# FACTORS ASSOCIATED WITH DEVELOPING COVID-19 AMONG HOSPITAL PERSONNEL AT A PEDIATRIC TERTIARY CARE CENTER IN BANGKOK, THAILAND

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**Abstract.** Hospital personnel (HP) are at greater risk for contracting coronavirus disease-2019 (COVID-19). In this retrospective study, we aimed to determine factors significantly associated with contracting COVID-19 among HP in order to inform efforts to prevent this from occurring. Factors were compared between those who did and did not contract COVID. Study subjects were HP who participated in a COVID-19 screening program at a tertiary care pediatric hospital in Bangkok, Thailand during April 2021-March 2022. During the screening program, all participating HP who were exposed to someone with COVID-19 or who developed COVID-19, had a confirmatory RT-PCR test or rapid antigen test performed and were included in the study. A total of 1,619 subjects were included in the study, 13.7% ($n$ = 222) males. The median (±interquartile range) age of study subjects was 37 years (30-47 years). Of the total of 1,619 subjects, 177 (10.9%) developed COVID-19, defined as having symptoms and a positive test for COVID-19. The factors significantly associated with contracting COVID-19 among study subjects were: having an underlying disease (odds ratio (OR) = 1.527, 95% confidence interval (CI): 1.037-2.248, $p$ = 0.032), working in a frontline role other than those of physicians, dentists, nurses and nurse assistants (eg, pharmacists, laboratory technicians, and radiologists) (OR = 2.511, 95% CI: 1.375-4.585, p=0.003), contracting COVID-19 when the omicron variant predominated (OR = 5.050, 95% CI: 3.403-7.493, $p$<0.001), sharing a sleeping space with someone with COVID-19 (OR = 5.046, 95% CI: 1.531-16.638, $p$ = 0.008) and using inappropriate personal protective equipment (PPE) during exposure (OR = 1.930, 95% CI: 1.061-3.510, $p$ = 0.031). In summary, factors significantly associated with contracting COVID-19 by subjects in our study were having an underlying disease, working in a frontline role other than being a physician, dentist, nurse or nurse assistant, working during the period when the omicron variant predominated, sleeping in

the same room as someone with COVID-19 and not using appropriate PPE when exposed to people with COVID-19. We conclude, HP at the study institution should be educated about these factors. Further studies are needed to determine if educating HP about these factors will reduce their risk of contracting COVID-19.

**Keywords:** COVID-19, SARS-CoV-2, healthcare worker, risk factors, pediatric

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## INTRODUCTION

The coronavirus disease-2019 (COVID-19) outbreak began in 2019 in Wuhan China, and subsequently escalated to a worldwide pandemic with relatively high morbidity and mortality rates (WHO, 2020).

The first wave of COVID-19 in Thailand occurred during March-May 2020 and COVID-19 has been endemic in Thailand since then (WHO Thailand, 2022). The largest COVID-19 outbreak in Thailand occurred during April 2021-April 2022 (WHO Thailand, 2022). This outbreak was divided into 2 parts based on the viral variants that predominated. During April-December 2021, the predominant variants were the alpha and delta variants comprising 2,189,565 reported cases with a 0.98% mortality rate and the omicron variant predominated during January-April 2022 comprising 2,020,905 reported cases with a 0.34% mortality rate (Department of Disease Control, 2022).

Hospital personnel (HP) are at greater risk of contracting COVID-19 than the general population (Nguyen *et al*, 2020). Several studies have reported factors significantly associated with contracting COVID-19 among HP: female sex, performing endotracheal intubation, lack of appropriate personal protective equipment (PPE) (Dzinamarira *et al*, 2022), contacts with COVID-19 infected people in the community

(Jacob *et al*, 2021), being a nurse and wearing gloves (Al Youha *et al*, 2021). However, there are no data regarding factors associated with contracting COVID-19 among HP working with pediatric patients in Thailand.

In this study, we aimed to determine factors significantly associated with contracting COVID-19 among HP at a children's hospital in order to inform efforts to prevent this from occurring.

## MATERIALS AND METHODS

### Study design and setting

We conducted this retrospective study at the Queen Sirikit National Institute of Child Health (QSNICH), a tertiary care pediatric hospital in Bangkok, Thailand. The data in this study were obtained from the database of a COVID-19 screening program carried out among HP, implemented by the QSNICH during April 2021-March 2022 (Fig 1). Three groups of HP were screened in this program: 1) HP with COVID-19 infection due to risks outside work at QSNICH, 2) HP with respiratory tract symptoms and 3) HP with COVID-19 exposure at QSNICH.

HP were urged to disclose COVID-19 exposure, respiratory tract symptoms or a diagnosis of COVID-19. Each of these HP were then interviewed and the following information obtained: subject name, contact number, demographic data, subject work position, protection methods used during exposure to a COVID-19 infected person and specifics about the COVID-19 infected person. After this, COVID-19 testing was performed on Days 5-7 and 10-14 post-exposure. The COVID-19 testing done was comprised of either of 2 methods: 1) reverse transcriptase polymerase chain reaction (RT-PCR) to detect the severe acute respiratory syndrome-coronavirus-2 (SARS-CoV-2) and 2) a SARS-CoV-2 rapid antigen test (Beijing Applied Biological Technologies Co Ltd, Beijing, PR China).

### Definitions used in this study

Appropriate PPE was defined as follows: 1) when performing a non-aerosol-generating procedure both the exposed individual and the infected individual must wear surgical masks. If the infected individual did not wear a surgical

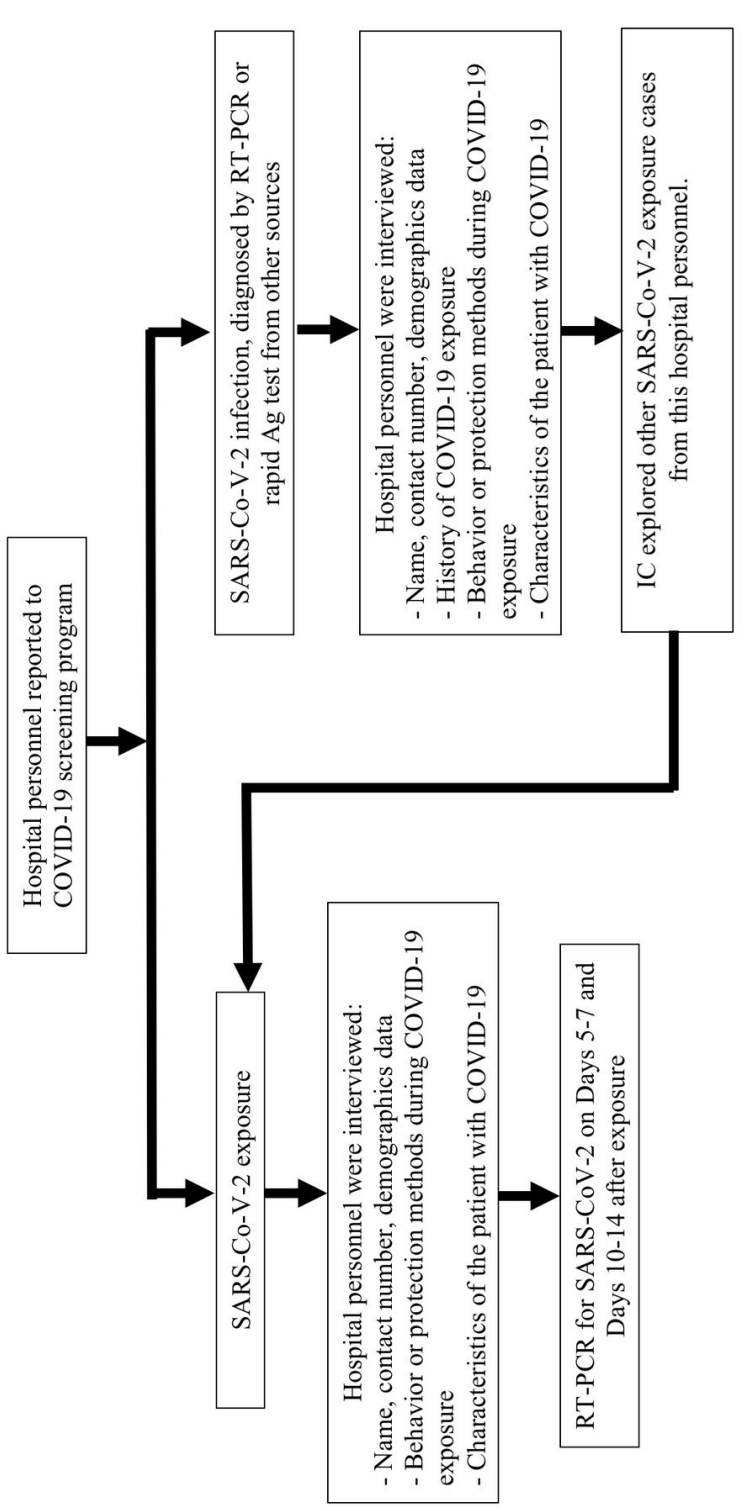


Fig 1 - The process of QSNICH COVID-19 screening program

Ag test: antigen test; COVID-19: coronavirus disease-2019; IC: Infection Prevention and Control Nursing Department; QSNICH: Queen Sirikit National Institute of Child Health; RT-PCR: reverse transcriptase polymerase chain reaction; SARS-CoV-2: severe acute respiratory syndrome-coronavirus-2

mask, the exposed individual must wear an N95 or higher mask (Andrejko *et al*, 2022; Riley *et al*, 2022); 2) when performing an aerosol-generating procedure the exposed individual must wear an N95 or higher mask (Andrejko *et al*, 2022; CDC, 2024). Inappropriate PPE use was considered failing to do the above.

Having COVID-19 was defined as having symptoms and a positive result on a SARS-CoV-2 RT-PCR or rapid antigen test.

The types of exposed environments were classified as: 1) having poor ventilation: defined as being in an enclosed, small space, such as a car, private room, small staff dining room or bedrooms; 2) having good ventilation: defined as being in a large or open space, such as an open-air area, a general hospital ward, a large conference room, a large restaurant or an airborne infection isolation rooms (AIIR).

The period when the alpha/delta variant predominated was April-December 2021 and when the omicron variant predominated was January-March 2022 (Department of Disease Control, 2022).

**Statistical analysis**

Frequencies and medians are used to summarize demographic data, COVID-19 exposure factors and the numbers of COVID-19 cases. We used univariate analyses and Chi-square testing to evaluate potential associations between selected factors and contraction of COVID-19. We used the Mann-Whitney U test to evaluate potential associations between continuous data and contraction of COVID-19. We used multiple logistics regression analyses, odds ratios (OR), and 95% confidence intervals (CI) to determine significant associations between selected factors and COVID-19. A $p$-value $<0.05$ was considered statistically significant. Statistical calculations were conducted using the Statistical Package for the Social Sciences (SPSS), version 25 (IBM SPSS Inc, Chicago, IL).

**Ethical approval**

This study was approved by the research ethics review committee of QSNICH (REC.074/2565) and followed the principles of the Declaration of Helsinki. We obtained informed consent from

all study subjects prior to inclusion in this study.

## RESULTS

A total of 1,619 subjects were included in this study, of whom 222 (13.7%) were males. The median (interquartile range) age of study subjects was 37 (30.0-47.0) years. 1,321 subjects (81.6%) were frontline healthcare personnel and 298 (18.4%) were back-office staff. The frontline healthcare personnel were divided into two groups: 1) close-contact frontline personnel: doctors ($n$ = 350, 26.5%), dentists ($n$ = 30, 2.3%), nurses ($n$ = 533, 40.3%) and nurse assistants ($n$ = 238, 18.0%); and 2) non-close-contact frontline personnel: pharmacists ($n$ = 61, 4.6%), laboratory staff ($n$ = 33, 2.5%), radiology staff ($n$ = 5, 0.4%) and other roles ($n$ = 71, 5.4%). Of the 1,619 total subjects, 505 (31.2%) had underlying medical conditions. The underlying medical conditions were: allergic diseases ($n$ = 164, 10.1%), hypertension ($n$ = 122, 7.5%), hyperlipidemia ($n$ = 68, 4.2%), diabetes mellitus ($n$ = 63, 3.9%), pulmonary disease ($n$ = 16, 1.0%), cardiovascular disease ($n$ = 6, 1.0%), renal disease ($n$ = 5, 0.3%), malignancy ($n$ = 5, 0.3%) and other conditions ($n$ = 155, 9.6%) (Table 1).

1,405 subjects (86.8%) reported having exposure to someone with COVID-19, while 214 participants (13.2%) reported no exposure (Table 1).

Of the 1,619 total subjects, 177 (10.9%) had a positive COVID-19 test: 158 (89.3%) had a positive RT-PCR test and 19 (10.7%) had a positive rapid antigen test (Fig.2). Of the 177 subjects who contracted COVID-19, 126 (71.2%) had a history of exposure to a person with COVID-19. Sources of exposure included family members/flat mates ($n$ = 52, 41.3%), friends/coworkers ($n$ = 52, 41.3%) and patients ($n$ = 22, 17.4%).

Factors significantly associated with contracting COVID-19 were: having an underlying medical condition (OR = 1.527, 95% CI: 1.037-2.248, $p$ = 0.032), being a non-close-contact frontline personnel (OR = 2.511, 95% CI: 1.375-4.585, $p$ = 0.003), contracting COVID-19 during omicron variant predominance (OR = 5.050, 95% CI: 3.403-7.493, $p$<0.001) and having no prior history of COVID-19 exposure

Table 1

Demographics of study subjects

| Demographics | Frequency* *n* (%) |
|---|---|
| Sex (N = 1,619) | |
| Male | 222 (13.7) |
| Female | 1,397 (86.3) |
| Age in years, median (IQR) | 37 (30.0-47.0) |
| Underlying disease (N = 1,619) | |
| Yes | 505 (31.2) |
| No | 1,114 (68.8) |
| Position (N = 1,619) | |
| Frontline | 1,321 (81.6) |
| Back office | 298 (18.4) |
| Frontline workers (N = 1,321) | |
| Physicians | 350 (26.5) |
| Dentists | 30 (2.3) |
| Nurses | 533 (40.3) |
| Nurse assistants | 238 (18.0) |
| Pharmacists | 61 (4.6) |
| Laboratory staff | 33 (2.5) |
| Radiology technician | 5 (0.4) |
| Others | 71 (5.4) |
| Ward (N = 1,262) | |
| COVID-19 ward | 48 (3.8) |
| Pediatric ward | 698 (55.3) |
| Surgery ward and others | 516 (40.9) |

Table 1 (cont)

| Demographics | Frequency* *n* (%) |
|---|---|
| History of COVID-19 exposure (N = 1,619) | |
| No | 214 (13.2) |
| Yes | 1,405 (86.8) |
| COVID-19 vaccination (N = 1,619) | |
| Completed | 1,309 (80.9) |
| Partially completed or none | 310 (19.1) |
| History of COVID-19 exposure (N = 1,405) | |
| Age of COVID-19 patient subject exposed to | |
| ≥18 years | 1,007 (71.7) |
| <18 years | 398 (28.3) |
| Clinical presentation of COVID-19 patient subject exposed to | |
| Asymptomatic | 360 (25.6) |
| Symptomatic | 1,045 (74.4) |
| Subject relationship with COVID-19 patient | |
| Family member/roommate | 211 (15.0) |
| Patient/relative | 400 (28.5) |
| Friend/colleague | 780 (55.5) |
| Others | 14 (1.0) |
| Exposure type to COVID-19 patient | |
| Took care of COVID-19 patient | 376 (26.8) |
| Worked/talked together | 721 (51.3) |
| Eat together | 180 (12.8) |
| Slept in the same room | 116 (8.2) |
| Others | 12 (0.9) |
| Environment | |
| Poor ventilation | 480 (34.2) |
| Good ventilation | 925 (65.8) |

Table 1 (cont)

| Demographics | Frequency* *n* (%) |
|---|---|
| PPE | |
| Inappropriate | 900 (64.1) |
| Appropriate | 505 (35.9) |

*Unless otherwise stated

COVID-19: coronavirus disease 2019; IQR: interquartile range; PPE: personal protective equipment

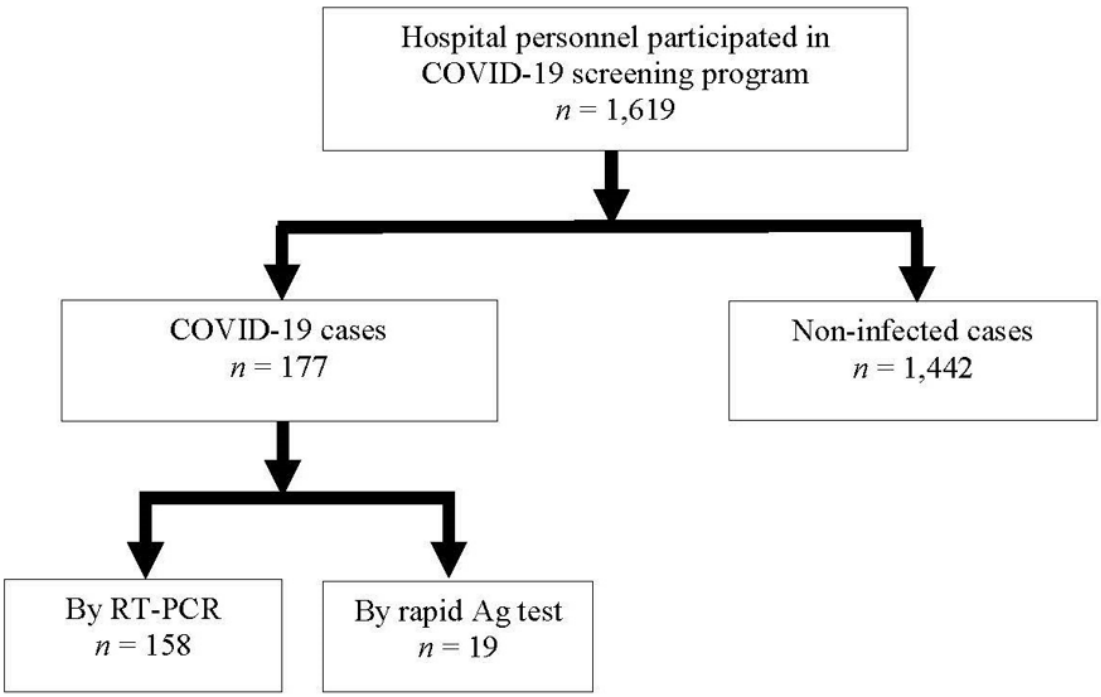


Fig 2 - Participant recruitment

Ag test: antigen test; COVID-19: coronavirus disease 2019; RT-PCR: reverse transcriptase polymerase chain reaction

(OR = 0.304, 95% CI: 0.199-0.466, $p$<0.001) (Table 2).

We found no significant difference in the proportion of subjects who contracted COVID-19 between all frontline personnel combined and back-office staff (OR = 0.694, 95% CI: 0.478–1.006, $p$ = 0.054). However, among the two groups of frontline personnel, non-close-contact frontline subjects were significantly more likely to contract COVID-19 than subjects who where doctors and dentists (OR = 2.511, 95% CI: 1.375–4.585, $p$ = 0.003). Among close-contact frontline subjects, we found no significant difference in the proportions of subjects who contracted COVID-19 between the group of physicians/dentists and the group of nurses/nurse assistants (OR = 1.435, 95% CI: 0.903–2.282, $p$ = 0.126) (Table 2). In the non-close-contact frontline group, 25 subjects contracted COVID-19, of whom 19 had a history of exposure to someone with COVID-19 and 6 did not. Among subjects who had a history of exposure to someone with COVID-19 and who contracted COVID-19, 8 were exposed to family members/roommates, 11 were exposed to friends/colleagues, of whom 5 were exposed by working together, 3 by dining together and all 11 by sleeping in the same room.

The COVID-19 infection rate was significantly higher when the omicron variant predominated than when the alpha/delta variants predominated (OR = 5.050, 95%CI: 3.403-7.493, $p$<0.001). Interestingly, subjects with a history of exposure to someone with COVID-19 were significantly less likely to contract COVID-19 than subjects with no exposure history (OR = 0.304, 95% CI: 0.199-0.466, $p$<0.001) (Table 2).

Factors not significantly associated with contracting COVID-19 were: subject gender, age, job position, ward assignment and complete vaccination status. We also found no significant difference in the proportions of subjects who contracted COVID-19 between those who worked on a COVID-19 ward and those who worked on a surgical ward (OR = 1.996, 95% CI: 0.882-4.514, $p$ = 0.097) or who worked on a pediatric ward (OR = 1.183, 95% CI: 0.805-1.739, $p$ = 0.391) (Table 2).

Table 2

Results of logistic regression analysis of selected factors and contraction of COVID-19

| Demographics | COVID-19 test result, *n* (%) | | Univariate analysis | | Multivariate analysis | |
|---|---|---|---|---|---|---|
| | Positive N = 177 | Negative N = 1,442 | OR (95% CI) | *p*-value | aOR (95% CI) | *p*-value |
| Sex | | | | | | |
| Male | 29 (16.4) | 193 (13.4) | 1.268 (0.828-1.941) | 0.274 | | |
| Female | 148 (83.6) | 1,249 (86.6) | Ref | | | |
| Age in years, median (IQR) | 37 (30.0-47.0) | 37 (30.0-48.0) | | 0.974 | | |
| Underlying disease | | | | | | |
| Yes | 67 (37.9) | 438 (30.4) | 1.396 (1.010-1.930) | 0.043 | 1.527 (1.037-2.248) | 0.032 |
| No | 110 (62.1) | 1,004 (69.6) | Ref | | Ref | |
| Position | | | | | | |
| Frontline | 135 (76.3) | 1,186 (82.2) | 0.694 (0.478-1.006) | 0.054 | | |
| Back office | 42 (23.7) | 256 (17.8) | Ref | | | |
| Frontline (calculations were based on 135 positive and 1,186 negative COVID-19 test results) | | | | | | |
| Physicians/dentists | 29 (21.5) | 351 (29.6) | Ref | | Ref | |
| Nurses/nurse assistants | 81 (60.0) | 690 (58.2) | 1.421 (0.912-2.213) | 0.120 | 1.435 (0.903-2.282) | 0.126 |
| Non-close-contact frontline subjects | 25 (18.5) | 145 (12.2) | 2.087 (1.182-3.686) | 0.011 | 2.511 (1.375-4.585) | 0.003 |

Table 2 (cont)

| Demographics | COVID-19 test result, *n* (%) | | Univariate analysis | | Multivariate analysis | |
|---|---|---|---|---|---|---|
| | Positive N = 177 | Negative N = 1,442 | OR (95% CI) | *p*-value | aOR (95% CI) | *p*-value |
| Ward (calculations were based on 129 positive and 1,133 negative COVID-19 test results) | | | | | | |
| COVID-19 ward | 8 (6.2) | 40 (3.5) | 1.996 (0.882-4.514) | 0.097 | | |
| Pediatric Ward | 74 (57.4) | 624 (55.1) | 1.183 (0.805-1.739) | 0.391 | | |
| Surgery ward and others | 47 (36.4) | 469 (41.4) | Ref | | | |
| Outbreak era | | | | | | |
| Alpha/delta variant | 70 (39.5) | 983 (68.2) | Ref | | Ref | |
| Omicron variant | 107 (60.5) | 459 (31.8) | 3.274 (2.375-4.513) | <0.001 | 5.050 (3.403-7.493) | <0.001 |
| History of COVID-19 exposure | | | | | | |
| No | 51 (28.8) | 163 (11.3) | Ref | | Ref | |
| Yes | 126 (71.2) | 1279 (88.7) | 0.315 (0.219-0.453) | <0.001 | 0.304 (0.199-0.466) | <0.001 |
| COVID-19 vaccination | | | | | | |
| Completed | 152 (85.9) | 1157 (80.2) | Ref | | | |
| Partially completed or none | 25 (14.1) | 285 (19.8) | 0.668 (0.429-1.039) | 0.074 | | |

Table 2 (cont)

| Demographics | COVID-19 test result, *n* (%) | | Univariate analysis | | Multivariate analysis | |
|---|---|---|---|---|---|---|
| | Positive N = 177 | Negative N = 1,442 | OR (95% CI) | *p*-value | aOR (95% CI) | *p*-value |
| Hospital personnel with history of COVID-19 exposure (calculations were based on 126 positive and 1,279 negative COVID-19 test results) | | | | | | |
| Age of COVID-19 patient subject exposed to | | | | | | |
| ≥18 years | 98 (77.8) | 909 (71.1) | 1.425 (0.920-2.206) | 0.112 | | |
| <18 years | 28 (22.2) | 370 (28.9) | Ref | | | |
| Symptoms of COVID-19 patient subject exposed to | | | | | | |
| Asymptomatic | 27 (21.4) | 333 (26.0) | Ref | | | |
| Symptomatic | 99 (78.6) | 946 (74.0) | 1.291 (0.828-2.011) | 0.259 | | |
| Relationship of subject to COVID-19 patient | | | | | | |
| Family member/ roommate | 52 (41.3) | 159 (12.4) | 5.619 (3.302-9.564) | <0.001 | 2.318 (0.756-7.112) | 0.141 |
| Patient/relative | 22 (17.4) | 378 (29.6) | Ref | | Ref | |
| Friend/colleague | 52 (41.3) | 728 (56.9) | 1.227 (0.734-2.051) | 0.435 | 0.877 (0.286-2.688) | 0.818 |
| Others | 0 (0.0) | 14 (1.1) | NA | | NA | |

Table 2 (cont)

| Demographics | COVID-19 test result, *n* (%) | | Univariate analysis | | Multivariate analysis | |
|---|---|---|---|---|---|---|
| | Positive N = 177 | Negative N = 1,442 | OR (95% CI) | *p*-value | aOR (95% CI) | *p*-value |
| Type of exposure | | | | | | |
| Took care of patient | 21 (16.7) | 355 (27.8) | Ref | | Ref | |
| Worked/talked together | 39 (31.0) | 682 (53.3) | 0.967 (0.560-1.668) | 0.903 | 1.122 (0.368-3.417) | 0.840 |
| Ate together | 26 (20.6) | 154 (12.0) | 2.854 (1.558-5.228) | <0.001 | 2.068 (0.626-6.831) | 0.233 |
| Slept in same room | 40 (31.7) | 76 (6.0) | 8.897 (4.965-15.945) | <0.001 | 5.046 (1.531-16.638) | 0.008 |
| Others | 0 (0.0) | 12 (0.9) | NA | | | |
| Environment | | | | | | |
| Poor ventilation | 58 (46.0) | 422 (33.0) | 1.732 (1.197-2.506) | 0.004 | 1.347 (0.899-2.017) | 0.148 |
| Good ventilation | 68 (54.0) | 857 (67.0) | Ref | | Ref | |
| PPE | | | | | | |
| Inappropriate | 109 (86.5) | 791 (61.8) | 3.956 (2.344-6.676) | <0.001 | 1.930 (1.061-3.510) | 0.031 |
| Appropriate | 17 (13.5) | 488 (38.2) | Ref | | Ref | |

aOR: adjusted odds ratio; CI: confidence interval; COVID-19: coronavirus disease 2019; IQR: interquartile range; NA: not applicable; OR: odds ratio; PPE: personal protective equipment; Ref: reference

We found subjects who slept in the same room as someone with COVID-19 were significantly more likely to contract COVID-19 than subjects who cared for COVID-19 patients (OR = 5.046, 95% CI: 1.531-16.638, $p$ = 0.008). However, we found no significant difference in proportion of subjects who contracted COVID-19 between those who cared for patients with COVID-19 and having a conversation with someone (OR = 1.122; 95% CI: 0.368-3.417, $p$ = 0.840 or dining with someone (OR = 2.068, 95% CI: 0.626-6.831, $p$ = 0.233) (Table 2).

Subjects who used PPE improperly, were significantly more likely to contract COVID-19 than subjects who used PPE appropriately (OR = 1.930, 95% CI: 1.061-3.510, $p$ = 0.031) (Table 2).

Among subjects reporting a history of exposure to someone with COVID-19, the following factors were not significantly associated with contracting COVID-19: subject age, symptoms of the person with COVID-19, relationship with the person with COVID-19 and ventilation in the room (Table 2).

## DISCUSSION

In our study, having an underlying health condition was significantly associated with contracting COVID-19. This finding is in contrast to studies from Kuwait (Al Youha *et al*, 2021), Thailand (Sirijatuphat *et al*, 2022), India, (Dev *et al*, 2021) and Greece (Galanis *et al*, 2021) which reported finding no association between an underlying health condition and contracting COVID-19. However, in our study allergies were the most common underlying disease reported. A study from China reported a higher prevalence of allergies among COVID-19 patients than in the general population (Gao *et al*, 2022). A study from South Korea found a significant association between both allergic rhinitis and asthma and the occurrence of COVID-19 but no such association was seen between allergic dermatitis and the occurrence of COVID-19 (Yang *et al*, 2020).

In our study, we found no significant difference in the incidence of COVID-19 among frontline personnel and back-office personnel, similar to studies

from the United States (Jacob *et al*, 2021), Spain (Algado-Sellés *et al*, 2020) and India (Dev *et al*, 2021). However, among frontline personnel, physicians, nurses and nurse assistants were significantly less likely to contract COVID-19 than non-close-contact frontline subjects. Our finding is similar to studies from the United States (Moscola *et al*, 2020) and India (Dev *et al*, 2021). This may be due to the extra care taken among subjects who were exposed to COVID-19 patients more frequently and not only were these subjects more careful at work, they were more likely to be more careful outside work as well. Most of our non-close-contact frontline subjects contracted COVID-19 from family members or friends/colleagues. Our findings are similar to the studies from Thailand (Sirijatuphat *et al*, 2022), Spain (Algado-Sellés *et al*, 2020) and Taiwan (Cheng *et al*, 2020) that reported non-healthcare staff were more likely to contract COVID-19 than frontline personnel and nearly all infections were contracted due to contact with a person with COVID-19 outside the hospital.

In our study, subjects working on COVID-19 wards did not have a higher incidence of COVID-19 than subjects working on non-COVID-19 wards, similar to studies from the United States (Moscola *et al*, 2020), India (Dev *et al*, 2021) and Spain (Algado-Sellés *et al*, 2020). A reason for this lack of difference in the incidence of COVID-19 by ward type could be that subjects working on COVID-19 wards are aware the subject had COVID-19 on admission so used full PPE. Using full PPE appears to have been effective in reducing risk of contracting COVID-19.

In our study, subjects who slept in the same room as someone with COVID-19 were significantly more likely to contract COVID-19 than providing care for COVID-19 patients. Studies from Taiwan (Cheng *et al*, 2020), China (Liu *et al*, 2020) and Thailand (Sirijatuphat *et al*, 2022) reported finding subjects were more likely to contract COVID-19 from family members and sleeping partners than in the healthcare setting. Being in a room with someone with COVID-19 without PPE for long periods, such as in a bedroom, can increase the

risk of contracting COVID-19 (Jones *et al*, 2020).

In our study, subjects without a history of exposure to a COVID-19 patient were more likely to have contracted COVID-19 than subject with a history of exposure to patient with COVID-19, in contrast to a previous study from the United States (Jacob *et al*, 2021). A study from Japan of screening serology for COVID-19 found 30% of subjects without a known history of exposure to someone with COVID-19 had antibodies showing they had a previous COVID-19 infection (Arashiro *et al*, 2022). Some people with COVID-19 are asymptomatic (Gao *et al*, 2021) or have only mild symptoms resembling a common cold (Guo *et al*, 2020; Stokes *et al*, 2020). Patients with asymptomatic COVID-19 may still be contagious (Johansson *et al*, 2021) and patients who later become symptomatic may be contagious before symptoms begin (Gregory and Hall, 2024; Walsh *et al*, 2020) increasing their chances of spreading the virus to others.

In our study, subjects who used PPE improperly were significantly more likely to contract COVID-19, similar to the findings of studies from Spain (Algado-Sellés *et al*, 2020), South Africa (Dzinamarira *et al*, 2022), the United States (Nguyen *et al*, 2020), India (Dev *et al*, 2021) and Thailand (Sirijatuphat *et al*, 2022). This shows the importance of correct PPE use in the prevention of COVID-19 among healthcare workers.

In summary, the key factors associated with COVID-19 among healthcare personnel identified in this study were: having an underlying health condition, being frontline personnel except for physicians, dentists, nurses and nurse assistants, sleeping in the same room as someone with COVID-19, not having a history of exposure to a person with COVID-19 and improper PPE use. Important findings where no association was found were the finding that frontline staff and back-office staff had the same incidence of COVID-19 and subjects who worked on COVID-19 wards had the same incidence of COVID-19 as subjects who worked on non-COVID-19 wards. Subjects who did not perceive a risk for contracting COVID-19 due to being in a lower

risk position were more likely to contract COVID-19 and a large proportion of subjects contracted COVID-19 from exposures outside the hospital. This suggests efforts to prevent contracting COVID-19 among study subjects should focus on lower risk personnel and workers should be informed about the risks of contact outside the hospital. Further studies are needed to determine if educating this study population about this risk will reduce the incidence of contracting COVID-19 in the study population.

## ACKNOWLEDGEMENTS

We would like to acknowledge Asst Prof Dr Sukhontha Siri, Faculty of Public Health, Mahidol University and Suchada Srisarang, Clinical Research Unit, QSNICH for statistical analysis consultation, Methinee Srisothornwongse for English language correction, and all the nurses and nurse assistants, Infection Prevention and Control Nursing Department, QSNICH for data collection.

## CONFLICT OF INTEREST DISCLOSURE

The authors declare that they have no known competing financial interests or personal relationships that could influence the study reported in this paper.

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