. Information gathered during the survey was assessed based on DDC COVID-19 quarantine guidelines.[21]

Results

Description of the Flight

The flight departed Delhi on 8 Aug 2020 at 12:35 AM and arrived in Thailand at 6:10 PM local time. With the addition of a two-hour waiting time onboard before take-off, the total time that passengers spent on the plane was approximately six hours. Hand sanitization and thermal-scanning were used on all passengers before boarding. There were nine cabin crew and two pilots. The seat occupancy was 88.6% (209 passengers/236 seats). There was no food service on the flight and all passengers were required to wear a face mask at all times.

Demographic, Clinical, and Epidemiologic Characteristics of Passengers

Of the 209 passengers on the flight, 200 were interviewed in person. The majority were Thai (n=126, 63.0%), followed by Indian (n=70, 35.0%). Males (n=105, 52.5%) slightly outnumbered females (n=95, 47.5%), and the median age was 36 years (IQR 26–45). Most (39.0%) were Hindu, followed by Buddhist (33.5%), and Muslim (24.0%). The most common occupations were merchants (22.5%), housewives (15.5%), and students (15.0%) (Table 1).

Twenty-three of the 209 (11.0%) passengers had at least one positive COVID-19 test at arrival, during the first (days 4–5) or the second (days 10–14) round of testing. Of these, 18 tested positive at the airport or during the first round. Among the remaining 191 passengers, 128 were defined as high-risk contacts and 63 were low-risk contacts of the first-round cases. There was no definite clustering pattern shown among cases. The seat positions of cases and contacts on the airplane are shown in Figure 1.

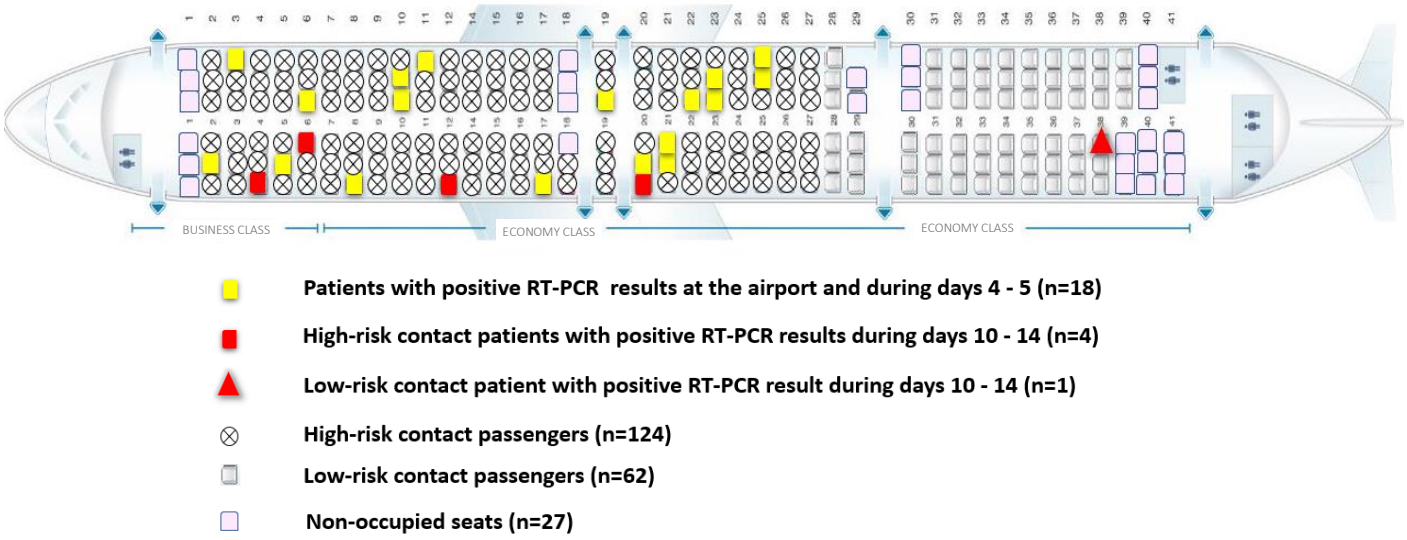

Figure 1. Aircraft seating plan and seat locations of COVID-19 cases detected during days 4–5 or days 10–14 upon arrival in Thailand (n=209)

Approximately three-quarters of cases returned positive results for SARS-CoV-2 within 0–5 days after arrival (1st round including test upon arrival), while the remaining five (21.7%) tested positive during days 10–14 (2nd round), as shown in Figure 2. Overall, cycle threshold values of N gene of SARS-CoV-2 ranged between 16.0–39.5 (median 34.7, IQR 26.9–36.2).

Among 200 passengers who were interviewed, 142 (71.0%) had obtained a CFC before boarding the plane. Of these, ten (7.0%) tested positive for SARS-CoV-2 and eight were detected during the first 4–5 days. Out of the 58 passengers who did not possess a CFC, 13 (22.4%) tested positive for SARS-CoV-2 with two testing positive at the airport, eight within the first 4–5 days and three during the 10-14 days (Figure 2). The reduction in percentage of cases between CFC holders and non-CFC holders was 68.8%. However, the difference in percentage of positive SARS-CoV-2 test between CFC holders and non-CFC holders was not significant in the second round of testing, mainly due to the low sample size.

Ten of the 23 (43.5%) cases were symptomatic and only one case developed pneumonia. All symptomatic patients were asymptomatic before boarding the plane. Among the ten symptomatic patients, seven had coughs and five presented with fever. All symptomatic patients, except the one who developed pneumonia, completely recovered within 14 days without complications. The pneumonia patient recovered within one month. The median duration of symptoms was ten days.

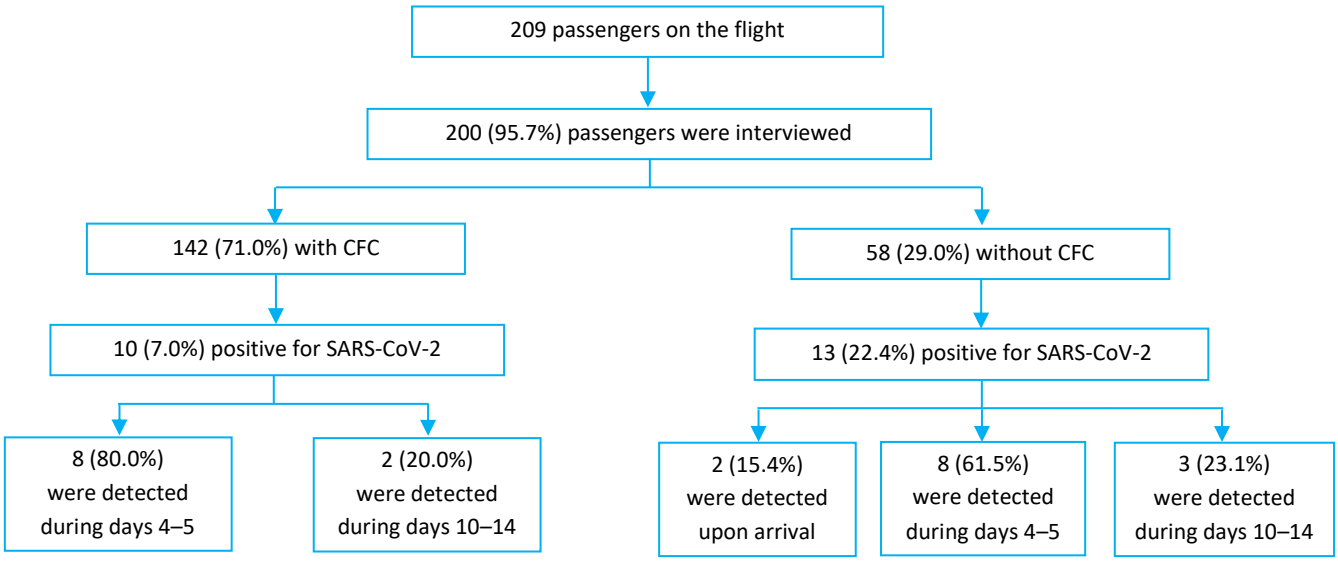

Figure 2. Flowchart showing the distribution of passengers who did and did not obtain a CFC and tested positive for SARS-CoV-2 (n=209)

Univariable and Multivariable Analyses

On univariable analysis, having COVID-19 infection upon arrival in Thailand was significantly associated with being Thai (OR 15.44, 95% CI 2.04–117.13), Buddhist (OR 3.55, 95% CI 1.06–11.89) or Muslim (OR 4.67, 95% CI 1.35–16.12), having a CFC before boarding (OR 0.26, 95% CI 0.11–0.64), and using public transport in India (e.g., bus or train) (OR 4.85, 95% CI 1.62–14.57). Being a massage therapist compared to merchant or others was significantly associated with COVID-19 infection (OR 7.18, 95% CI 1.71–30.26). When comparing being massage therapist to all other occupations, massage therapist also presented a significant association (OR 6.00, 95% CI 1.55–30.17) (Table 1).

Table 1. Univariable analysis determining the association between COVID-19 infection and each independent variable

Variable	COVID-19 positive N=23 n (%)	COVID-19 negative N=177 n (%)	Total passengers N=200 n (%)	OR (95% CI)	*P*-value by Fisher's exact test
Demographic					
Median age (IQR)	35 (28.0-41.0)	36 (25.0-45.0)	-	-	-
Age group (years)					0.467±
≥60	2 (8.7)	12 (6.8)	14 (7.0)	Ref	Ref
1–14	3 (13.0)	28 (15.8)	31 (15.5)	0.64 (0.09–4.35)	0.651
15–19	3 (13.0)	36 (20.3)	39 (19.5)	0.50 (0.07–3.35)	0.476
30–44	13 (56.5)	67 (37.9)	80 (40.0)	1.16 (0.23–5.82)	0.853
45–49	2 (8.7)	34 (19.2)	36 (18.0)	0.35 (0.04–2.79)	0.324
Male	12 (52.2)	93 (52.5)	105 (52.5)	0.99 (0.41–2.35)	0.973
Thai	22 (95.7)	104 (58.8)	126 (63.0)	15.44 (2.04–117.13)	0.008
Religion					0.044±
Hindu or others	4 (17.4)	81 (45.8)	85 (42.5)	Ref	Ref
Buddhist	10 (43.5)	57 (32.2)	67 (33.5)	3.55 (1.06–11.89)	0.040
Muslim	9 (39.1)	39 (22.0)	48 (24.0)	4.67 (1.35–16.12)	0.015
Occupation#					0.113±
Merchant or others	9 (39.1)	97 (54.8)	106 (53.0)	Ref	Ref
Massage therapist	4 (17.4)	6 (3.4)	10 (5.0)	7.18 (1.71–30.26)	0.007
Housewife	3 (13.0)	28 (15.8)	31 (15.5)	1.15 (0.29–4.56)	0.837
Student	4 (17.4)	26 (14.7)	30 (15.0)	1.66 (0.47–5.81)	0.430
Employee	3 (13.0)	20 (11.3)	23 (11.5)	1.62 (0.40–6.51)	0.500
Documentation of RT-PCR for SARS-CoV-2 negative before boarding					
Pre-flight screening (CFC)	10 (43.5)	132 (74.6)	142 (71.0)	0.26 (0.11–0.64)	0.003

Table 1. Univariable analysis determining the association between COVID-19 infection and each independent variable (cont.)

Variable	COVID-19 positive N=23 n (%)	COVID-19 negative N=177 n (%)	Total passengers N=200 n (%)	OR (95% CI)	*P*-value by Fisher's exact test
Symptoms and laboratory result					
Having symptoms	10 (43.5)	3 (1.7)	13 (6.5)	44.62 (10.92–182.36)	<0.001
Cough	7 (30.4)	1 (0.6)	8 (4.0)	77.00 (8.91–665.60)	<0.001
Fever	5 (21.7)	0 (0)	5 (2.5)	NA	NA
Rhinorrhea	4 (17.4)	2 (1.1)	6 (3.0)	18.42 (3.16–107.30)	0.001
Anosmia	3 (13.0)	0 (0)	3 (1.5)	NA	NA
Sore throat	3 (13.0)	0 (0)	3 (1.5)	NA	NA
Myalgia	3 (13.0)	0 (0)	3 (1.5)	NA	NA
Phlegm	2 (8.7)	0 (0)	2 (1.0)	NA	NA
Diarrhea	1 (4.4)	0 (0)	1 (0.5)	NA	NA
Pneumonia	1 (4.4)	0 (0)	1 (0.5)	NA	NA
Pre-departure behavior (2 weeks before boarding)					
Visiting a mosque	8 (34.8)	31 (17.5)	39 (19.5)	2.51 (0.97–6.44)	0.055
Using public transportation	6 (26.1)	12 (6.8)	18 (9.0)	4.85 (1.62–14.57)	0.005
Not always wearing a mask while going outside	4 (17.4)	0 (0)	4 (2.0)	NA	NA
In-flight behavior					
Not wearing a mask all the time	0 (0)	2 (1.1)	2 (1.0)	NA	NA
Not using hand sanitizer	0 (0)	9 (5.1)	9 (4.5)	NA	NA
Seat swapping	0 (0)	3 (1.6)	3 (1.5)	NA	NA

Note: NA denotes "not applicable" as the software failed to determine the strength of association due to perfect prediction.
‡P-value by Wald test. #Being a massage therapist compared to all other occupations, show OR of 6.00 (95% CI 1.55-30.17).
CFC: COVID-19-free certificate, IQR: interquartile range, OR: crude odds ratio, CI: confidence interval, Ref: reference group

On multivariable analysis, CFC possession was negatively associated with COVID-19 infection (AOR 0.04, 95% CI 0.01–0.44). Working as massage therapist during COVID-19 pandemic (AOR 17.04, 95% CI 2.37-122.37), and use of public transportation in India was significantly associated with COVID-19 infection (AOR 5.30, 95% CI 1.49–18.77). There was no multicollinearity among nationality, religion, and visiting a mosque (variance inflation factors=2.3, 2.31, and 1.18 respectively) (Table 2).

Table 2. Multivariable analysis determining the association between COVID-19 infection and selected independent variables

Independent variables	AOR	95% CI
Thai	4.69	0.47–46.83
Religion		
Hindu or others	Ref	Ref
Buddhist	0.40	0.08–1.97
Muslim	6.42	0.24–172.10
Massage therapist	17.04	2.37–122.37
CFC possession	0.04	0.01–0.44
Visiting a mosque within 2 weeks before departure	2.01	0.20–20.22
Using public transportation within 2 weeks before departure	5.30	1.49–18.77

Note: CFC: COVID-19-free certificate, AOR: adjusted odds ratio, CI: confidence interval, Ref: reference group

Environmental Survey

We visited the main quarantine facility where 142 passengers stayed to assess the risk of post-arrival infection and hygiene standards. We found that all quarantine staff strictly followed guidelines stipulated by the DDC during the period of the passengers' stay.[21] Cleaning staff were prohibited from entering passengers' rooms and guests were not allowed to leave their rooms. The video coverage showed no transgression of the regulations. Medical and cleaning staff were regularly trained on PPE application and removal.

Discussion

Our findings suggest that pre-flight screening with a CFC, in the context when a COVID-19 vaccine was unavailable, effectively prevented COVID-19 infections among international visitors and returnees. The odds of testing positive for COVID-19 after arrival amongst non-CFC-holders was 25 times as large as the odds amongst CFC holders. A simulation study by Kiang et al suggested that the pre-travel RT-PCR test (within three days before boarding) reduced the number of infectious days by 36% and could identify approximately 88.0% of the actively infectious travelers.[22]

Our study found that the case reduction percentage of pre-flight screening was 68.8%, potentially preventing COVID-19 importation to Thailand. Despite limited evidence of the exact case reduction percentage of pre-flight screening in other countries, during 6 Jun to 14 Nov 2020, SARS-CoV-2 testing on arrival in Alaska airports identified 951 SARS-CoV-2 infections, or one per 406 arriving travelers, which might have contributed to Alaska's low incidence during summer.[12]

The quarantine measure after arrival should continue regardless of the possession of CFC given vaccine unavailability. This is because, based on our findings, about 7.0% of CFC holders were still found positive for SARS-CoV-2 after arrival. A possible explanation for this is that the incubation period of COVID-19 can range from 2–14 days and extend to 24 days in a few extreme settings.[23] For this reason, it is necessary to deliver the quarantine measure for all cross-country visitors and returnees. During the period of investigation, many countries such as Canada and the United Kingdom still imposed quarantine measures on travelers regardless of the RT-PCR result before departure.[24,25]

Our study found that massage therapists are at risk of COVID-19 infection. It is because they might be in close contact with clients and may encounter respiratory droplets or other bodily fluids.[26–28] A study in Norway found similar results. It showed individuals employed as physiotherapists had two times the odds of COVID-19 infection during the first wave of infection compared to every one of their working age.[29]

Showed in our study, using public transportation in India during the early phase of the pandemic before departure is associated with positive SARS-CoV-2. Consistent with a large prospective cohort in Norway, people with COVID-19 infection were more likely to be using public transport than those who were not getting an infection.[30] Moreover, during the early pandemic in China, COVID-19 transmission was also detected on bus travel.[31]

Regarding infection risk, cases were likely to be infected before they left India. Supporting evidence included the fact that, at that time, the COVID-19 situation in India was pronounced, and the multivariable analysis found a strong association of working as massage therapist and a history of public transport use in India with positive SARS-CoV-2.[32] In contrast, other factors such as religion and nationality were not significant. Evidence of disease transmission on board the plane and at the quarantine center could not be found. This is probably because all cabin crew and staff at the quarantine center complied with the protocols, and there was no clear clustering pattern in terms of the flight seats amongst the cases. The environment in the quarantine center was also well-managed.

This study contained both strengths and limitations. In terms of strengths, we were able to obtain information from almost all passengers on the flight. Additionally, we exercised various data collection methods including interviews and observations. However, some limitations remained. Firstly, as the study was part of the DDC's routine investigation, which required only RT-PCR test for disease screening, we did not perform a whole genome study to prove if the viral clade of the cases matched the clade prevailing in India. Therefore, our suggestion that the cases were infected with SARS-CoV-2 in India was only speculative. Secondly, as some interview topics were about history, recall bias was inevitable. However, the history we explored was quite recent, thus any recall bias would be minimal, and would not severely affect the validity of the findings. Thirdly, since the interviews were conducted in English for non-Thai participants (who were mostly Indian), there might be some degree of language misunderstanding or varying interpretations across passengers. However, this factor might not hugely undermine the findings as most of the interview questions were not complicate. Lastly, this study was not free from social desirability bias when we interviewed the participants or observed the management of the quarantine center. The research team did not have enough time to stay and observe the actual practice of the staff of the quarantine center. Nonetheless, we exercised multiple data collection techniques to triangulate the findings.

Conclusion and Recommendations

This study revealed that the pre-flight CFC acquisition helped mitigate the risk of COVID-19 infection after arrival more than half. Other key risk factors included

working as massage therapist and using public transport in India. The risk of infection on board and in the quarantine center was minimal. Concerning recommendations, the quarantine measure should continue for all visiting travelers and Thai returnees regardless of the possession of a CFC. Maintaining the CFC policy for unvaccinated people as long as the ongoing pandemic should be considered. An emphasizing message for travelers visiting other countries to avoid public transport and consider a temporary pause of working in close contact with other people, such as massage therapists, during the early stages of a pandemic should be delivered.

Acknowledgments

We would like to thank the following institutes for the huge support throughout the study—the Institute for Urban Disease Control and Prevention, the Office of Disease Prevention and Control Region 6 Chonburi, and Somdej Pranangchao Sirikit Hospital, Chonburi. We are also grateful for the advice from Dr.Wiwat Rojanapithayakorn and Dr.Witaya Sawaddiwudhipon, that helped honing the manuscript enormously.

Author Contributions

Conceptualization: KS, and RS; Methodology: KS, and RS; Formal analysis: KS and RS; Investigation: KS, TC, PP, and NS; Writing—original draft: KS, and RS; Writing—review and editing: KS, and RS; Supervision: RS.

Declaration of Conflict of Interest

The author(s) declare no conflicts of interest.

Funding

The author(s) received no financial support for the research authorship and/or publication of this article.

Ethics Approval

This study was part of the disease investigation operation under the Department of Disease Control of the Ministry of Public Health. Therefore, ethics approval was not needed. However, the authors strictly followed the ethical standards for research and publication. Individual data were kept strictly confidential.

Suggested Citation

Sawangsrisutikul K, Chuxnum T, Promduangsi P, Saritapirak N, Suphanchaimat R. Risk factors of COVID-19 infection and the effectiveness of pre-flight screening from an investigation of an international flight to Thailand, 2020. OSIR. 2023 Mar;16(1):31–9. doi:10.59096/osir.v16i1.262039.

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