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EDITORIAL STATEMENT

ORIGINAL ARTICLES

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Editorial Statement: The Last Issue of Vajira Medical Journal: Journal of Urban Medicine

Jitti Hanprasertpong MD

Editor-in-Chief,
Vajira Medical Journal: Journal of Urban Medicine

With this issue, we mark the final publication under the name *Vajira Medical Journal: Journal of Urban Medicine*. Since its inception in 1957, the journal has served as a trusted platform for disseminating high-quality research, including basic sciences, clinical insights, and medical innovations from the Vajira Hospital community and beyond in Thailand. Over the years, it has grown significantly in the number of high-quality submissions, the diversity of contributing authors, the volume of citations, and the breadth of its readership. This progress has been recognized by its recent inclusion in Tier 1 of the Thai-Journal Citation Index (TCI), as officially announced by the TCI Center on February 4th, 2025.

We are proud to announce that, beginning with our next issue, the journal will be relaunched under the new title *Journal of Medicine and Urban Health*. This change signifies far more than a new name—it marks a comprehensive transformation in our identity, vision, and global engagement. To support this transition, we have welcomed a distinguished group of national and international editorial board members who bring diverse expertise and a strong commitment to academic excellence. Our goal is to establish a leading international platform for research that addresses medical and public health challenges, with a particular focus on urban populations around the world.

We are also pleased to share that the journal's next major goal is to be indexed in Scopus or another internationally recognized database—an important step in expanding our global reach and impact. As we move forward under our new name, we remain firmly committed to publishing high-quality, peer-reviewed content that integrates clinical research (including basic science), medical innovation, public health, and health policy—particularly within the context of urban health.

We extend our sincere gratitude to our contributors, reviewers, and readers for your continued support. This transition is not an end, but the beginning of an exciting new chapter.

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Corresponding author: Jitti Hanprasertpong
E-mail: jitti.han@nmu.ac.th, hjitti@yahoo.com
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Original Article

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Prevalence, Symptoms, and Associated Factors of Long COVID-19: A Cross-Sectional Survey Study

Rapeephan R Maude MD[1], **Siriwan Tangjitgamol** MD[2], **Kasem Sirithanakul** MD[1], **Yanisa Duangduen** MNS[2], **Natapon Ativanichayapong** BSC[2]

[1] *Internal Medicine Center, MedPark Hospital, Bangkok 10110, Thailand*
[2] *Research Center, MedPark Hospital, Bangkok 10110, Thailand*

ABSTRACT

OBJECTIVE: Long COVID is defined as persistent or newly developed symptoms after the acute phase of COVID-19 infection. This study aimed to evaluate the prevalence of long COVID, types of symptoms, and associated factors.

METHODS: This was a cross-sectional survey including individuals with a history of COVID-19 infection aged ≥ 18 years who were followed up at our hospital. The presence of abnormal symptoms and clinical features were obtained through a questionnaire.

RESULTS: A total of 307 individuals with a median age of 58 years (interquartile range 35–74 years) were included in this study. Among them, 53.1% were females, and 56.0% had underlying diseases. The prevalence of long COVID was 40.1%. Cardiopulmonary (36.6%) and nonspecific general symptoms (22.0%) were the most common symptoms. We did not find significant association long COVID and any characteristic features of the participants, numbers of COVID vaccination or infection episodes.

CONCLUSION: The prevalence of long COVID was 40.1%. No factors significantly associated with long COVID were observed. Cardiopulmonary and general symptoms were the most common symptoms.

KEYWORDS: cardiopulmonary symptoms, COVID-19 infection, long COVID

INTRODUCTION

In 2020, the coronavirus disease 2019 (COVID-19) pandemic was declared a global health emergency by the World Health Organization (WHO). The WHO reported approximately 515 million COVID-19 cases and 6.25 million deaths worldwide by 2022. In Thailand, 4.71 million cases and 33,505 deaths were reported[1]. Although the Centers for Disease Control and Prevention recommends that unvaccinated individuals initiating the COVID-19 vaccination series receive a third dose[2] or above can help to reduce effect from COVID-19 infection[3], data from the Israeli Ministry of Health show that the incidence of COVID-19 infection and severe illness declined significantly following the administration of a third (booster) dose[4]. However, long COVID conditions have still been reported[5].

COVID-19 infection can have short- and long-term effects. COVID-19 symptoms, such as fever, chills, coughing, tiredness, muscle pain, headache, loss of taste and smell, sore throat, stuffy or runny nose, nausea or vomiting, diarrhea, and pale or purple color of skin, lips, or fingernails, may manifest within 2-14 days

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after infection[6]. Severe cases may experience chest pain, shortness of breath, progressive respiratory failure, confusion, or unconsciousness[6].

After recovery, some patients may continue to experience lingering symptoms or develop new abnormalities. According to the Centers for Disease Control and Prevention, the post-COVID-19 condition or "long COVID" is a phenomenon confronting the global community[6]. The WHO has defined long COVID as the persistence or emergence of symptoms within 3 months after the infection, lasting at least 2 months[7]. Others also specified that complications resulting from the acute phase of infection are not classified as part of long COVID[8].

Various symptoms can serve as indicative measures for long COVID, such as (1) general symptoms (exhaustion, fatigue, postexertional malaise, and fever); (2) cardiopulmonary symptoms (shortness of breath, dyspnea, chest pain, and unexplained tachycardia); (3) neurological symptoms (brain fog, memory loss, headache, insomnia, sleep disorder, numbness, loss of taste or smell, depression, and anxiety); (4) gastrointestinal symptoms (diarrhea and stomachache); (5) other nonspecific symptoms (joint pain, muscle pain, rash, and abnormal menstruation)[9]. Several studies have investigated the efficacy of vaccination and the course of acute COVID-19 infection. Additionally, many studies[10-17] and systematic literature reviews have been conducted on long COVID[18-25]. Moreover, a study found that older participants had higher rates of long COVID symptoms compared to younger individuals[26].

Our hospital provided medical services to many patients with COVID-19 during the outbreak. Our healthcare support was extended beyond the initial treatment to posttreatment surveillance with a scheduled follow-up visit. Half of the COVID-19 infections occurred in the central region of Thailand[27], where our hospital is located. Therefore, collecting data on the long-term effects of COVID-19 infection from an Asian perspective can provide valuable insights.

This study aimed to evaluate the prevalence of long COVID among previously infected individuals, the type of symptoms, and associated factors.

METHODS

This cross-sectional survey study was conducted at our hospital between February 1, 2021, and June 30, 2022. This study was approved by the Institutional Review Board (COA-MPIRB 004/2022). The requirement for informed consent was waived due to the nature of the study.

The sample size was determined using Cochran's Formula[28] ($N = Z^2P(1-p)/e^2$) based on data from a previous study that reported an 80% prevalence of long COVID among COVID-19 cases[18]. The population proportion was 0.8 ($p = 0.8$), the reliability level of this study was 95% ($Z = 1.96$), and acceptable sampling error was 0.05 ($e = 0.05$); therefore, a minimum of 246 participants were required to collect data in this study. After adding an attrition rate of 10%, at least 270 participants were required.

This study collected data by using the purposive sampling method. The inclusion criteria were individuals aged > 18 years with a history of COVID-19 infection within the past 14 days, who had received treatment at our hospital/hospitals network, and those who had scheduled follow-ups (in-hospital or telephone) with a physician during the study period. The exclusion criteria were individual who did not attend follow-up appointments at hospital, could not be contact, or declined to participate in the study. The researcher collected data from the Electronic Medical Record of the hospital.

After the participants were informed about the study, they were interviewed according to the questionnaire during their in-hospital or telephone follow-up. The questionnaire comprised three parts: part I involved demographic data, including age, gender, weight, height, and personal illnesses; part II was about the history of COVID-19 vaccination, including the vaccine type and

self-report side effects severity from vaccination, history of COVID-19 infection, including time of diagnosis; part III included the change of health status after COVID-19 infection and current symptoms.

Data analysis was performed using IBM SPSS Statistics for Windows, Version 22.0 (IBM Corporation, Armonk, NY, USA). Normally distributed data were presented as mean ± standard deviation, continuous data as median and interquartile range (IQR), and categorical data as frequencies with percentages. The prevalence of long COVID was determined based on the presence of any abnormal symptoms persisting or newly developed at least 30 days after recovery from acute illness or hospital discharge[19,29]. The interval between the last COVID-19 vaccination and infection and between the infection and long COVID symptom assessment were calculated. The presence of long COVID and the type of common symptoms according to sociodemographic features, history of COVID-19 vaccination, and COVID-19 infection were examined. The association was investigated by categorizing the data as follows: age as < 60 or ≥ 60 years; body mass index (BMI) as < 30 kg/m^2 or ≥ 30 kg/m^2 [30]; underlying diseases as yes or no; number of vaccinations as ≤ 3 or > 3[3]; self-report side effects severity from vaccination as no/mild or moderate/severe; and episode of COVID-19 infection as once or more. Between-group comparisons were performed using Pearson's Chi-square test or Fisher's exact test, as appropriate. Significant features from the univariate analysis were analyzed using logistic regression to identify independent risk factors associated with long COVID. A p-value of 0.05 indicated statistical significance.

RESULTS

A total of 314 individuals who underwent either in-hospital or telephone follow-ups by our hospital staff were enrolled in this study. Of the 314 individuals, 7 were excluded due to being < 18 years old. Finally, 307 patients met the inclusion criteria and were included in the study. Of the 307 patients, 120 had follow-up visits, and 187 received telephone follow-ups.

The median age of the participants was 58 years (IQR 35–74 years), and 53.1% were females. The mean BMI was 24.0 ± 4.5 kg/m^2, with 26.0% being overweight (≥ 25 kg/m^2) and 9.1% obese (≥ 30 kg/m^2) (Table 1). Among 172 individuals (56.0%) who had underlying diseases, 109 (35.5%) had multiple illnesses with more than one system involvement, followed by cardiovascular disease including hypertension in 23 (7.5%) and endocrine disorders including diabetes mellitus in 14 (4.6%).

Table 1 Baselines characteristics of the total participants

Baselines characteristics	n	%
Age		
< 60 years	158	51.5
≥ 60 years	149	48.5
Gender		
Male	114	37.1
Female	163	53.1
Body mass index		
< 30 kg/m^2	279	90.9
≥ 30 kg/m^2	28	9.1
Underlying disease		
No	135	44.0
Yes	172	56.0

Table 1 Baselines characteristics of the total participants (continued)

Baselines characteristics	n	%
Number of vaccination		
≤ 3	165	53.7
> 3	142	46.3
Vaccine side effects		
No/ mild	281	91.5
Moderate/ severe	26	8.5
Number of COVID infection		
Once	289	94.1
More than once	18	5.9
Interval from infection to survey		
< 3 months	81	26.4
3 to < 6 months	45	14.7
6 to < 12 months	62	20.2
> 12 months	119	38.8

Abbreviations: kg/m^2, kilogram per square metre; n, number

After excluding 17 patients (5.5%) who never received COVID-19 vaccination, the remaining patients received a median of 3 doses (IQR 2.25–4.0 doses). A total of 1,006 doses were administered, with AstraZeneca and Pfizer as the most frequently used as 365 doses (36.3%) and 236 doses (23.4%), respectively. On the other hand, the percentages of COVID vaccine received for the individuals were AstraZeneca (66.4%), Pfizer (53.9%), Moderna (36.6%), Sinovac (28.5%), Sinopharm (10.2%), and Evusheld (0.7%). Of note, one participant may have one or more types of vaccines.

Episodes of COVID-19 infection ranged from 1 to 3: 94.1% of the participants had one episode, 5.2% had two episodes, and 0.7% had three episodes. Of the two participants with three episodes of infection, one had never received COVID-19 vaccination, whereas the other had already received six doses. The median interval from the preceding COVID-19 vaccination to the following infection was 23 weeks (IQR 12.3–31.0 weeks).

The median interval from (the latest) infection to the survey was 8.8 months (IQR 2.9–16.0 months; range 1.1–18.6 months). The interval was < 3 months in 26.4% of the participants, 3 months to < 6 months in 14.7%, 6 months to < 12 months in 20.2%, and > 12 months in 38.8%.

At the time of our assessment, 40.1% of the participants reported one or more abnormal symptoms after the acute phase of COVID-19 infection. The most common symptoms were cardiopulmonary symptoms (36.6%) and general symptoms (22.0%). Notably, 12.7% of the participants had multiple symptoms (Table 2). Among the 27 symptoms from 123 participants, 230 events were reported. Figure 1 shows the numbers and percentages of symptoms. Tiredness (25.2%), cough (25.2%), and breathing difficulty (10.0%) were the most common symptoms. Notably, of the 172 participants with preexisting illnesses, the conditions remained unchanged in 58.2%, worsened in 8.7%, and improved in 33.1%.

Furthermore, the prevalence of long COVID was investigated at different time points of assessment. The prevalence was highest (55.6%) with an interval of assessment between 3 months and < 6 months, followed by an interval between 6 months and < 12 months (46.8%) and within 3 months (40.7%). The prevalence decreased to 30.3% with an interval of > 12 months.

Table 2 Health condition after COVID-19 infection (n = 307)

Health condition after COVID-19 infection	n (%)
Abnormal symptoms	
None	184 (59.9)
Yes, systems involvement	123 (40.1)
General symptoms	27 (22.0)
Cardio-pulmonary symptoms	45 (36.6)
Neurological symptoms	2 (0.7)
Gastrointestinal symptoms	1 (0.3)
Musculoskeletal symptoms	1 (0.3)
Skin symptoms	8 (2.6)
Multiple symptoms	39 (12.7)
Status of pre-existent illnesses after COVID-19 infection, n=172 (56.0%)	
Stable or the same	100 (58.2)
Worse	15 (8.7)
Better	57 (33.1)

Abbreviation: n, number
Note: Percentage of each symptom obtained from number of affected individuals

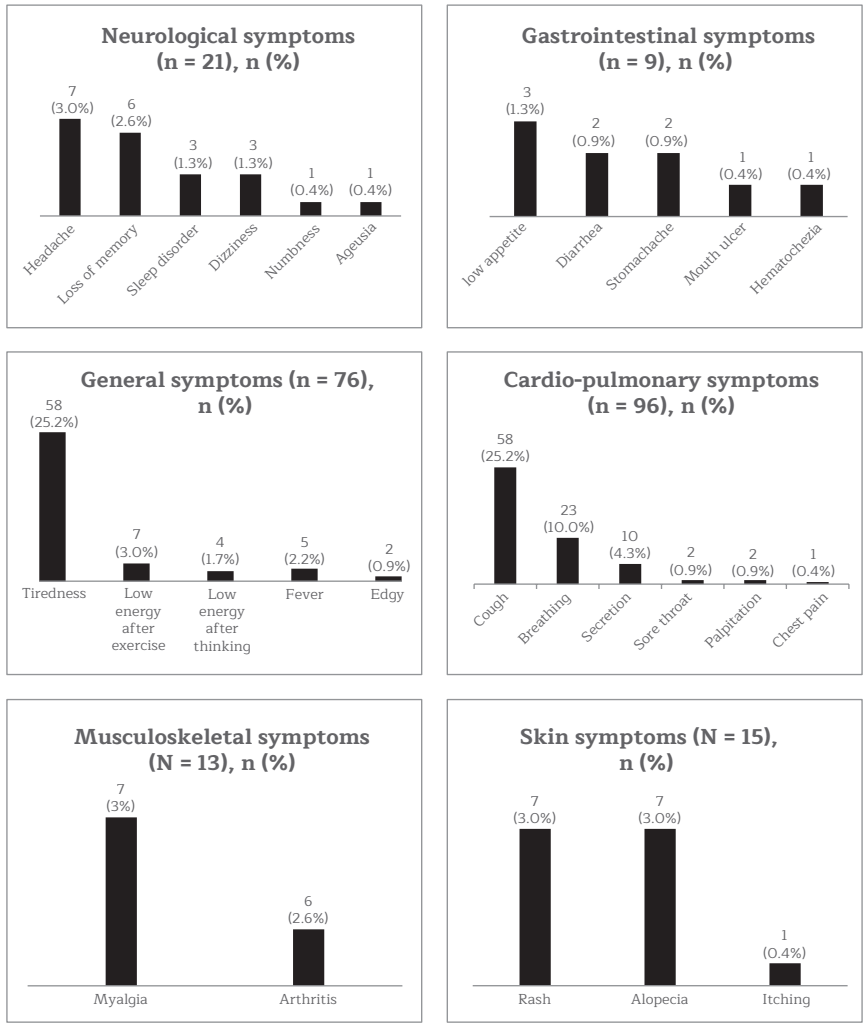

Figure 1 Number and percentages of long COVID symptoms among all symptoms by system of involvement

The association between the presence of long COVID and the characteristic features of the participants and the history of COVID-19 vaccination and infection was also investigated (Table 3). The univariate analyses revealed that moderate/severe side effects from vaccination (odds ratios [OR] 1.84), BMI ≥ 30 kg/m^2 (OR 1.56), COVID-19 infection more than once (OR 1.54), vaccination > 3 doses (OR 1.47), female (OR 1.44), age ≥ 60 years (OR 1.20), and presence of underlying diseases (OR 1.19) were associated with a higher prevalence of long COVID. However, the association was not statistically significant.

The characteristic features of the participants were analyzed according to the three common symptoms encountered: tiredness, cough, and breathing difficulty. The analysis revealed that the presence of underlying diseases and vaccination > 3 doses were significantly associated with tiredness (23.3% vs. 13.3%, p = 0.03 and 23.9% vs. 14.5%, p = 0.04, respectively), and obesity was significantly associated with cough (35.7% vs. 17.2%, p = 0.02) and breathing difficulty (17.9% vs. 6.5%, p = 0.05).

Table 3 Factors association with long COVID-19 conditions

Clinical characteristics	N=307	Long COVID-19 (%)		Crude odds ratio (95% CI)	P-value
		None	Yes		
Age					
< 60 years	158	98 (62.0)	60 (38.0)	-	-
≥ 60 years	149	86 (57.7)	63 (42.3)	1.20 (0.76-1.90)	0.441
Gender					
Male	114	93 (64.6)	51 (35.4)	-	-
Female	163	91 (55.8)	72 (44.2)	1.44 (0.91-2.29)	0.118
Body mass index					
< 30 kg/m^2	279	170 (60.9)	109 (39.1)	-	-
≥ 30 kg/m^2	28	14 (50.0)	14 (50.0)	1.56 (0.72-3.40)	0.260
Underlying disease					
No	135	84 (62.2)	51 (37.8)		
Yes	172	100 (58.1)	72 (41.9)	1.19 (0.75-1.90)	0.469
Number of vaccination					
≤ 3	165	106 (64.2)	59 (35.8)	-	-
> 3	142	78 (54.9)	64 (45.1)	1.47 (0.93-2.33)	0.097
Vaccine side effects					
No/ mild	281	172 (61.2)	109 (38.8)	-	-
Moderate/ severe	26	12 (46.2)	14 (53.8)	1.84 (0.82-4.13)	0.134
Number of COVID infection					
Once	289	175 (60.6)	114 (39.4)		
More than once	18	9 (50.0)	9 (50.0)	1.54 (0.60-3.98)	0.375
Interval from infection to survey					
< 3 months	81	48 (59.3)	33 (40.7)	Reference	
3 to < 6 months	45	20 (44.4)	25 (55.6)	1.82 (0.88-3.80)	0.112
6 to < 12 months	62	33 (53.2)	29 (46.8)	1.28 (0.66-2.50)	0.471
> 12 months	119	83 (69.7)	36 (30.3)	0.63 (0.35-1.14)	0.127

Abbreviations: CI, confidence interval; kg/m^2, kilogram per square metre; n, number
P-value = .05 was considered statistically significant.

DISCUSSION

This study showed that 40.1% of the participants who were infected with COVID-19 experienced long COVID. This rate was in the range reported in previous studies and systematic reviews (Table 4). The prevalence from each single study varied from 27% to 90%[6-17]. The prevalence of 40.1% demonstrated in this study was close to the pooled prevalence of 42%–45% from two large systematic reviews[21,23] or 49% from the most recent systematic review[25].

Table 4 Summary of selected systematic reviews and single studies of long COVID

Author, year[ref]	Study period	Population, N (studies)	Definition of persistence or *timing of survey	Prevalence	Features	Symptoms (one may have > 1 symptom)
Systematic review with or without meta-analysis						
Lopez-Leon, 2021[18]	til Jan 2021	47,910 (15 studies, each > 100 patients)	≥ 14- 110 days after infection*	80%	NA	• Fatigue 58% • Headache 44% • Attention disorder 27% • Hair loss 25% • Dyspnea 24%
Nasserie, 2021[19]	Jan 2020 to Mar 2021	9,751 (45 studies)	≥ 60 days after onset or ≥ 30 days after recovery	72.5%	NA	• Fatigue/exhaustion 40% • Breathlessness 36% • Sleep disturbance 29%
Maglietta, 2022[20]	til Sep 2021	13,340 (20 studies)	≥ 4 months	NA	Risk: female, disease severity	NA
O'Mahoney, 2022[21]	til Jan 2022	735,006 (194 studies, each > 100 patients)	≥ 28-387 days after infection*	37.8%	NA	• Abnormal CT/X-rays 45% • Fatigue 28% • Breathlessness 18% • Impaired activity, taste loss 15% each • Loss of smell 14%
Notarte, 2022[22]	til Sep 2022	2,000,973 (37 studies)	≥ 2 months	NA	Risk: female, comorbidities Non-risk: elder	NA
Woodrow, 2023[23]	Jan 2020 to Nov 2021	NA (130 studies in English, each > 100 patients)	≥ 4-12 months of follow-up*	0%–93% (pooled estimate 42.1%)	Risk: hospitalization, severity of acute infection	• Fatigue 22% • Breathlessness 15% • Sleep disturbance 13% • Tingling/ itching, joint/muscle pains 11% each
Tsampasian, 2023[24]	Dec 2022 to Feb 2023	860,783 (41 studies)	≥ 3 months	NA	• Risk: elder, female, obesity, smoking, comorbidities, hospitalization, admit ICU • Lower risk: 2-doses vaccination	NA
Frallonardo, 2023[25]	til Feb 2023	29,213 (25 studies from African countries)	≥ 0.5-12 months of follow-up*	48.6%	• Risk: elder, hospitalization	• Fatigue 35% • Psychiatric conditions 26% • Dyspnea 18% • Myalgia 16% • Loss of appetite 13% • Cough 11% • Weight loss 10%

Table 4 Summary of selected systematic reviews and single studies of long COVID (continued)

Author, year[ref]	Study period	Population, N (studies)	Definition of persistence or *timing of survey	Prevalence	Features	Symptoms (one may have > 1 symptom)
Single study						
Wong, 2023 (cross-sectional survey)[10]	June 2022	2,712	≥ 3 months	90.4%	• Risk: female, smoking, poor self-perceived health status, comorbidities, medication use, severity of infection, Lower risk: 2-doses vaccination	• Fatigue 34% • Cough 32% • Sore throat, attention disorder 31% each • Anxiety, myalgia, arthralgia 30% each
Jang, 2023 (descriptive)[11]	July-Aug, 2021	585	≥ 1 month	27.2%	• Risk: hospitalization • Non-risk: gender, elder, underlying disease, ethnicity	• Loss of smell 60% • Sore throat 38% • Fever, chills, cough 37% each
Chelly, 2023 (cross-sectional)[12]	Mar 2020 - Feb 2022	1,911	≥ 2 months	46.5%	• Risk: female, elder, obesity, comorbidities • Lower risk: complete anti-COVID vaccination	• Fatigue 64% • Memory, attention disorder 49% each • Hair loss 48% • Mood swings 41% • Sleep disturbance 39% • Depression, anxiety 36% each • Difficulty finding words, irritability 34% each • Joint pain, headache 32% each
Cazé, 2023 (prospective)[13]	Sep 2020 - Apr 2021	814	> 1 month	29.6%	• Risk: elder, having > five symptoms during the acute phase	• Fatigue 14% • Olfactory disorder 10% • Myalgia 9% • Gustatory disorder 7% • Headache 6%
Subramanian, 2022 (retrospective)[14]	Jan 2020 - Apr 2021	2,430,729	≥ 3 months	NA	• Risk: elder, female, ethnic, smoking, comorbidities, obesity, low socioeconomic	• Anosmia, hair loss, sneezing, ejaculation difficulty, reduced libido
Phu, 2023 (cross-sectional)[15]	Jan 2021 - May 2022	939	≥ 3 months	79.3%	• Risk: female, underlying disease, low socioeconomic	• Fatigue 73% • Cough 66% • Muscle pain 54% • Insomnia, headache 49% each • Joint pain 45% • Breathlessness 44% • Dizziness 42% • Amnesia 41% • Hair loss 30% • Palpitation 25% • Chest tightness 15% • Asthenia 13%
Debski, 2022 (cross-sectional)[16]	til Feb 2021	1,487	≥ 1 month	52.1%	• Risk: female, obesity	• Fatigue 58% • Headache 44% • Attention disorder 27% • Hair loss 25% • Dyspnea 24%
Somboonviboon, 2024[17]	Sep 2021 to Jan 2022	277	> 4 week after infection	80.9%	• Risk: female, oxygentherapy	• Dyspnea 48.2% • Insomnia 42.4% • Myalgia 42.1% • Fatigue 41.4% • Brain fog 37.8%

Abbreviations: n, number; NA, not applicable; ref, reference

This wide range of prevalence may be due to many factors. First, no clear consensus has been reached on the definition of long COVID[21,22], resulting in various timing criteria of symptom onset in each study (Table 4). Second, the proportion of participants with risk features for long COVID in each study, such as older age, low socioeconomic background, female gender, existing illness, obesity, smoking, history of COVID-19 vaccination, or type of participants regarding the severity of infection reflected by simple community or complexed hospital healthcare, absence of awareness, or little access to healthcare services, might have affected the prevalence[2,12-14,16,20,22,23-25]. Third, data collection or symptom assessment methods might have influenced the long COVID detection rate. For example, studies using telephone interviews reported 27%–30% prevalence[7,9], whereas other studies reported 52% prevalence based on systematic pathological investigations, 44% based on self-report, and only 14% based on medical record review[23].

This study set a 30-day interval after recovery to ensure that the symptoms were not due to active infection. This interval was set based on previous studies[19,20]. The modest prevalence of long COVID in this study may be due to some features. The participants had risk features in mixed proportions. Nearly half of the participants were aged ≥ 60 years, and slightly more than half of them were female or had comorbidities. These risk factors should be considered for long COVID. However, some features in this study may carry a lower risk profile. For example, only a few were obese, and almost all had COVID-19 vaccination and had mixed types of medical services either in hospitals of our service (less severe infection) or in the hospital (more severe infection). The interval between the survey and infection and follow-up duration were factors that may have impacted the prevalence. The highest prevalence of long COVID was observed with an interval of assessment of 3-6 months (55.6%), whereas the lowest was observed with an interval of > 12 months. These findings indicate that the participants were concerned about their symptoms as time passed beyond a recuperation period. Conversely, a lower prevalence with a long interval of assessment could be interpreted as the symptoms had resolved over time.

This study showed that 7 features were associated with a higher prevalence of long COVID, including age ≥ 60 years, female gender, BMI ≥ 30 kg/m^2, presence of underlying diseases, history of side effects from vaccination, having COVID-19 infection more than once, and interval from last infection to survey of < 6 months. Some of these risk features for long COVID were also reported in previous studies (Table 4). Although the features identified in this study were not statistically significant, the findings may be useful for comparison with previous studies.

In this study, the factor with the highest risk was moderate/severe side effects from vaccination (OR 1.84). A systematic review reported controversial findings regarding the impact of vaccination on long COVID development, either increasing the prevalence or having no effect at all[31]. Obesity (OR 1.56) and COVID-19 infection more than once (OR 1.54) were other features that posed a higher risk for long COVID in this study. Few studies[14,16] and systematic reviews[22,24] have reported an association between higher BMI or obesity and long COVID. Obesity with a metabolic proinflammatory process may enhance the inflammatory process in many organs, leading to severe or prolonged symptoms[14,16]. Several studies have reported an association between long COVID and severe acute infection[10,20,14]. Consistent with our finding, only one study showed an increased risk of long COVID after reinfection, even in vaccinated individuals[32]. Multiple infections may cause additional susceptibility to myalgic encephalomyelitis or chronic fatigue syndrome[33]. Consistent with

many single studies[10-16] and systematic reviews[18-25], female preponderance for long COVID was observed (OR 1.44). The higher incidence of long COVID among females may be due to sex hormones and higher immunoglobulin G antibodies in the early phase of the disease, leading to a higher risk of severe disease in females than in males even after recovery[34,35].

This study reported that age ≥ 60 years was a risk factor for long COVID (OR 1.20). This may be due to weak immunity and organ dysfunction, leading to poor recovery or persistent symptoms[36]. These findings are consistent with those of previous studies[12,13] and systematic reviews[24,25]. However, other studies did not show consistent findings. Some studies reported that age > 40 years was associated with lower risk[14], whereas others did not show such association[22].

Previous studies have shown an association between the presence of underlying diseases and long COVID[10,14,15,22,24]. However, our study showed a weak association between long COVID and underlying diseases (OR 1.19). We could not compare the system and severity of preexisting illnesses, which might affect the prevalence of long COVID, across the studies.

In contrast to the other studies, this study showed that vaccination > 3 doses was slightly associated with a higher risk of long COVID (OR 1.47). Other studies have found a lower risk of long COVID with at least 2 doses[10,24] or complete doses of vaccination[12]. This could be due to younger age or the absence of comorbidities in patients receiving fewer than three doses. Moreover, we remains unknown due to the uncertain safety of some COVID-19 vaccinations[37] and mixed vaccination types.

This study showed that cardiopulmonary symptoms (36.6%) were the two most prevalent symptoms, followed by general symptoms (22.0%) (Table 2). These findings are consistent with those reported in most previous studies and systematic reviews, but the order of frequency differs (Table 4)[10-13,15,18,19,22,23,25].

This study investigated features associated with the three common symptoms observed in this study: tiredness (25.2%), protracted cough (25.2%), and breathing difficulty (10.0%). A higher frequency of these symptoms was observed in certain groups: tiredness in individuals with underlying diseases and vaccination > 3 doses; cough and breathing difficulty in patients with obesity. Although the numbers in each subgroup analysis were small, and it was challenging to explore the underlying reasons for all such findings, especially when data on affected systems during the acute phase of infection were lacking, we proposed possible explanations for these findings. The presence of underlying diseases or > 3 COVID-19 vaccinations might have affected immunity, resulting in tiredness or a sense of agility. Regarding the significant association between breathing difficulty or protracted cough and obesity, it is quite clear that obesity with lower lung capacity can result in these symptoms[38].

This study has some limitations. First, this was a survey study, it is subject to potential recall bias on self-reported symptoms, which were not verified through medical examination. This may have led to an under- or overestimation of the prevalence. Second, data on the severity of infection, which may have influenced the presence of long COVID, were unavailable. Third, there is a risk of selection bias, as the study included only patients who were reachable or had a follow-up visit, which may limit the generalizability of the findings to rural areas or non-hospitalized patients. Moreover, cross-sectional study precludes the ability to establish causal relationships. Fourth, the questions were the items used in usual practice, so validation process was not performed. This might have led relative non-thorough of the questionnaire. Finally, the actual onset of symptoms was not recalled in most of the participants, and the remedies for such symptoms, which varied, could not be systemically summarized.

Despite these limitations, this study provided valuable data from our country, which is such information, particularly regarding the number of vaccine doses received and the incidence of COVID-19 infection, that has been limited. Further research in diverse settings is needed to explore the clinical implications of these findings in a broader population. Additionally, a long survey follow-up period should have revealed the duration of symptoms and the dynamic nature of long COVID symptoms. The findings of this study indicate that patients with COVID-19 infection and healthcare providers should be aware of long COVID. Additionally, an appropriate follow-up and medical care plan for this condition should be implemented.

CONCLUSION

Nearly half of the participants in this study experienced long COVID. Future studies should focus on reliable measures with direct questions about these proposed factors. This should be coupled with a thorough medical examination that will yield more reliable data on this morbidity for the future development of public health policies. Patients with COVID-19 infection and healthcare providers should be aware of the long-term COVID symptoms which may have disturbed the affected individuals' health and well-being. Healthcare services should be extended beyond the acute phase of infection.

CONFLICT OF INTEREST

The authors have no conflicts of interest associated with the material presented in this paper.

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DATA AVAILABILITY STATEMENT

Data generated or analyzed during this study are included in this article. Future enquiries can be directed to the corresponding author.

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Original Article

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Assessing COVID-19 Preparedness and Perception among Thai Paramedics in Thailand: A Cross-Sectional Study

Pramote Papukdee MNS[1], Thanawoot Kanha BSc (Paramedicine)[2], Krittatath Muangkhot BSc (Paramedicine)[2], Kransara Sangcharoen BSc (Paramedicine)[2], Chomchanok Gaerlan BSc (Paramedicine)[2], Supakorn Sae-wong BSc (Paramedicine)[2], Aphisit Moolsombat BSc (Paramedicine)[2], Thongpitak Huabbangyang PhD[1], Areeya Jirathananuwat PhD[3]

[1] *Department of Disaster and Emergency Medical Operation, Faculty of Sciences and Health Technology, Navamindradhiraj University, Bangkok 10300, Thailand*
[2] *Bachelor of Science Program in Paramedicine, Faculty of Medicine Vajira Hospital, Navamindradhiraj University, Bangkok 10300, Thailand*
[3] *Department of Health Technology, Faculty of Sciences and Health Technology, Navamindradhiraj University, Bangkok 10300, Thailand*

ABSTRACT

OBJECTIVE: The coronavirus disease (COVID-19) outbreak has had widespread impacts on global public health systems, including Thailand's. Preparedness for public health emergencies is therefore critical. This study aimed to assess Thai paramedics' operational preparedness and perception in response to the COVID-19 pandemic.

METHODS: A cross-sectional descriptive study was conducted among 225 paramedics in Thailand. Data were collected via an online questionnaire between August and December 2021, covering general information, perceptions of infectious diseases, and COVID-19 response preparedness. The questionnaire on preparedness was a binary response format, with yes scored as 1 and no scored as 0. In contrast, the questionnaire on COVID-19 perception was measured using a 5-point rating scale, with the lowest score being 1 and the highest score being 5. The results were then categorized into three levels: high, moderate, and low. Analyses included frequencies, percentages, means, and standard deviations. Logistic regression was used to assess relationships between basic characteristics, perceptions, and preparedness.

RESULTS: Operational preparedness was moderate, with structural preparedness at 53.3% and operational preparedness at 54.2%. Only 38.7% of the participants were fully prepared across all aspects. Meanwhile, perceived was found to be at a high level for both risk perception and perceived severity (mean scores: 4.50 ± 0.44 and 4.60 ± 0.44 respectively). Logistic regression identified key predictors of preparedness: prior training in COVID-19 patient management (adjusted odds ratio (OR) = 1.79, 95% confidence interval (CI) = 1.01-3.17) and hands-on experience with COVID-19 patients (adjusted OR = 3.33, 95%CI = 1.56-7.12).

CONCLUSION: Integrating knowledge with practical experience enhances emergency preparedness. To improve readiness, capacity development through targeted training, simulation exercises, and real-world practice opportunities is essential for paramedics.

KEYWORDS: COVID-19, cross-sectional studies, emergency medical services, paramedics, preparedness, risk perception

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INTRODUCTION

The coronavirus disease 2019 (COVID-19) outbreak has profoundly impacted healthcare systems worldwide, including Thailand's. The first confirmed case in Thailand was reported in January 2020, making it the first country outside China to detect the virus. As the pandemic evolved, Thailand experienced several waves of infection, with major outbreaks occurring in March 2020, April 2021, and mid-2022. As the pandemic intensified, it strained medical and public health operations, exposing critical challenges such as healthcare workforce shortages, insufficient protective and treatment supplies, difficulties in transporting infected patients, and contamination control issues. In response, the World Health Organization (WHO) declared COVID-19 a public health emergency of international concern[1].

Thailand's Ministry of Public Health classified COVID-19 as the 14th dangerous communicable disease under the Communicable Diseases Act, enforcing stringent surveillance, prevention, and control measures[2,3]. During this crisis, the Emergency Medical Services (EMS) system became pivotal in delivering prehospital care and ensuring safe patient transport. Maintaining high preparedness among EMS personnel is thus essential for effective emergency response.

The National Institute for Emergency Medicine (NIEM) of Thailand reported operational disruptions during the pandemic, including delayed emergency dispatches and suspended services by some organizations due to safety concerns. To address these challenges, NIEM established the Special COVID-19 Operation Team (SCOT) to optimize infected patient transportation and minimize systemic disruptions[4].

Paramedics, as frontline providers in Thailand's EMS system, play a critical role in bridging community care and hospital services. They are core members of the Advanced Life Support-SCOT, trained in infection control for hazardous communicable diseases and emergency patient safety[4]. However, their direct exposure to patients' bodily fluids and contaminated equipment heightens infection risks. Rising disease severity and occupational stressors further compromise their mental well-being and service quality[5,6].

Literature underscores that paramedics' preparedness hinges on COVID-19 awareness and adherence to infection prevention protocols. Accurate knowledge of transmission modes and preventive measures can mitigate infection risks and curb viral spread[7]. Equally vital are adequate personal protective equipment (PPE) and clear operational guidelines to ensure safe and efficient service delivery[8]. Perceived risk severity and occupational exposure awareness also directly influence preventive behaviors[9]. Studies note that healthcare workers with advanced infectious disease training exhibit stronger compliance with prevention protocols[10,11], underscoring the role of knowledge and resource accessibility. Despite these insights, research on Thai paramedics' pandemic response remains limited. As frontline responders, their role in managing health crises demands urgent examination to bolster future outbreak preparedness. This study aimed to assess Thai paramedics' operational preparedness and perception in response to the COVID-19 pandemic. The findings are expected to inform evidence-based recommendations for EMS system enhancement and individual capacity-building initiatives.

METHODS

This cross-sectional descriptive study utilized an online questionnaire to collect data from Thai paramedics actively working under the EMS system between August and December 2021. The inclusion criteria were: (1) being a licensed paramedic registered with the NIEM; (2) currently working in an EMS unit (pre-hospital, hospital-based, or field operations); and (3) voluntarily consenting to participate. The exclusion criterion was having less than one year of EMS work experience.

The sample size was calculated using a population proportion formula (95% confidence interval [CI], margin of error = 0.05) based on 465 licensed paramedics (as of March 1, 2021)[12]. The initial target was 211 participants, with an additional 10% (total n = 230) to account for potential data loss.

A convenience sampling method was employed, as participation in the study was entirely voluntary and not mandatory for all invitees. Email addresses of eligible paramedics were obtained through collaboration with the NIEM. The online questionnaire was distributed to the full list via email. Paramedics with less than one year of work experience were not invited to participate and therefore did not receive the questionnaire. To enhance participation, reminder emails were sent biweekly over a three-month period. The initial response rate was approximately 20%. Ultimately, 230 responses were received. All submitted questionnaires were reviewed manually. A response was excluded only if it contained more than one missing item in any of the key domains (i.e., perception or preparedness). Based on this criterion, 225 complete and valid datasets were retained for final analysis, as shown in Figure 1.

The study adhered to the ethical principles of the Belmont Report and received approval from the Ethics Review Committee of the Faculty of Medicine Vajira Hospital, Navamindradhiraj University (COA 087/2564). Online informed consent was obtained, and all data were anonymized and aggregated to ensure confidentiality.

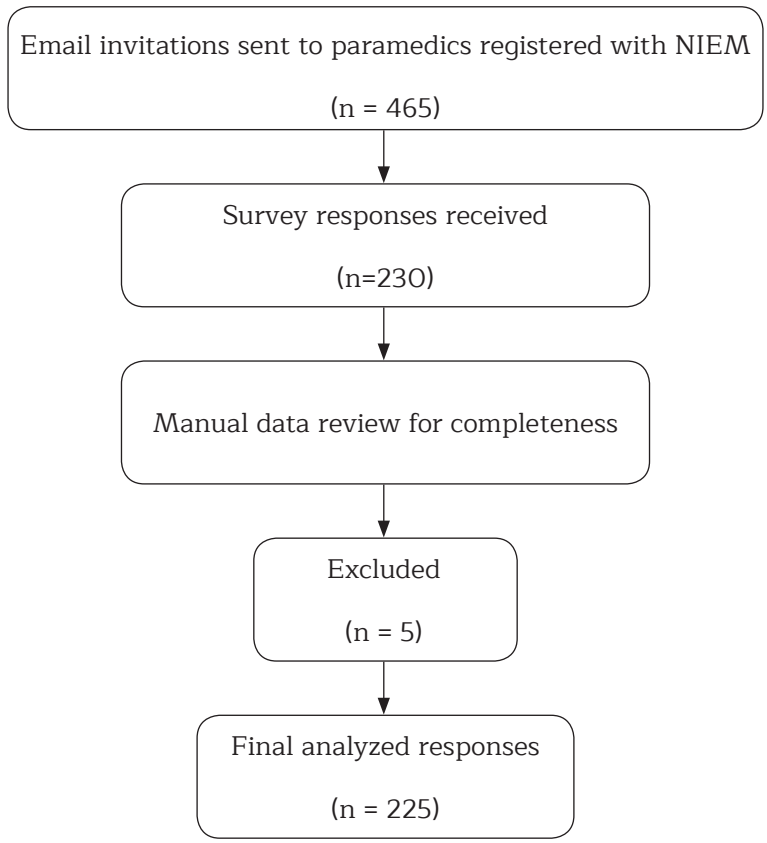

Figure 1 Participant flow diagram

The research instrument used in this study was an online questionnaire consisting of three sections: (1) basic characteristics, (2) perception of COVID-19, and (3) preparedness for emergency operations during the COVID-19 pandemic. The questionnaire on COVID-19 perception was adapted from the study by Singveeratham et al.[13], which focused on risk perception and perceived severity of COVID-19. The questions were modified to align with the work context of paramedics. Responses were measured using a 5-point rating scale, ranging from 1 (strongly disagree) to 5 (strongly agree). The questionnaire included nine questions on risk perception and six questions on perceived severity, totaling 15 items. The questionnaire on preparedness for emergency operations during the COVID-19 pandemic was adapted from the SCOT preparedness assessment and pre-deployment checklist from the NIEM's operational guidelines[4]. It consisted of two main sections: (1) structural preparedness (9 items) and (2) operational preparedness (24 items), which was further divided into pre-operation preparedness (7 items), preparedness during operation (12 items), and post-operation preparedness (5 items). In total, the questionnaire comprised 33 items. The questions on preparedness were closed-ended, with only two response options: "yes" (1 point) and "no" (0 points). The content validity of the questionnaire was assessed by three experts, including an emergency medicine physician, a specialist in health systems and EMS, and an expert in pre-hospital emergency operations. Each expert independently evaluated the relevance and clarity of the questionnaire items using a structured rating scale. Based on their assessments, the content validity index was found to be 0.80. Reliability testing was subsequently conducted through a pilot study. The reliability score for the perception section was 0.85, while the preparedness section had a reliability score of 0.87.

Data interpretation for perception scores showed that a mean score of 4.0 or higher indicated a high level, a mean score between 3.0 and 3.9 indicated a moderate level, and a mean score below 3.0 indicated a low level of perception. For preparedness scores, a total score of 33 indicated full preparedness, while any score below 33 indicated a lack of full preparedness. Given the highly contagious nature of COVID-19 and its widespread impact, effective prevention measures are crucial. Operational preparedness was assessed based on the highest safety standards, as errors in real-world emergency response situations could have serious consequences.

Data were analyzed using SPSS version 29 (IBM SPSS Statistics for Windows, version 29.0. Armonk, NY: IBM Corp). Descriptive statistics, including frequency, percentage, mean, and standard deviation, were used. Factors influencing operational preparedness were analyzed using logistic regression analysis.

RESULTS

The study included a total of 225 participants, the majority of whom were female (57.8%). The median age of participants was 26.0 years, and 85.3% were single. Most participants had obtained a bachelor's degree (96.9%). Regarding work experience, the majority had been employed as paramedics for 1-3 years, with a median work experience of 3.0 years. The highest proportion of participants (53.3%) worked in general hospitals, university-affiliated hospitals, or the Erawan Emergency Medical Center. Additionally, 53.3% had undergone COVID-19-related training, while 75.6% had experience in handling COVID-19 cases. The data are presented in Table 1.

Table 1 Baseline characteristics (N = 225)

Variables	N = 225 (%)
Gender	
Male	95 (42.2)
Female	130 (57.8)
Age (years)	
21-25	102 (45.3)
> 25	123 (54.7)
Median = 26.0 (Min = 21, Max = 48)	
Status	
Single	192 (85.3)
Couple	33 (14.7)
Education	
Bachelor	218 (96.9)
Postgraduate	7 (3.1)
Experience (years)	
1-3	138 (61.3)
> 3	87 (38.7)
Median = 3.2 (Min = 1, Max = 8)	
Place of work	
Community hospitals/ Private hospitals/ Local administrative Organization	105 (46.7)
General hospitals/ University-affiliated hospitals/ Erawan Emergency Medical Center	120 (53.3)
Training experience on COVID-19	
No	105 (46.7)
Yes	120 (53.3)
Prior hands-on experience in COVID-19 patient retrieval	
No	55 (24.4)
Yes	170 (75.6)

Abbreviation: N, number

The assessment of COVID-19 response preparedness was divided into two main components: infrastructure preparedness and operational capacity. The findings revealed that 53.3% of participants were structurally ready (mean = 7.70/9.00 ± 1.86), while 54.2% were operationally ready (mean = 22.40/24.00 ± 2.61). When both aspects were combined, only 38.7% of participants were fully prepared in all areas, with a total preparedness score of mean = 30.1/33.00 ± 3.97 (Table 2).

Table 2 COVID-19 response preparedness assessment (N = 225)

Variables	Preparedness		Mean (SD)
	No N (%)	Yes N (%)	
Infrastructure preparedness (9 items)	105 (46.7)	120 (53.3)	7.7 (1.86)
Operational capacity (24 items)	103 (45.8)	122 (54.2)	22.4 (2.61)
Total Preparedness Score (33 items)	138 (61.3)	87 (38.7)	30.1 (3.97)

Abbreviations: N, number; SD, standard deviation

The overall perceived risk of exposure and perceived severity of COVID-19 infection were at a high level, with mean scores of 4.50 ± 0.44 and 4.60 ± 0.44, respectively. An item-by-item analysis of perceived risk of exposure and perceived severity indicated that all individual items were rated at a high level (Table 3).

An analysis of the association between basic characteristics, COVID-19 perception, and operational preparedness for COVID-19 response found that prior training on COVID-19 and experience in handling COVID-19 cases were significant factors influencing emergency preparedness. Participants with COVID-19 training were significantly more prepared than those without training (adjusted OR = 1.79; 95%CI = 1.01-3.17, p = 0.043). Meanwhile, participants with prior experience handling COVID-19 patients were significantly more prepared than those without such experience (adjusted OR = 3.33; 95%CI = 1.56-7.12, p = 0.002). The data are presented in Table 4.

Table 3 Perceived risk of exposure and perceived severity of COVID-19 infection (N = 225)

Variables	Mean (SD)	Meaning
Perceived risk of exposure		
1. Chest compressions pose a risk of COVID-19 virus transmission	4.6 (0.66)	High
2. Open-system tracheal suctioning increases the risk of COVID-19 infection	4.7 (0.52)	High
3. Endotracheal intubation carries a risk of COVID-19 virus exposure	4.7 (0.60)	High
4. Procedures requiring high-flow oxygen (e.g., nebulizer therapy, bag-valve mask ventilation, high-flow nasal cannula) increase the risk of COVID-19 transmission	4.7 (0.61)	High
5. If patients are not pre-screened for COVID-19 by the dispatch and coordination center, responders are at higher risk of infection	4.6 (0.60)	High
6. Treating patients during transport in an air-conditioned ambulance may lead to COVID-19 virus spread	4.0 (1.01)	High
7. Healthcare workers may contract COVID-19 from patients if they fail to wash hands after procedures	4.5 (0.67)	High
8. Close contact (< 2 meters) between patients and responders increases the risk of COVID-19 transmission	4.2 (0.84)	High
9. Wearing a surgical mask or face shield reduces the risk of COVID-19 infection	4.5 (0.66)	High
Total	4.5 (0.44)	High
Perceived severity		
1. Do you think COVID-19 is a dangerous communicable disease?	4.6 (0.67)	High
2. Do you believe COVID-19 is a life-threatening disease?	4.6 (0.60)	High
3. Do you think COVID-19 causes severe lung infection?	4.7 (0.50)	High
4. If a person has underlying medical conditions and contracts COVID-19, does it increase the risk of severe/fatal outcomes?	4.8 (0.50)	High
5. Do you believe elderly individuals have a higher risk of death if infected with COVID-19?	4.7 (0.53)	High
6. Do you think healthy individuals who contract COVID-19 will only experience mild symptoms (like a common cold)?	4.0 (1.01)	High
Total	4.6 (0.44)	High

Abbreviation: SD, standard deviation

Table 4 Association between basic characteristics, perception of COVID-19, and operational preparedness for COVID-19 response (N = 225)

Variables	Categories	Preparedness		Crude OR (95%CI)	P-value	Adjusted OR (95%CI)	P-value
		No N (%)	Yes N (%)				
Sex	Male	60 (63.2)	35 (36.8)	Ref.			
	Female	78 (60.0)	52 (40.0)	1.33 (0.73-2.42)	0.347		
Age (years)	21-25	65 (63.7)	37 (36.3)	Ref.			
	> 25	73 (59.3)	50 (40.7)	1.14 (0.50-2.59)	0.743		
Status	Single	119 (62.0)	73 (38.0)	Ref.			
	Couple	19 (57.6)	14 (42.4)	1.04 (0.44-2.44)	0.918		
Education	Bachelor	137 (62.8)	81 (37.2)	Ref.			
	Postgraduate	1 (14.3)	6 (85.7)	8.39 (0.94-74.91)	0.057		
Experience (years)	1-3	87 (63.0)	51 (37.0)	Ref.			
	> 3	51 (58.6)	36 (41.4)	1.00 (0.43-2.32)	0.990		
Place of work	Community hospitals/ Private hospitals/ Local administrative organization	69 (65.7)	36 (34.3)	Ref.			
	General hospitals/ University-affiliated hospitals/ Erawan Emergency Medical Center	69 (57.5)	51 (42.5)	1.34 (0.74-2.42)	0.321		
Training experience on COVID-19	No	74 (70.5)	31 (29.5)	Ref.			
	Yes	64 (53.3)	56 (46.7)	1.83 (1.01-3.31)	0.045	1.79 (1.01-3.17)	0.043*
Prior hands-on experience in COVID-19 patient retrieval	No	45 (81.8)	10 (18.2)	Ref.			
	Yes	93 (54.7)	77 (45.3)	2.86 (1.32-6.21)	0.008	3.33 (1.56-7.12)	0.002*
Perceived risk of exposure	Low to moderate	15 (75.0)	5 (25.0)	Ref.			
	High	123 (60.0)	82 (40.0)	1.57 (0.48-5.14)	0.455		
Perceived severity	Low to moderate	10 (66.7)	5 (33.3)	Ref.			
	High	128 (61.0)	82 (39.0)	0.87 (0.24-3.11)	0.834		

Abbreviations: CI, confidence interval; n, number; OR, odds ratio; Ref, reference

DISCUSSION

This study revealed that paramedic preparedness for handling COVID-19 cases remained moderate, with only 38.7% of participants demonstrating full preparedness. While structural and operational readiness scores averaged approximately 50%, this figure falls significantly short of the standards required for effective emergency response during high-risk outbreaks. The findings point to systemic limitations, such as inadequate infrastructure, insufficient access to PPE, and resource constraints, which undermined paramedics' readiness and confidence. During Thailand's third wave, resource shortages, excessive workloads, equipment deficits, and public communication challenges further strained EMS capacity. Effective outbreak response demands near-perfect safety standards, as even minor errors can compromise patient outcomes. Prior research emphasizes that EMS readiness hinges on supportive policies such as compensation and access to high-quality protective gear[14]. Systematic reviews cite personal risk, PPE shortages, and evolving guidelines as key barriers[15]. As a critical public health sector, EMS requires robust medical resources, PPE, specialized equipment, transport vehicles, institutional collaboration, and community engagement to mitigate infection risks[16].

Importantly, this study found that training and previous experience in managing COVID-19 cases were statistically significant predictors of individual preparedness. Paramedics who had received training were 1.79 times more likely to be prepared (95% CI = 1.01-3.17), while those with prior hands-on experience were 3.33 times more likely to be prepared (95% CI = 1.56-7.12) (Table 4).

Although the original conceptual framework did not explicitly incorporate the relationship between training, experience and practice, these results necessitate a clearer theoretical distinction between these constructs. In this context, training refers to formal, structured educational interventions including didactic instruction and simulation-based learning. Experience encompasses direct exposure to COVID-19 patient care and real-world clinical encounters. Practice represents the ongoing application and refinement of both trained skills and experiential knowledge in clinical settings. The substantially higher odds ratio for experience (OR = 3.33) compared to training (OR = 1.79) suggests that hands-on exposure provides more robust preparedness than formal instruction alone. This differential impact aligns with experiential learning theory, which posits that learning through direct experience yields deeper understanding and better skill retention than passive knowledge acquisition. The nearly two-fold difference in effect sizes indicates that contextual and adaptive learning occurring during real patient encounters may be more effective in developing emergency preparedness competencies than standardized training protocols alone. These results suggest that training and experiential learning play a pivotal role in shaping the actual practice behaviors of paramedics in the field. This is consistent with well-established theories of adult learning and emergency preparedness, which emphasize that structured training improves not only knowledge acquisition but also behavioral response capacity during real-world emergencies. However, our findings indicate that the combination of both modalities may be optimal, as training provides foundational knowledge frameworks while experience develops practical expertise and adaptive problem-solving skills necessary for complex emergency situations.

Given the moderate preparedness levels found, this evidence supports the potential for simulation-based and virtual training to address identified gaps in emergency preparedness among paramedics[17,18]. Importantly, training programs should be designed to bridge the gap between theoretical knowledge and practical application, potentially through progressive exposure models that combine classroom instruction with supervised clinical experience. The results of this study can be applied in public health, particularly in training, to help healthcare personnel gain confidence in dealing with epidemic situations, reduce stress, and be better prepared to manage more complex situations[19]. It also ensures that they receive continuous updates and real-time information necessary for effective practice. Additionally, real-world experience further boosts healthcare professionals' confidence, enhances their adaptability to diverse situations, facilitates rapid clinical decision-making, strengthens team communication, and improves coordination efficiency. Experience fosters the development of strategic response plans, aligning with the WHO's preparedness guidelines, which emphasize that experience helps healthcare systems refine their approaches to respiratory infectious disease outbreaks[20].

The results consistently demonstrated that paramedics, as frontline healthcare workers, exhibited a high level of risk perception and awareness regarding the severity of COVID-19 infection, reflecting their professional understanding of the disease's dangers and the critical need for preventive measures. Given their frequent exposure during patient care, commuting, and work in high-risk environments, such awareness is essential. These findings align with previous studies[21,22], which have established that healthcare professionals perceive COVID-19 as a significant threat and recognize their elevated infection risk compared to the general population. Paramedics' heightened awareness, which likely exceeded that of the general public[23], may have been influenced by the widespread outbreaks occurring in Thailand during the study period[24]. However, while this heightened risk perception and awareness reflect paramedics' professional vigilance and commitment to safety, the findings indicate that perception alone was insufficient to ensure full operational preparedness. This gap between awareness and action underscores the need for comprehensive

structural support and targeted skill-based training to bridge the divide between knowledge and its practical application in emergency response settings.

Several limitations must be noted. First, online surveys may have introduced response biases due to potential misinterpretations. Second, the findings are specific to frontline paramedics and may not extend to other healthcare roles. Third, generalizability of findings to the broader paramedic population may be limited due to potential selection bias, as survey respondents may represent a subset of particularly engaged or motivated individuals with specific perspectives on emergency preparedness. Fourth, the study did not assess participants' physical and mental health status, which could potentially influence their preparedness levels. Finally, preparedness was evaluated at the individual level, excluding systemic factors (e.g., policies, management, and technology) that shape overall preparedness.

CONCLUSION

Paramedics play a crucial frontline role in patient care, ranging from community-based responses to advanced emergency medical systems. The study found that paramedics had a high level of COVID-19 perception, but only 38.7% were fully prepared for operations during the pandemic. The findings emphasize that training and hands-on experience in handling COVID-19 cases significantly enhance paramedics' operational preparedness. To improve individual-level preparedness, it is essential to develop comprehensive training programs to build protocol proficiency and provide practical experience opportunities to enhance confidence and efficiency in public health emergencies.

CONFLICT OF INTEREST

The authors declare no conflicts of interest regarding the research, authorship, or publication.

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DATA AVAILABILITY STATEMENT

The datasets utilized and/or analyzed throughout the present study may be obtained from the corresponding author upon reasonable request.

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Original Article

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Prevalence of Left Ventricular Hypertrophy and Its Association with Blood Pressure Control in Hypertensive Patients at Vajira Hospital, Navamindradhiraj University

Pakatorn Supasittikulchai MD[1], Prayuth Rasmeehirun MD[1], Phanthaphan Sureeyathanaphat MD[1]

[1] *Cardiology Division, Department of Internal Medicine, Faculty of Medicine Vajira Hospital, Navamindradhiraj University, Bangkok 10300, Thailand*

ABSTRACT

OBJECTIVES: This study aimed to determine the prevalence of left ventricular hypertrophy (LVH) diagnosed via echocardiography and the relationship between blood pressure (BP) control and LVH and identify factors associated with LVH among patients with hypertension in Thailand.

METHODS: This cross-sectional study included 107 patients with hypertension who visited a cardiology clinic between March 2024 and August 2024. The baseline characteristics, office BP, and morning and evening home BP measurements of the participants were obtained. Echocardiographic criteria for LVH diagnosis are left ventricular mass index > 95 g/m^2 in women and > 115 g/m^2 in men. The primary outcomes were to determine the prevalence of LVH and assess the relationship between BP control and LVH.

RESULTS: The prevalence of LVH was 32.70%, with all the patients diagnosed with LVH exhibiting a concentric hypertrophy phenotype. Among the patients, 59.80% had controlled home BP, whereas 42% had controlled office BP. The prevalence of LVH was 22.50% among patients with both controlled office and home BP, 44.70% among those with both uncontrolled office and home BP, 20% in the group with controlled office but uncontrolled home BP, and 33.30% in the group with uncontrolled office BP but controlled home BP. Multivariate analysis showed that the number of antihypertensive drugs use was the only significant associated factor.

CONCLUSION: The prevalence of LVH is high among patients with hypertension, particularly those with uncontrolled office and home BP. This indicates the need for effective hypertension management strategies to prevent hypertension-mediated organ damage associated with LVH.

KEYWORDS: hypertension, hypertensive heart disease, left ventricular hypertrophy

INTRODUCTION

Cardiovascular disease remains a leading cause of death and disability, with hypertension as a major contributing factor[1,2]. Prolonged hypertension affects the left ventricle, leading to left ventricular hypertrophy (LVH) due to increased blood pressure (BP) and neurohormonal activation[3]. LVH is an early indication of cardiac damage, classified as hypertension-mediated organ damage, and is associated with cardiovascular events from conditions such as heart failure, diastolic dysfunction, stroke, congestive heart failure, coronary artery disease (CAD), ventricular arrhythmia, and sudden cardiac death[4-8].

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BP control is key to LVH management, reducing its incidence and improving prognosis[9,10]. Early detection of LVH is crucial for risk stratification and appropriate intervention.

Echocardiography is used to assess LVH; it offers greater sensitivity and accuracy than electrocardiography[11,12]. Research reveals that LVH identified through echocardiography can be a predictor of cardiovascular mortality[13-15]. LVH is a well-established consequence of long-standing uncontrolled hypertension. The prevalence of LVH among patients with hypertension varies from 24% to 72.20%[16-18], whereas studies in Thailand report prevalence rates between 28% and 62%, depending on diagnostic criteria used[19]. Key factors linked to LVH include male sex, advanced age, obesity, and increased BP[14,16,18-20]. However, the manifestation and risk profile of LVH can vary across ethnic groups due to genetic predisposition, environmental exposures, lifestyle behaviors (e.g., diet, salt sensitivity), and healthcare access. While international data provide useful insights, Thai-specific data are limited. Given the unique demographic and clinical characteristics of Thai patients, including differences in obesity patterns, dietary sodium intake, and hypertension control rates, studying LVH in this population is essential for more accurate risk stratification and targeted interventions.

Out-of-office BP measurement, such as ambulatory BP monitoring and home BP monitoring (HBPM), have shown a stronger correlation with LVH than in-office measurement[21,22]. Despite these known associations, data on LVH and its relationship with BP control in Thai hypertensive patients remain scarce.

The current study aimed to determine the prevalence of LVH diagnosed using echocardiography and investigate its relationship with office BP and home BP control in patients with hypertension admitted at Vajira Hospital, Navamindradhiraj University.

The primary objectives of this study were to confirm the prevalence of LVH in hypertensive patients at Vajira Hospital and examine the relationship between BP control and presence of LVH using echocardiography in Thai patients with hypertension and investigate its relationship with office BP and home BP control. By focusing on a Thai cohort, we sought to provide region-specific insights that may differ from those reported in other populations and inform clinical management. The secondary objective was to identify other factors associated with LVH in these patients.

METHODS

This single-center cross-sectional study was approved by the Ethical Committee of the Faculty of Medicine Vajira Hospital, Navamindradhiraj University (certificate of approval 044/2567 protocol 017-67). The study population included patients diagnosed with hypertension who visited the cardiology clinic of the Faculty of Medicine Vajira Hospital, Navamindradhiraj University between March 01, 2024, and August 31, 2024. The inclusion criteria were patients aged ≥ 18 years and those who had their own BP monitoring apparatus and can perform home BP measurement. Patients with a clinical diagnosis of hypertension were eligible regardless of whether they were treated with antihypertensive medications or managed with lifestyle modification alone. No changes to antihypertensive therapy were made before enrollment, and all participants were enrolled during routine clinical follow-up. In contrast, the exclusion criteria were patients with a poor echocardiographic window, patients with moderate or severe valvular heart disease, and patients with comorbidities including atrial fibrillation, secondary hypertension, other myocardial diseases/cardiomyopathies, left ventricular dysfunction (left ventricular ejection fraction of less than 40%), and congenital heart disease.

Electronic medical records and patient interviews for baseline characteristics, including age, sex, body mass index (BMI), smoking status, duration of hypertension, hypertension treatment status, number of antihypertensive drug classes prescribed, and comorbidities, were studied. Smoking history was defined as current or former smoking of ≥ 100 cigarettes in a lifetime (quantified in pack-years). Chronic kidney disease (CKD) was defined as an estimated glomerular filtration rate < 60 mL/min/1.73 m^2 for ≥ 3 months (CKD- exocrine pancreatic insufficiency (EPI) equation). CAD was defined by prior myocardial infarction, history of percutaneous coronary intervention or coronary artery bypass grafting, or angiographic evidence of ≥ 50% stenosis in a major coronary artery.

Office BP was measured with the patient in a seated position, using the arm for measurement. Systolic BP (SBP) and diastolic BP (DBP) was taken twice, 5 minutes apart. The average of these two readings was considered the office SBP and DBP. If patients had previous treatment records in their medical history with BP measurements taken within the past 6 months, the values were averaged to verify whether the patient's hypertension was controlled or uncontrolled. An SBP < 140 mmHg and DBP < 90 mmHg were considered controlled office BP.

The patients were advised to record their home BP in the morning and evening for 1 month with a semiautomatic BP apparatus of any brand or model. All home BP values were recorded within one month before echocardiography, and no changes to antihypertensive medications were made during this monitoring period. They were instructed to measure their BP at home twice daily—once in the morning (between 7:00 AM and 10:00 AM) and once in the evening (between 5:00 PM and 8:00 PM), at a consistent time each day. Each measurement consisted of two consecutive readings, and the average of these two readings was recorded. These time windows were chosen based on standard recommendations that morning BP should be measured within 1 hour of waking and before medication or meals, and evening BP should be measured before bedtime, consistent with major hypertension guidelines[23,24]. Moreover, they were asked to record the measurements for 1 month in a BP logbook provided by the researcher. The average of the morning and evening readings were used to obtain the home SBP and DBP. An SBP < 130 mmHg and DBP < 80 mmHg were considered controlled home BP. Patients were then categorized into four groups based on BP control status: (1) controlled both office and home BP, (2) uncontrolled both office and home BP, (3) uncontrolled office BP but controlled home BP, and (4) controlled office BP but uncontrolled home BP.

Two-dimensional transthoracic echocardiography was performed in all participants using a Philips EPIQ CVx machine after completing the one-month of BP recording. Echocardiographic variables included interventricular septal diameter in diastole (IVSd), left ventricular diameter in diastole (LVDd), left ventricular posterior wall thickness in diastole (LVPWd), and relative wall thickness (RWT). LVH by echocardiography was defined according to the criteria of the American Society of Echocardiography: LV mass index (LVMI) > 115 g/m^2 for men and > 95 g/m^2 for women, measured using the 2D-linear measurement method. The LV mass is calculated using 0.8 x 1.04 x [(IVSd + LVDd + LVPWd)^3 – LVDd^3]+ 0.6 grams[25]. LV mass was then indexed to body surface area to obtain the LVMI, expressed in g/m^2. Furthermore, RWT was calculated using the formula RWT = ((2 × LVPWd)/LVDd). The types of LVH were classified by the geometric patterns into concentric hypertrophy (RWT > 0.42) and eccentric hypertrophy (RWT ≤ 0.42). Concentric remodeling was defined as LVMI not meeting the criteria for LVH and RWT > 0.42. Image acquisition was performed by a cardiology fellow in training, using standardized parasternal long-axis views. Each echocardiographic study took approximately 10–20 minutes.

Measurements of IVSd, LVDd, LVPWd, LV mass, and RWT were independently obtained by the acquisition operator. All measurements were then reviewed by a board-certified cardiologist with expertise in echocardiography, who was blinded to the patients' BP status.

The prevalence of LVH in patients was presented in numbers and percentages. Continuous variables with a normal distribution were demonstrated as mean and standard deviation (SD) (mean ± SD). Continuous variables with skew distribution were shown as the median and interquartile range (IQR) (median ± IQR).

The sample size for this study was calculated based on two primary objectives. For the first objective—determining the prevalence of LVH in patients with hypertension—the sample size was estimated using the formula for a single proportion. Based on a previous study reporting an LVH prevalence of 36%[17], with a 95% confidence level (Z = 1.96) and a margin of error of 10%, the required sample size was 89 participants. After accounting for an estimated 10% rate of incomplete data, the adjusted sample size was 98 participants. For the second objective—assessing the association between BP control (office and home BP) and the presence of LVH—the sample size was calculated using the formula for comparing two proportions. Based on reported LVH prevalences of 32% in patients with controlled BP and 17% in those with uncontrolled BP[21], with a power of 80% ($Z\beta$ = 0.84) and a significance level of 0.05 ($Z\alpha$ = 1.96), the required sample size was 126 participants per group. After adjusting for 10% data incompleteness, the total required sample size was 277 participants. Therefore, we used 277 as the final sample size for this study.

Analysis of the correlation between BP control (i.e., office BP measurement and home BP) and LVH employed regression analysis. We used multinomial logistic regression to assess the relationship between the number of antihypertensive drug classes and BP control categories. Univariate and multivariate logistic regression analyses were used to determine the predictive factors for LVH. Data were analyzed using the statistical software STATA version MP17.

RESULTS

This study enrolled 107 hypertensive patients who visited the cardiology clinic between March 1, 2024, and August 31, 2024. The mean age of the patients was 68.80 ± 10.20 years, and 73% were females. The mean BMI of the patients was 25.46 ± 4.56 kg/m^2. Smoking history was found in 19.60% of the patients. The most common comorbidities included diabetes mellitus (38.30%), dyslipidemia (86.90%) and coronary artery disease (36.40%). The mean duration of hypertension was 13.54 ± 8.55 years. Moreover, the mean number of antihypertensive drug groups used was 2.50 ± 1.20. Regarding echocardiographic parameters, the patients' mean LVMI was 98.80 ± 32.20 g/m^2. The mean IVSd was 1.07 ± 0.23 cm. The mean LVPWd was 1.08 ± 0.23. Additionally, the mean LVDd was 4.28 ± 0.64 cm, and the mean RWT was 0.51 ± 0.16.

The baseline characteristics, including various clinical, demographic, and echocardiographic variables, were grouped into four according to patterns of LVH: all patients, normal geometry thickness, concentric remodeling, and concentric hypertrophy (Table 1). No patient met the definition of eccentric hypertrophy. The concentric hypertrophy group had the highest mean age (72.30 years), BMI (26.42 kg/m^2), duration of hypertension (17.50 years), and average use of antihypertensive drugs (3.20 kinds).

Table 1 Patient baseline characteristics and echocardiographic values (n = 107)

	All (n = 107)	Normal geometry (n = 24)	Concentric remodeling (n = 48)	Concentric hypertrophy (n = 35)	P-value
Age (mean ± SD)	68.77 ± 10.22	63.91 ± 10.57	68.62 ± 9.01	72.31 ± 10.39	0.007
BMI (mean ± SD)	25.46 ± 4.56	23.78 ± 3.97	26.42 ± 4.55	25.09 ± 4.69	5.829
Male (%)	29 (27.10%)	5 (20.83%)	20 (41.67%)	4 (11.43%)	0.007
Smoking history (%)	21 (19.63%)	5 (20.83%)	13 (27.08%)	3 (8.57%)	0.109
Duration HT (year)	13.54 ± 8.55	8.75 ± 7.91	13.00 ± 8.00	17.50 ± 8.00	< 0.001
anti-HT Drug (number)	2.50 ± 1.20	1.83 ± 1.09	2.45 ± 1.03	3.25 ± 1.17	< 0.001
Diabetes mellitus (%)	41 (38.32%)	6 (25.00%)	19 (39.58%)	16 (45.71%)	0.267
Dyslipidemia (%)	93 (86.92%)	20 (83.33%)	41 (85.42%)	32 (91.43%)	0.609
Stroke (%)	17 (15.89%)	4 (16.67%)	9 (18.75%)	4 (11.43%)	0.662
CAD (%)	39 (36.45%)	11 (45.83%)	12 (25.00%)	16 (45.71%)	0.085
CKD (%)	25 (23.30%)	1 (4.17%)	12 (25.00%)	12 (34.29%)	0.025
LV mass index (g/m^2)	98.80 ± 32.20	80.70 ± 13.40	85.30 ± 15.30	129.80 ± 36.20	
Men	99.56 ± 22.73	79.56 ± 21.96	95.93 ± 10.98	142.75 ± 13.25	< 0.001
Women	98.51 ± 35.21	80.96 ± 11.01	77.64 ± 13.25	128.11 ± 38.00	< 0.001
IVSd (cm)	1.07 ± 0.23	0.88 ± 0.12	1.06 ± 0.17	1.21 ± 0.26	< 0.001
LVPWd (cm)	1.08 ± 0.23	0.81 ± 0.09	1.11 ± 0.19	1.21 ± 0.19	< 0.001
LVIDd (cm)	4.28 ± 0.64	4.55 ± 0.49	4.01 ± 0.56	4.47 ± 0.71	< 0.001
RWT	0.51 ± 0.16	0.35 ± 0.39	0.57 ± 0.14	0.56 ± 0.17	< 0.001

Abbreviations: BMI, body mass index; CAD, coronary artery disease; CKD, chronic kidney disease; cm, centimeter; g/m^2, grams per square meter; HT, hypertension; IVSd, interventricular septal diameter in diastole; LV, left ventricle; LVIDd, left ventricular diameter in diastole; LVPWd, left ventricular posterior wall thickness in diastole; n, number; RWT, relative wall thickness; SD, standard deviation
Data are presented as n (%) of row total.

The prevalence of echocardiography-diagnosed LVH was 32.70% (24 of 107 patients), which is consistent with hypertensive heart disease. All patients with LVH met the geometric pattern of concentric hypertrophy. The remaining 83 (67.30%) patients manifested no LVH on echocardiography. Of these patients, 48 (44.90% of total population) met the concentric remodeling criteria.

The percentage of patients achieving target office BP and home BP were 42.10% and 59.80%, respectively. These results can be further classified into the following categories. A 37.40% had both controlled office and home BP, 35.50% had both uncontrolled office and home BP, 4.70% had controlled office BP but uncontrolled home BP, and 22.40% had uncontrolled office BP but controlled home BP. When stratified by BP control patterns, LVH was present in 9 of 40 patients (22.50%) with both controlled office and home BP, 17 of 38 patients (44.70%) with both uncontrolled office and home BP, 1 of 5 patients (20.00%) with controlled office BP but uncontrolled home BP, and 8 of 24 patients (33.30%) with uncontrolled office BP but controlled home BP. Table 2 demonstrates BP control and the prevalence of LVH in each BP control category.

In the multinomial model, each additional antihypertensive agent was associated with 1.83-fold higher odds of having both uncontrolled office and home BP (95% CI 1.20–2.78; p = 0.005), with no significant associations in the other BP categories. Accordingly, the number of anti-hypertensive agents was included in the LVH multivariate analysis.

Table 2 Blood pressure control and LV geometry in each blood pressure control category

Blood pressure categories	Normal geometry (n = 24)	Concentric remodeling (n = 48)	Concentric hypertrophy (n = 35)
Controlled office BP and controlled home BP, n (%)	19 (47.50)	12 (30.00)	9 (22.50)
Uncontrolled office BP and uncontrolled home BP, n (%)	1 (2.63)	20 (52.63)	17 (44.74)
Uncontrolled office BP but controlled home BP, n (%)	3 (12.50)	13 (54.17)	8 (33.33)
Controlled office BP but uncontrolled home BP, n (%)	1 (20.00)	3 (60.00)	1 (20.00)

Abbreviations: BP, blood pressure; HT, hypertension; LV, left ventricular; LVH, left ventricular hypertrophy; n, number
Data are presented as n (%) of row total.

Univariate analysis found that the number of antihypertensive drugs use and uncontrolled both office and home BP subgroup are predictive factors of LVH. However, after adjusting for other variables in the multivariate analysis, the number of anti-hypertensive agent use remained significantly associated with LVH (Table 3.)

Table 3 Univariate and multivariate analysis of factors associated with LV hypertrophy

Characteristic	Univariate analysis			Multivariate analysis		
	Odds ratio	95% CI	P-value	Odds ratio	95% CI	P-value
Age	1.02	0.96-1.08	0.581	1.02	0.97-1.08	0.417
BMI	0.96	0.85-1.09	0.551			
Male	0.57	0.13-2.54	0.464	0.48	0.13-2.55	0.476
Smoking	0.40	0.07-2.19	0.291	0.23	0.07-1.91	0.229
Duration of hypertension	1.05	0.98-1.13	0.194	1.04	0.97-1.11	0.243
Number of anti-hypertensive drug	1.90	1.14-3.15	0.013	1.88	1.14-3.09	0.013
Diabetes mellitus	0.99	0.33-3.02	0.997			
Dyslipidemia	0.96	0.17-5.44	0.964			
Stroke	0.56	0.13-2.45	0.440			
CAD	1.96	0.67-5.70	0.219	2.34	0.86-6.36	0.095
CKD	1.29	0.33- 4.88	0.730	1.22	0.37-4.05	0.744
Controlled office BP	0.44	0.04-5.50	0.526			
Controlled home BP	1.12	0.09-13.64	0.931			
BP control categories						
Controlled both office and home BP (reference)	1			1		
Uncontrolled both office and home BP	2.79	1.05-7.43	0.040	1.84	0.58-5.98	0.309
Uncontrol office BP but controlled home BP	1.72	0.56-5.32	0.345	1.13	0.30-4.23	0.860
Controlled office BP but uncontrolled home BP	0.86	0.09-8.71	0.899	0.80	0.07-9.32	0.857

Abbreviations: BMI, body mass index; BP, blood pressure; CAD, coronary artery disease; CI, confidence interval; CKD, chronic kidney disease; HT, hypertension; LV, left ventricular; n, number
Multivariate model: logistic regression including age, sex, smoking history, duration of hypertension, number of hypertensive drugs, CAD, CKD and blood pressure–control category.

We also performed a sensitivity analysis which applied more stringent control criteria defining controlled BP as < 130/80 mmHg for office BP and < 120/70 mmHg for home BP measurements and re-examined its association with LVH. We found only the "uncontrolled office but controlled home BP" category was associated with significantly higher odds of LVH (OR 9.17; 95% CI 1.15–73.24; p = 0.0037) in univariate analysis. However, after adjusting for other variables in the multivariate analysis, it does not show statistically significant (Table 4 and Table 5).

DISCUSSION

The current study focuses on the prevalence of LVH diagnosed by echocardiography in patients with hypertension at Vajira Hospital, Navamindradhiraj University, which may represent an urban population. Moreover, the relationship between LVH and BP control status was assessed, and other factors associated with the echocardiographic evidence of LVH in this patient population were identified.

Table 4 Univariate sensitivity analysis using stricter BP thresholds (office BP < 130/80 mmHg, home BP < 120/70 mmHg)

BP control categories	odds ratio	95% CI	P-value
Controlled both office and home BP (reference)	1		
Uncontrolled both office and home BP	1.69	0.43-6.63	0.454
Uncontrol office BP but controlled home BP	9.17	1.15-73.2	0.037
Controlled office BP but uncontrolled home BP	1.63	0.29-9.26	0.582

Abbreviations: BP, blood pressure; CI, confidence interval

Table 5 Multivariate analysis of factors associated with LV hypertrophy using stricter BP thresholds (office BP < 130/80 mmHg, home BP < 120/70 mmHg)

Characteristic	Multivariate analysis		
	odds ratio	95% CI	P-value
Age	1.02	0.97-1.08	0.417
Male	0.63	0.13-2.92	0.476
Smoking	0.39	0.07-2.25	0.229
Duration of hypertension	1.03	0.96-1.10	0.243
Number of anti -hypertensive drug	2.18	1.29-3.69	0.013
CAD	1.99	0.72-5.51	0.095
CKD	1.20	0.35-4.13	0.744
BP control categories			
Controlled both office and home BP (reference)	1		
Uncontrolled both office and home BP	2.44	0.47-12.70	0.289
Uncontrol office BP but controlled home BP	12.78	0.97-167.86	0.052
Controlled office BP but uncontrolled home BP	2.90	0.36-23.12	0.314

Abbreviations: BMI, body mass index; BP, blood pressure; CAD, coronary artery disease; CI, confidence interval; CKD, chronic kidney disease; HT, hypertension; LV, left ventricular; n, number
Multivariate model: logistic regression including age, sex, smoking history, duration of hypertension, number of hypertensive drugs, CAD, CKD and blood pressure–control category.

This study revealed that approximately 32.70% of hypertensive patients have LVH, which is comparable to the results of a literature review by Cuspidi et al., reporting an LVH prevalence of 36%-41%, depending on the criteria used[17]. However, a recent study by Apitz et al., using the same echocardiographic LVH criteria, showed a relatively low LVH prevalence (20%) compared with our findings[26]. In contrast, a higher prevalence of LVH in patients with hypertension was demonstrated in studies by Behera et al. and Conrady et al., with rates of 66.50% and 55.20%-72.20%, respectively, despite using the higher threshold for LVH than those applied in our study[16,18]. The overall varying prevalence of hypertensive heart disease among global populations can be attributed to different echocardiographic criteria, diverse patient populations, and varying degrees of hypertension. Additionally, approximately 50% of our study patients was able to control their office BP or home BP, which could affect the degree of LV remodeling and thus contribute to the prevalence of LVH. Furthermore, this could indicate that urban patients, who are more educated and have access to HBPM, are more attentive to their health care. Notably, regarding the pattern of LVH, all the study patients demonstrated a concentric hypertrophy geometric pattern, which is consistent with findings from several studies[16,27-28]. However, ethnic-specific reference values for LVMI may affect the estimation of LVH prevalence in different populations. A prior Thai study by Wong et al[29]. (2008) reported lower normal LVMI values in healthy Thai adults compared to American Society of Echocardiography (ASE) guidelines. Therefore, applying ASE cut-offs (> 115 g/m² for men, > 95 g/m² for women) might underestimate hypertensive LVH in this population. Future research is warranted to validate the appropriateness of international reference thresholds in Thai cohorts and consider ethnicity-specific criteria for LVH diagnosis.

According to current hypertension guidelines, BP control should be assessed using out-of-office measurements, such as HBPM or ambulatory BP monitoring, due to their stronger association with target organ damage. Thus, patients with elevated office BP but controlled home BP—often labeled as having white coat hypertension—are classified as having controlled BP. Conversely, patients with normal office BP but elevated home BP—defined as having masked hypertension—are considered uncontrolled and at higher cardiovascular risk. This study showed the highest prevalence of LVH in patients who could not control both their office and home BP to the target. Interestingly, patients with controlled office BP but uncontrolled home BP, indicating marked hypertension, had the lowest prevalence of LVH than the other subgroups. Our result may be partly due to the relatively small number of patients in this subgroup or possible misclassification caused by short-term BP variability or incorrect home BP technique. Additionally, it is possible that the duration or severity of elevated home BP in these patients was insufficient to produce measurable structural cardiac changes such as LVH. Future studies with longitudinal data and larger subgroup samples are needed to better understand these findings. The present study showed a much lower prevalence than a study by Cuspidi et al., which identified individuals who have masked hypertension with normal office BP and increased ambulatory BP or home BP or both[30]. Moreover, even patients with controlled office BP and home BP can still develop LV hypertrophy. This highlights the need for focusing on both home BP control and office control in patients with hypertension.

The current study found that the number of antihypertensive drugs was the only predictive factor for LVH after multivariate analysis, differing from previous studies that identified male sex, advanced age, obesity, and elevated BP as significant factors[14,16,18-20]. This difference may reflect variations in study populations,

definitions of LVH, and BP measurement methods. Importantly, the number of antihypertensive agents likely reflects treatment resistance or disease severity rather than being an independent causal factor. We addressed this by adjusting for it in our model, following a multinomial logistic regression that linked higher drug use with poor BP control. Nonetheless, this variable should be interpreted cautiously in regression analyses.

Although patients with both uncontrolled office and home BP are at high risk for LVH, no significant association was observed in our study. This may be due to the limited number of participants in this subgroup, reducing the power to detect a meaningful difference. Larger studies are needed to confirm this finding. Moreover, some predictors in the multivariate analysis showed wide confidence intervals and lacked statistical significance. This is likely attributable to small subgroup sample sizes, which resulted in less precise estimates and insufficient power to detect meaningful associations. Larger studies are warranted to clarify the impact of these factors on LVH. Nevertheless, our sensitivity analysis using lower BP cut-off threshold showed that patients with uncontrolled office, but controlled home BP had significantly higher odds of LVH. This suggests that episodic clinic BP elevations may drive ventricular remodeling despite acceptable home readings in this subgroup. Given the small subgroup size and wide CI, these findings should be confirmed in larger, prospective studies.

This study has several limitations. First, as an observational study, causality between BP control and LVH cannot be established. Second, as a single-center study with a relatively small sample size, the findings may not be generalizable to broader populations. Although the sample size was adequate for addressing the primary objectives, it may have limited the statistical power for secondary analyses, increasing the risk of false-negative results. Third, the absence of ambulatory BP monitoring and limited data on factors such as antihypertensive drug classes, salt intake, and physical activity may affect the robustness of the associations observed. Fourth, home BP was assessed over a short period, which may not capture long-term control and could be influenced by the Hawthorne effect. Fifth, while validated devices were recommended, there was no independent calibration of home BP monitors, introducing potential variability. Sixth, we did not assess several important factors that may influence LVH, such as antihypertensive drug classes, high salt intake, and physical activity. Lastly, although all echocardiographic studies were reviewed by a board-certified cardiologist, the use of a single operator may introduce intra-observer variability, which could affect the consistency of LVH assessment. However, this approach also reduced inter-observer variability and ensured procedural consistency throughout the study. Despite these limitations, we believe that the study results are beneficial for daily clinical practice and in developing strategies to identify LVH and consider more hypertension control in these patient populations. Future studies should focus on the clinical outcomes in these patient populations to gain clearer insight into the long-term implications of LVH and its management.

CONCLUSION

The prevalence of LVH is high among patients with hypertension, particularly those with uncontrolled office and home BP. This emphasizes the need for effective hypertension management strategies to prevent hypertension-mediated organ damage associated with LVH.

CONFLICT OF INTEREST

The authors have no financial interest in any of the products mentioned in this article.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to restrictions.

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Original Article

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Impact of Oral Health Knowledge and Attitude on the Severity of Periodontitis among Patients with Type 2 Diabetes Mellitus: A Cross-Sectional Study

Tipphawan Angkanusorn DDS[1], Pirasut Rodanant MDSc[1], Petch Rawdaree MD[2]

[1] *Department of Advanced General Dentistry, Faculty of Dentistry, Mahidol University, Bangkok 10400, Thailand*
[2] *Department of Medicine, Faculty of Medicine Vajira Hospital, Navamindradhiraj University, Bangkok 10300, Thailand*

ABSTRACT

OBJECTIVES: The aim of this study was to evaluate whether the level of oral health knowledge and attitudes of type 2 diabetes mellitus (T2DM) patients affected their periodontitis severity.

METHODS: Descriptive and statistical analysis of secondary data collected from follow-up 184 T2DM patients attending at Endocrinology Unit, Faculty of Medicine Vajira Hospital, was used.

RESULTS: All T2DM subjects were diagnosed as having periodontitis but with different degrees of severity: 64.7% and 70.0% of subjects with mild-to-moderate periodontitis had high knowledge and high attitude scores, respectively. A higher proportion of subjects (76.3%) with severe periodontitis had low attitude score. Of well-controlled diabetic subjects 20.6% had severe periodontitis, while of uncontrolled patients 40.8% suffered severe periodontitis. There was no significant difference between knowledge or attitude score and the level of periodontitis severity in T2DM. However, experiencing gingival problems was significantly related to periodontitis severity ($p = 0.024$).

CONCLUSION: General oral health knowledge does not have any impact on periodontitis severity while attitude seemingly does. Emphasize the knowledge on characteristic of gingival problems might affect periodontal health in people living with diabetes.

KEYWORDS: attitude, knowledge, periodontitis severity, T2DM

INTRODUCTION

Periodontitis is a persistent inflammatory condition that impacts the periodontium, which includes gingiva, alveolar bone, cementum and periodontal ligament. The accumulation of various periodontopathic bacteria in the dental biofilm due to inadequate oral hygiene care and lack of regular annual dental check-ups is the primary cause of the initiation and progression of periodontitis[1-3]. Several studies have indicated that patients with fair to poor oral hygiene had a 2-to 3- times higher risk of suffering from periodontitis comparing to those with good oral hygiene[4-6]. Epidemiologically, periodontitis is associated with various non-communicable chronic diseases (NCDs) including diabetes mellitus (DM), which is a two-way relationship. Evidence has shown that people living with diabetes have a 3- to 4-fold increase in the risk of periodontitis and, conversely, a significant increase in the severity of periodontitis presents in uncontrolled diabetic patients[7-11]. The European Federation of Periodontology (EFP) and the American Academy of Periodontology (AAP)

Corresponding author: Pirasut Rodanant, pirasut.rod@mahidol.ac.th
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have included DM as one of the risk factors contributing to the progression of periodontal disease[7]. Evidence has revealed links between the occurrence of microvascular complications and the severity of periodontitis[12], and several studies have demonstrated that uncontrolled diabetic patients were more prone to develop microvascular complications comparing to non-diabetic or controlled diabetic patients[13,14].

Though both DM and periodontitis are chronic inflammatory conditions that cannot be completely cured, adherence to effective measures could prevent an individual from being harmed by these conditions[4,7]. Adequate oral health care has been shown to help prevent and reduce the severity of periodontal disease, which might consequently improve diabetic condition[4]. It is widely accepted that human behaviors toward something are often influenced by their knowledge, which eventually affects their attitude[15,16]. Evidence also shows that lack of knowledge, attitude, and awareness regarding periodontitis in people living with diabetes may affect the severity of periodontitis and impact patients' quality of life (QoL)[17,18]. Nonetheless, a number of study have demonstrated inconclusive correlation between knowledge and attitude on the practice of oral health care among periodontitis in people living with diabetes[19-23].

This cross-sectional study aimed to investigate whether the level of knowledge and attitude related to the severity of periodontitis among patients with T2DM. The results might yield primary data for further comprehensive prevention programs for these groups of patients.

METHODS

This study was an observational study based on secondary data collected from subjects who were recruited for the previous study "Association between Periodontitis and Microvascular Complications among Patients with Type 2 Diabetes Mellitus"[24]. Prior to initiation of the study, approval was obtained from the Faculty of Dentistry/Faculty of Pharmacy, Mahidol University, Institutional Review Board (COE.No.MU-DT/PY-IRB 2023/031.1007). To maintain subject confidentiality, reporting of results will not include subjects' names.

The data collection was conducted between May 2018 to June 2018 from 184 T2DM patients attending a follow-up program at the Endocrinology Unit, Department of Medicine, Faculty of Medicine Vajira Hospital, Navamindradhiraj University.

The data collected from the patient chart record included the following: demographic data (i.e., gender, age, weight, height); duration of T2DM; laboratory investigation (i.e., fasting plasma glucose (FPG) level; glycosylated hemoglobin (HbA1c)).

Full mouth periodontal examination consisted of measuring gingival sulcus depth, clinical attachment level and bleeding on probing. Six locations on each tooth were probed with a manual periodontal probe (North Carolina periodontal probe UNC-15 Hu Friedy Manufacturing Inc, Chicago, IL) using an artificial dental unit light to obtain the measurements which were then recorded as mesiobuccal, midbuccal, distobuccal, distolingual, midlingual and mesiolingual. All the dental examinations were conducted by Assoc.Prof. Pirasut Rodanant. Periodontitis was classified into 3 severity levels[1]: mild periodontitis was defined as having at least one tooth but < 30% of the teeth with lost gingival attachment of ≥ 1 mm but ≥ 3 mm; moderate periodontitis was defined as 30-60% of the teeth with lost gingival attachment ≥ 3 mm or < 30% of the teeth with lost gingival attachment ≥ 5 mm; severe periodontitis was defined as ≥ 60% of the teeth with lost gingival attachment of ≥ 3 mm or ≥ 30% of the teeth having lost gingival attachment of ≥ 5 mm.

The questionnaire comprised 14 questions developed under the consensus of the members of the research team. A small-scale pre-test was conducted (n = 20). Cronbach alpha was calculated and found to be 0.502. A correct answer will be rewarded 1 point whereas 0 points for the

incorrect answer. An in-person interview was conducted whereby subjects were asked to answer the following questions: question numbers 1-8 measured oral health knowledge level. Subjects were divided into 2 groups (high and low knowledge level) according to the points they received from their answers; question numbers 9-12 measured oral health attitude level. Subjects were divided into 2 groups (high and low attitude level) according to the points they received from their answer; question numbers 13-14 evaluated subjects' perception of their oral health. The knowledge and attitude scores were initially evaluated using their means in order to approximate the central tendency of the sample and provide a balanced division for analysis[25], thus, the cut-off points for knowledge score and attitude score were as follow: patients who got ≥ 6 points were categorized as having high knowledge level, and patients who got < 6 points were categorized as having low knowledge level; patients who got ≥ 2 points were categorized as having high attitude level, and patients who got < 2 points were categorized as having low attitude level. Subjects were excluded from the study if they had incomplete details of the data (Figure 1). The SPSS Statistics 28.0.1.1 (IBM Corp. Released 2021. IBM SPSS Statistics for Macintosh, Version 28.0. Armonk, NY: IBM Corp.) was used to analyze data. Descriptive statistics is applied for elucidating general characteristics, DM status, periodontal status and oral health knowledge and attitude level. Analytical statistics is applied for assessing associations between clinical/laboratory characteristics and periodontal status via using independent sample *t*-test, association between DM status/knowledge level/attitude level and periodontal status via using Chi-square. Then the variables potentially associated with periodontal status are assessed via univariable and multivariable analysis.

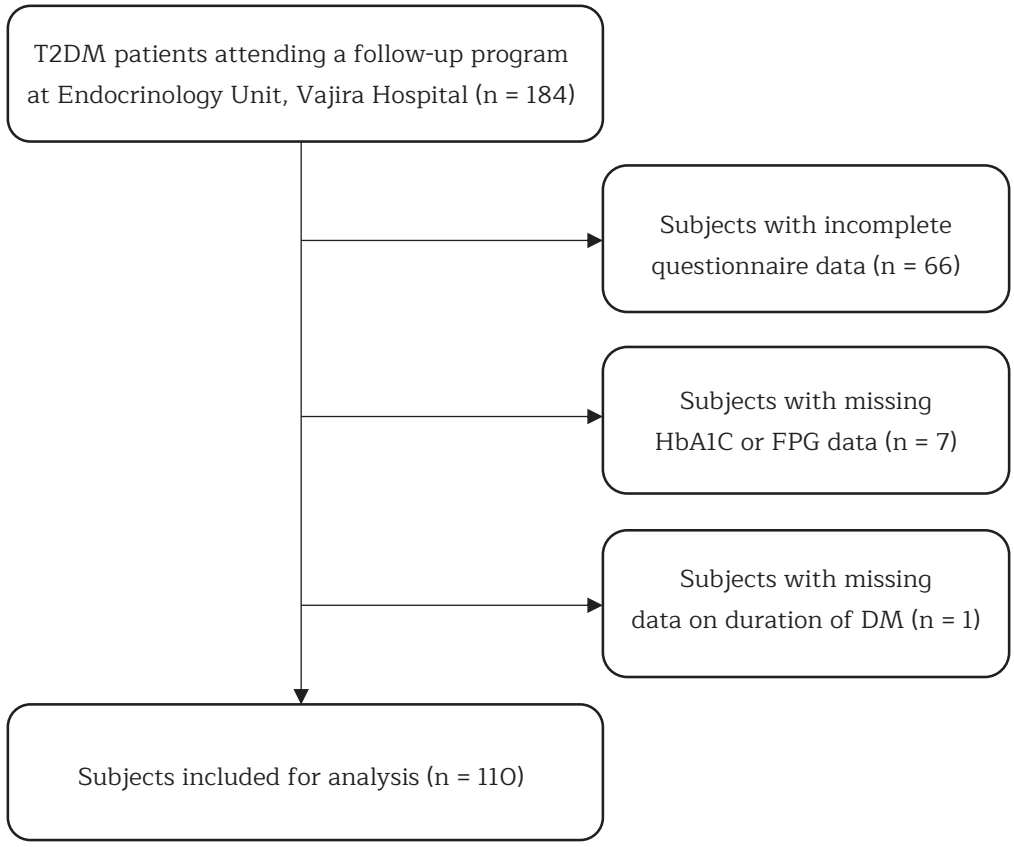

Figure 1 Number of participants recruited, excluded and included in the final analysis

RESULTS

Data of 110 subjects were collected for analysis. Thirty-eight subjects (34.5%) were diagnosed as having severe periodontitis. Sixty-five subjects (59.1%) suffered from moderate periodontitis. While seven subjects (6.4%) exhibited mild periodontitis. Demographic data of subjects are shown in Table 1.

The average knowledge score in these subjects was high (6.25 ± 1.17 points), while the average attitude score was low (0.99 ± 0.80 point). The details of the responses to each question are shown in Table 2.

Univariable analysis of factors potentially associated with periodontitis severity is demonstrated in Table 3. Regardless of the level of periodontitis severity, the majority of subjects had high knowledge scores (6-8 points) but low attitude score (0-1 points). Knowledge and attitude scores did not show any significant association with the level of periodontitis severity (p = 0.761 and p = 0.540, respectively). No matter the level of knowledge or attitude, about one-third of the subjects had severe periodontitis. Uncontrolled T2DM subjects (HbA1c > 7) were more likely to have severe periodontitis, which is statistically significant (p = 0.044, odds ratio 2.66, 95% confidence interval [1.03, 6.86]). An average body mass index (BMI) in subjects who were diagnosed with severe periodontitis (28.43 ± 5.13 kg/m^2) was higher than that of mild-to-moderate periodontitis subjects (26.48 ± 4.37 kg/m^2). There was a statistically significant association between BMI and the level of periodontitis severity (p = 0.044). FPG and HbA1c levels were notably higher in severe periodontitis subjects (179.0 ± 75.6 mg/dl and 8.6 ± 2.0%, respectively) than in mild-to-moderate periodontitis subjects (148.7 ± 36.5 mg/dl and 7.5 ± 1.3%, respectively). Statistically significant association was found between FPG and HbA1c and the level of periodontitis severity (p = 0.008 and p = 0.002, respectively). Nevertheless, using multivariable analysis, there was no statistically significant association between other potential factors and periodontitis severity (Table 4).

Table 1 Baseline characteristics of diabetic patients

1. Age (years)	
Mean ± SD	58.50 ± 10.44
2. Sex	
Male	43 (39.1%)
Female	67 (60.9%)
3. Duration	
Mean ± SD (years)	13.06 ± 7.02
≤ 10 years	40 (36.4%)
> 10 years	70 (63.6%)
4. BMI (kg/m^2)	
Mean ± SD	27.15 ± 4.72
5. FPG (mg/dl)	
Mean ± SD	159.13 ± 54.48
6. HbA1c (mg%)	
Mean ± SD	7.89 ± 1.62
≤ 7 (controlled DM)	38 (34.5%)
> 7 (uncontrolled DM)	72 (64.5%)
7. Periodontal status	
Mild	7 (6.4%)
Moderate	65 (59.1%)
Severe	38 (34.5%)

Abbreviations: BMI, body mass index; DM, diabetes mellitus; FPG, fasting plasma glucose; HbA1c, glycosylated hemoglobin; kg/m^2, kilogram per square metre; mg, milligrams; mg/dl, milligrams per deciliter; SD, standard deviation

Table 2 Response to questionnaire regarding knowledge and attitude in oral health according to periodontal status

Questions	Periodontal status	
	Mild-to-moderate N* (%)	Severe N* (%)
1. You should have a dental check-up at least twice a year.	43 (65.3)	27 (71.1)
2. Soft-bristled toothbrushes should be used.	59 (81.9)	30 (78.9)
3. Dental floss should be used after tooth brushing.	25 (34.7)	11 (28.9)
4. Mouthwash can be used to replace tooth brushing.	22 (30.6)	17 (44.7)
5. You should brush your teeth at least twice a day.	71 (98.6)	37 (97.4)
6. The type of food you consume affects your teeth and oral health.	55 (76.4)	29 (76.3)
7. People with diabetes are at a higher risk of periodontitis.	52 (72.2)	32 (83.2)
8. Improper brushing techniques can cause tooth wear.	67 (93.1)	36 (94.7)
9. You have a dental check-up regularly, at least twice a year.	27 (37.5)	12 (31.6)
10. Having been older could lead to tooth loss.	71 (98.6)	37 (97.4)
11. Experiencing toothache, swollen gingiva, or needing a tooth extraction is embarrassing.	11 (15.3)	10 (26.3)
12. Visiting a dentist makes you feel worry.	41 (56.9)	22 (57.9)
13. You do know how to well-maintain your oral hygiene.	48 (66.7)	22 (57.9)
14. You are currently experiencing negative issues with your gingiva.	33 (45.8)	26 (68.4)

Abbreviation: N, number
* Number of subjects who respond 'YES' to each question.

Table 3 Univariable analysis of factors associated with periodontitis severity

	Periodontal status		Crude OR (95%CI)	P-value
	Mild/Moderate	Severe		
Knowledge score				
Low	17	8	0.86 (0.33, 2.23)	0.761
High	55	30	1	
Attitude score				
Low	51	29	1.33 (0.54, 3.28)	0.540
High	21	9	1	
DM status				
Uncontrolled	45	31	2.66 (1.03, 6.86)	0.044
Controlled	27	7	1	
DM indicators				
BMI	26.48 ± 4.37	28.43 ± 5.13	1.09 (1.00, 1.20)	0.044
FPG	148.67 ± 36.46	178.95 ± 75.59	1.01 (1.00, 1.19)	0.008
HbA1C	7.52 ± 1.29	8.57 ± 1.95	1.59 (1.16, 1.97)	0.002

Abbreviations: BMI, body mass index; CI, confidence interval; DM, diabetes mellitus; FPG, fasting plasma glucose; HbA1c, glycosylated hemoglobin; OR, odds ratio

Table 4 Multivariable analysis of factors associated with periodontitis severity

	Adjusted or (95%CI)	P-value
Knowledge score: low	0.86 (0.32, 2.34)	0.766
Attitude score: low	1.35 (0.54, 3.55)	0.506
DM status: Uncontrolled (HbA1C > 7)	2.28 (0.86, 6.06)	0.098
BMI	1.08 (0.99, 1.18)	0.097

Abbreviations: BMI, body mass index; CI, confidence interval; DM, diabetes mellitus; HbA1c, glycosylated hemoglobin.

DISCUSSION

This study found that people living with diabetes have satisfactory knowledge but low attitude toward oral health. Interestingly, among people living with diabetes categorized as having severe periodontitis, a high proportion of subjects had low attitude score. Nevertheless, statistical significance could not be demonstrated. This finding is consistent with the study of Penmetsa et al., which stated that a positive attitude plays a key role in achieving better periodontal status[26].

This study showed that the level of oral health knowledge and attitude did not correlate with the level of the severity of periodontitis in patients with T2DM. The multivariable analysis demonstrated that knowledge and attitude towards periodontal health are not strong dependent factors in predicting periodontal disease severity. Our results suggested that knowledge and attitude would have less significant impact on the progression of periodontitis than other variables in these subjects. Several epidemiological studies have identified many risk factors to be implicated in the manifestation and progression of periodontal diseases such as age, gender, oral hygiene habits, frequency of dental visits, income level, education attainment, residence place, cigarette smoking, DM, ethnicity, microbiological factors, genetic factors, immunity, social and behavioral factors, and psychological factors[27-29]. Our study indicated a statistically significant association between uncontrolled DM (HbA1c > 7) and severe periodontitis. This result is consistent with a study by Tsai et al. who found that adults with diabetes exhibited a higher prevalence of severe periodontitis than those without diabetes, and highest prevalence was observed in individuals with poorly controlled diabetes[30]. The analysis demonstrated a potential trend indicating that systemic factors such as uncontrolled diabetes and higher BMI may have a more considerable independent effect on periodontal health. Results from this study align with the findings of Saito et al. who reported that the greater the BMI, the greater the risk of having periodontitis[31]. Our findings also align with other studies which revealed the interrelationship between oral health and systemic diseases (including DM)[7,11,14,30,32,33].

Interestingly, while a majority of subjects had a high knowledge score regarding oral health care, their attitude scores were low. This finding suggested that while subjects had knowledge regarding good oral hygiene practices, this knowledge does not raise their awareness towards a positive attitude on oral health care. This observation seemed to conform with the characteristics of our subjects. They were elderly individuals who had an experience of having poor oral hygiene status for a long time and were familiar with negative attitude in oral health, such as the perception that tooth loss is a natural process of their lifetime. It indicates a gap between knowledge and practice that needs to be addressed through behavioral interventions[33]. This observation might point out the need for public health initiatives not only to educate generally about oral health concerns but also to provide declarative and procedural knowledge to T2DM patients in order to emphasize that individuals engage with health behavior that positively impacts their QoL[34,35]. Moreover, repetition making concrete examples that impact their QoL concerning their gingival problems might elevate the possibility of raising their awareness practice adequate oral hygiene care[36,37].

Our results showed that people with severe periodontal status are more likely to report having gingival problems than those with mild/moderate periodontal status. Gingival problems provoked difficulty in food mastication which might impact QoL and eventually raise health issue concerns[38,39]. This result aligns with what one would expect intuitively, as more severe periodontal conditions would likely lead to more noticeable gingival issues. The statistical significance implies that this is not likely due to random chance, but rather there is a true association between

the severity of periodontal disease and the experience of gingival issues. This finding might indicate a crucial need to align knowledge with their QoL to improve attitudes and foster better oral health behavior[40].

Another explanation on the lack of correlation between knowledge and periodontitis severity was the appropriateness of the knowledge content. Evidence has shown that lack of knowledge and awareness about the etiology of periodontal diseases and the effect of proper treatment in maintaining and preventing further destruction of periodontal tissues led to the further destruction of periodontal tissues[40]. Our results demonstrated good knowledge on periodontal health issues, which generally emphasize disease prevention. However, the lack of correlation between knowledge and periodontal status presenting in our study might imply that these subjects did have knowledge in preventing disease occurrence but not enough to stop the disease progression[41].

Although our study did not find any correlation between attitude and the periodontitis severity, it suggested the importance of positive attitude toward having better oral health status. Subjects with positive attitude could perform better oral hygiene practice than those without.

As the characteristic of cross sectional study, relatively small sample size from one specific institution, and the use of secondary data set which might limit the ability to detect some potentially relevant psychosocial and behavioral variables (eg. smoking habit), the results of our study might not be a strong inferrence for the general diabetic population in the country. The use of secondary data which did not contain oral radiographic examination also limited us to use the old version of periodontal disease classification which categorize periodontitis severity into 3 levels rather than the use of a recent 2018 AAP/EFP classification of periodontal diseases which categorize periodontal severity into 4 satges. Another flaw of this study included the reliability of the questionnaires (ie. the process of validation and the ambiguous phrases of question items wording) which might affect the interpretation of the results. Larger sample sizes from multi-center institutions, a design of case-control study, the construction of clear and understandable question items, or the thoroughness of data collection concerning the initiation and progression of periodontitis might be necessary to fully elucidate the relationships between knowledge, attitudes, and the severity of periodontal disease and to validate the associations observed in this study.

CONCLUSION

With certain limitations, this study has highlighted a crucial link between diabetes and periodontitis, showcasing the impact of knowledge and attitudes on oral health outcomes in diabetic patients. General oral health knowledge does not have strong effect on periodontitis severity while attitude seemingly affects periodontitis severity. Providing appropriate knowledge concerning patients' QoL is necessary. The present findings emphasized the need for integrated care approaches by including oral health promotion intervention into the components of T2DM management. Addressing this issue requires a multifaceted approach that includes providing targeted oral health education, improving oral health attitude, and fostering collaboration between dental and medical healthcare providers.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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DATA AVAILABILITY STATEMENT

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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Original Article

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COVID-19 Infection Rate and Cofactor in Non-Patients under Investigation: Rethinking the COVID-19 Screening Policy

Chayada Chanasriyotin MD[1], Sirinan Junthong MD[1], Piyarat Parklug MD[2], Kawinyarat Jitaroon MD[1], Naruporn Marukatat MD[2]

[1] *Department of Otolaryngology–Head and Neck Surgery, Faculty of Medicine Vajira Hospital, Navamindradhiraj University, Bangkok 10300, Thailand*

[2] *Department of Radiology, Faculty of Medicine Vajira Hospital, Navamindradhiraj University, Bangkok 10300, Thailand*

ABSTRACT

OBJECTIVE: To determine the infection rate and cofactors of coronavirus disease (COVID-19) in individuals who are not patients under investigation (non-PUIs) at a tertiary hospital.

METHODS: In this cross-sectional descriptive study conducted between October 2022 and April 2023, the infection rate of COVID-19 in non-PUIs was determined, and the general characteristics, underlying diseases, occupations, number of vaccinations, and signs and symptoms were studied.

RESULTS: The infection rate in non-PUIs was 9.9% (n = 31), and 90.1% (n = 282) were negative. The signs and symptoms significantly associated with COVID-19 positivity were fever (odds ratio (OR) 22.32, 95% confidence interval (CI) 5.26-94.68), malaise (OR 19.10, 95% CI 8.10-45.06), myalgia (OR 16.61, 95% CI 6.14-44.95), sore throat (OR 11.71, 95% CI 4.62-29.67), tiredness (OR 10.00, 95% CI 4.26-23.42), headache (OR 7.94, 95% CI 3.55-17.77), diarrhea (OR 7.42, 95% CI 3.02-18.23), cough (OR 7.39, 95% CI 3.17-17.21), rhinorrhea (OR 6.40, 95% CI 2.82-14.49), phlegm (OR 3.94, 95% CI 1.81-8.58), and vaccination with 0-2 shots (OR 2.22, 95% CI 1.01-4.90). Anosmia (OR 1.67, 95% CI 0.54-5.18), rash (OR 1.86, 95% CI 0.72-4.92), and dizziness (OR 1.08, 95% CI 0.36-3.28) were not significantly associated (p > 0.05).

CONCLUSION: Symptom-based screening among pre-admission patients not meeting PUI criteria may help detect overlooked COVID-19 cases. Key symptoms associated with infection included fever, cough, sore throat, phlegm, and myalgia. Additionally, individuals who received fewer than three vaccine doses had higher infection rates. These findings support the need to refine screening protocols to include clinical and vaccination risk factors in non-PUI populations.

KEYWORDS: COVID-19, infection, screening, symptoms, Thailand, vaccine

INTRODUCTION

Coronavirus disease 2019 (COVID-19), defined as enigmatic viral pneumonia, was first identified in December 2019 in Wuhan, China, from where it subsequently transcended national boundaries, effectuating global dissemination[1]. By March 2020, the World Health Organization formally acknowledged the outbreak as a pandemic[2]. In Thailand, the emergence of COVID-19 among the population was initially noted in January 2020[3], and a resurgence was observed in December 2020. The number of confirmed cases increased incrementally, recording 1,651 cases with a mortality rate of 0.6%

Corresponding author: Naruporn Marukatat, mnaruporn@gmail.com, naruporn@nmu.ac.th
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by March 2020[4]. By April 2020, the number of cases had risen to 2,907 with a mortality rate of 1.8%[5].

A notable and steady surge in case numbers was observed during the 3rd and 4th waves that began in April 2021, with 50,189 cases and 121 deaths reported in the same month[6]. Further, the B.1.1.7 variant emerged in May and June, accounting for 40%-70% of new cases. This variant is characterized by increased virulence and prolonged presence within the host and also displays a propensity for transmission across age groups. Typically, affected individuals present with symptoms similar to those of influenza, making this outbreak a significant health concern in Thailand.

Patients under investigation (PUIs) are those who present with symptoms of COVID-19 and have been in close contact with individuals with confirmed infection. PUIs may present with a variety of symptoms, each with a different prevalence. The most common symptoms among PUIs were coughing (73.6%), fever (58.5%), sore throat (39.6%), and muscle aches (37.4%)[7]. In Thailand, respiratory symptoms were the most common clinical manifestations in PUIs (69.8 %), followed by common cold-like symptoms (15.1%) and pneumonia (11.3%), whereas a small percentage of PUIs were asymptomatic (3.8%)[7]. In an alarming statistic from Italy, approximately 45% of asymptomatic individuals were found to be carriers of the infection, potentially spreading the virus without knowing[8]. Both symptomatic and asymptomatic carriers can transmit the virus, with the infectious period lasting up to 14 days[9,10].

Notably, unlike symptomatic patients, asymptomatic patients do not present with a level of viral material that can be detected using real-time polymerase chain reaction (RT-PCR); this make it challenge to identify asymptomatic carriers through standard nasopharyngeal swab screening alone[11].

In Thailand, the rapid SARS-CoV-2 antigen detection assay demonstrated sensitivity and specificity comparable to those of RT-PCR assay[11]. Consequently, this rapid and straightforward antigen detection test was used as a screening tool. Nasal swabs were selected for the antigen test to aid in diagnostic procedures and in adherence to hospital policy and for convenience[11]. However, screening was typically performed on PUIs. Thus, data on non-PUIs in Thailand are limited. This group may include patients with asymptomatic infections who can contribute to the undetected and rapid spread of COVID-19. Therefore, it is important to investigate this cohort more thoroughly.

Diagnostic imaging, particularly computed tomography (CT), plays a crucial role in identifying infections. Pulmonary abnormalities were identified in 47.6% of asymptomatic individuals, with ground-glass opacities (GGO) being the most prevalent finding, reported in 94.8% of asymptomatic patients who had positive chest computed tomography (CT) findings in a study conducted by Meng et al[12]. These finding suggest that even in the absence symptoms, imaging may reveal early pulmonary involvement, highlighting the potential for undetected disease progression and transmission. These opacities were more commonly present in the periphery of the lungs (75.9%) than in unilateral locations (58.6%) and involved the lower lungs more than the upper lungs[13,14]. Chest radiography was not typically conducted for non-PUIs unless they exhibited symptoms of dyspnea. Moreover, abnormalities on pulmonary CT could be due to respiratory pathologies other than COVID-19. These findings highlight the complexity and variability of disease presentation, the significant role of diagnostic imaging in identifying pulmonary manifestations, and the challenges in identifying asymptomatic carriers and controlling the spread of the virus.

In this study, we focused on individuals who were scheduled for hospital admission or preoperative procedures but did not meet the official criteria for PUIs as defined by national guidelines. These individuals, henceforth referred to as “pre-admission patients not meeting PUI criteria”

(or "non-PUIs" for brevity), were screened per hospital protocol using antigen testing. Despite lacking epidemiologic risk factors or a clear contact history, many presented with mild, non-specific symptoms such as phlegm, cough, or myalgia, which may not trigger PUI classification under standard criteria—especially during overwhelming surges. This raises concerns that such patients might represent a reservoir of undetected transmission, necessitating further investigation into their infection rate and associated factors.

METHODS

This cross-sectional descriptive study was conducted at Vajira Hospital, Navamindradhiraj University, a tertiary care center in Bangkok, Thailand, between October 2022 and April 2023 and included non-PUIs aged 18-90 years. Pregnant women were excluded from the study. According to Bruminhent et al.[7], PUIs are individuals exhibiting specific combinations of symptoms and epidemiologic risk factors (e.g., known contact with confirmed cases, travel to outbreak areas, or working in high-risk settings). In contrast, non-PUIs in this study were defined as patients scheduled for hospital admission or elective procedures who did not meet PUI criteria at the time of evaluation. While some participants exhibited mild respiratory symptoms, they lacked contact history or epidemiologic risk factors required for PUI classification. This reflects real-world scenarios where mildly symptomatic or asymptomatic patients may not be identified as high-risk but could still contribute to viral transmission. For clarity, these individuals are hereafter referred to as "pre-admission patients not meeting PUI criteria." The criteria for PUIs, based on Bruminhent et al., include individuals with at least one of the following: (1) Fever (> 37.5°C) and respiratory symptoms (e.g., cough, sore throat, nasal congestion, dyspnea) along with a history of travel to outbreak areas, exposure to crowded settings, or contact with confirmed COVID-19 cases; (2) Pneumonia with a history of COVID-19 exposure, unknown etiology unresponsive to treatment within 48–72 hours, or suspected COVID-19 pneumonia; (3) Fever and respiratory symptoms in high-risk individuals as determined by clinicians or public health authorities; (4) Association with a defined community cluster during an outbreak.

Non-PUIs included in this study were patients requiring hospital admission or pre-admission for surgery without contact history with patients with a confirmed COVID-19 diagnosis, patients with respiratory symptoms, or those not fitting the PUI criteria. An antigen testing kit (ATK) was used to test for COVID-19 via nasal or nasopharyngeal swabs at the Acute Respiratory Infection Clinic and the Otolaryngology Department for outpatients and inpatients. Written informed consent was obtained from all participants. All nasal swab procedures were performed by an otolaryngology resident and a trained research assistant using the Food and Drug Administration-approved ATKs. This study was approved by the Research Ethics Review Committee for Research Involving Human Subjects of the Vajira Hospital Faculty of Medicine (COA 222/2564).

The initial number of index cases with documented comprehensive contact tracing was 319. The analysis included 313 cases after excluding 6 with incomplete data. The collected data included demographics (gender, age, body mass index (BMI), underlying diseases, occupation, vaccination details, smoking, and alcohol consumption history) and clinical features during admission (fever, cough, phlegm, headache, malaise, sore throat, rhinorrhea, tired, myalgia, anosmia, diarrhea, rash, and dizziness). These measures were used to evaluate the infection rate and potential cofactors of COVID-19.

Using a reference from Bruminhent et al.[7], the previously determined COVID-19 infection rate of 13.1% (p = 0.13) with D = 0.04 was used to achieve a 95% confidence interval. Nevertheless, we increased the number to include > 300 patients to enhance the robustness of the results.

Statistical analyses were performed using IBM SPSS® version 23.0 (IBM Corp Armonk, NY). Using a significance level of 0.05, Chi-squared tests were applied to evaluate the association between categorical variables and COVID-19 positivity. Furthermore, multivariable logistic regression analysis was performed to identify independent cofactors associated with COVID-19 infection.

RESULTS

A total of 313 individuals were tested for COVID-19 during the study period, including 41.9% men (Table 1). The average age of the participants was 53.63 ± 17.85 years (range 18–90), and the average BMI was 24.39 ± 4.92 (range 14.90–49.12). Approximately 38.3% of the participants did not have any underlying diseases. Among those with underlying diseases, the most common comorbidities were hypertension (58.1%), dyslipidemia (28.0%), diabetes (23.8%), allergy (14.5%), thyroid disease (11.4%), and kidney disease (9.3%). Of the 313 individuals, 114 (36.4%) were unemployed, 180 (57.5%) were employed (government officer, business owner, or employee), and 17 (5.4%) were students. Additionally, 283 patients (90.4%) were non-smokers, and 264 (84.3%) did not consume alcohol.

Table 1 Characteristics of the patients who were not classified as PUI for COVID-19

Variable		Number	Percentage
Age (± SD, min-max)		**53.63 ± 17.85, 18-19**	
Sex	Male	131	41.9
	Female	182	58.1
Underlying diseases	None	120	38.3
	Hypertension	101	58.1
	Hyperlipidemia	54	28.0
	Diabetes	46	23.8
	Allergy	28	14.5
	Thyroid disease	22	11.4
	Kidney disease	18	9.3
Occupation	Unemployed	114	36.4
	Government officer	42	13.4
	Private officer	41	13.1
	Owner business	33	10.5
	Student	17	5.4
	Employee	64	20.4
Smoking history	Non-smoker	283	90.4
	Smoker	30	9.6
Alcohol consumption	None	264	84.3
	Drinks alcohol	17	15.7
Vaccination (No. of shot)	0	14	4.5
	1	5	1.6
	2	48	15.3
	3	133	42.5
	4	96	30.7
	5	16	5.1
	6	1	0.3

Table 1 Characteristics of the patients who were not classified as PUI for COVID-19 (continued)

Variable		Number	Percentage
Age (± SD, min-max)		**53.63 ± 17.85, 18-19**	
Vaccination details (Type of vaccine and no. of shot)	Sinovac	64	20.4
	1	18	28.1
	2	46	71.9
	Sinopharm	19	6.1
	1	5	1.6
	2	14	4.5
	AstraZeneca	249	79.6
	1	49	15.7
	2	185	59.1
	3	15	4.8
	Moderna	64	20.4
	1	40	12.8
	2	22	7.0
	3	2	0.6
	Pfizer	182	58.1
	1	102	32.6
	2	68	21.7
	3	12	3.8

Abbreviation: SD, standard deviation

The number of vaccination shots the participants received ranged from 0 to 6, with the majority having received 3 shots (42.5%) followed by 4 shots (30.7%). The participants received varying combinations of vaccines, with AstraZeneca being the most common (79.6%). Of these, 15.7%, 59.1%, and 4.8% received 1, 2, and 3 shots, respectively. Additionally, 58.1% of the participants received Pfizer vaccine, whereas 20.4%, 20.4%, and 6.1% received Moderna, Sinopharm, and Sinovac vaccines, respectively.

Of the 313 participants, 217 (69.3%) reported experiencing at least one symptom potentially associated with COVID-19, while 96 participants (30.7%) were asymptomatic at the time of screening. Among the 31 COVID-19-positive cases, 29 were symptomatic (93.5%) and only 2 (6.5%) were completely asymptomatic. The most common symptoms in positive cases were phlegm (n = 20, 64.5%), cough (n = 19, 61.3%), sore throat (n = 18, 58.1%), myalgia (n = 17, 54.8%), tiredness (n = 16, 51.6%), and headache (n = 15, 48.4%).

Symptomatic individuals demonstrated a significantly higher COVID-19 positivity rate (13.4%) compared to asymptomatic individuals (2.1%) ($p < 0.001$). These findings support the association between the presence of symptoms and a higher likelihood of infection. However, the presence of two asymptomatic positive cases underscores the potential role of this group in silent transmission.

Our analysis also revealed that 9.9% of the non-PUIs tested positive for COVID-19 (Table 2), with commonly observed symptoms being phlegm in the throat (34.8%), cough (32.6%), rhinorrhea (31.9%), sore throat (31.6%), myalgia (29.7%), tiredness (27.5%), and headache (25.6%). In contrast, rash, dizziness, anosmia, diarrhea, and fever were less common (2.9%-12.1%).

Table 2 Frequency of signs and symptoms among non-PUI patients and overall COVID-19 positivity rate

Signs and symptoms	Number	Percentage
Fever	9	2.9
Cough	102	32.6
Phlegm	109	34.8
Headache	80	25.6
Malaise	54	17.3
Sore throat	99	31.6
Rhinorrhea	100	31.9
Tiredness	86	27.5
Myalgia	93	29.7
Anosmia	27	8.6
Diarrhea	27	8.6
Rash	38	12.1
Dizziness	38	12.1
Infection rate		
Negative	282	90.1
Positive	31	9.9

Using the Chi-squared test, the symptoms found to be significantly correlated with a positive COVID-19 test were fever, cough, phlegm, headache, malaise, sore throat, rhinorrhea, tiredness, myalgia, and diarrhea ($p < 0.001$). Additionally, a vaccination history of 0, 1, or 2 shots was significantly associated with COVID-19 positivity ($p < 0.05$). Conversely, sex, age, BMI, underlying disease, history of smoking and alcohol consumption, anosmia, rash, and dizziness were not significantly associated with COVID-19 positivity ($p > 0.05$; Table 3).

Table 3 Association between clinical factors and COVID-19 positivity on Chi-square test

Cofactors	Positive		Negative		P-value*
Demographic	n	%	n	%	
Sex					0.449
Male	11	8.4	120	91.6	
Female	20	11	162	89.0	
Age					0.202
< 60	20	11.9	148	88.1	
≥ 60	11	7.6	134	92.4	
Body Mass Index					0.366
< 25	17	8.7	178	91.3	
≥ 25	14	11.9	104	88.1	
Underlying disease					0.410
Yes	17	8.8	176	91.2	
No	14	11.7	106	88.3	
Smoking history					0.056
Yes	0	0	30	100	
No	31	11	252	89	

Table 3 Association between clinical factors and COVID-19 positivity on Chi-square test (continued)

Cofactors	Positive		Negative		P-value*
Demographic	n	%	n	%	
Alcohol consumption					0.601
Yes	6	12.2	43	87.8	
No	25	9.5	239	90.5	
Covid-19 vaccine					0.048
0-2 shots	11	16.4	56	83.6	
> 2 shots	20	8.1	226	91.9	
Signs and symptoms					
Fever					< 0.001
Yes	6	66.7	3	33.3	
No	25	8.2	278	91.8	
Cough					< 0.001
Yes	23	22.5	79	77.5	
No	8	3.8	203	96.2	
Phlegm					< 0.001
Yes	20	18.3	89	81.7	
No	11	5.4	193	94.6	
Headache					< 0.001
Yes	21	26.3	59	73.8	
No	10	4.3	223	95.7	
Malaise					< 0.001
Yes	22	40.7	32	59.3	
No	9	3.5	250	96.5	
Sore Throat					< 0.001
Yes	25	25.3	74	74.7	
No	6	2.8	208	97.2	
Rhinorrhea					< 0.001
Yes	22	22.0	78	78.0	
No	9	4.2	204	95.8	
Tiredness					< 0.001
Yes	23	26.7	63	73.3	
No	8	3.5	219	96.5	
Myalgia					< 0.001
Yes	26	28.0	67	72.0	
No	5	2.3	214	97.7	
Anosmia					0.324
Yes	4	14.8	23	85.2	
No	27	9.4	259	90.6	
Diarrhea					< 0.001
Yes	10	37.0	17	63.0	
No	21	7.3	265	92.7	
Rash					0.240
Yes	6	15.8	32	84.2	
No	25	9.1	250	90.9	
Dizziness					0.778
Yes	4	10.5	34	89.5	
No	27	9.8	248	90.2	

Abbreviations: n, number; *, significant

After evaluating all cofactors in Table 3, we identified the variables that showed a statistically significant association with COVID-19 positivity. These significant variables were then included in a multivariable logistic regression analysis, the results of which are presented in Table 4.

Moreover, multiple logistic regression analysis revealed a correlation between multiple cofactors (signs and symptoms and vaccination status) and COVID-19 positivity. Symptoms such as fever, malaise, myalgia, sore throat, tiredness, headache, diarrhea, cough, rhinorrhea, and phlegm were significantly correlated with COVID-19 positivity, whereas anosmia, rash, and dizziness were not ($p > 0.05$). Additionally, vaccination with 0-2 shots was significantly correlated with COVID-19 positivity (Table 4).

Of the 31 patients positive for COVID-19, 5 underwent chest radiography based on clinical concerns from the physicians. The first case was of a 73-year-old woman presenting with symptoms of cough, headache, and tiredness. Her chest radiograph revealed ground-glass opacity in the peripheral left lung, resulting in the diagnosis of COVID-19. The second case was a 68-year-old obese male patient (BMI > 30) with symptoms of cough, sore throat, and diarrhea. His radiograph revealed poorly defined GGO in the bilateral lower lungs. Both patients were prescribed molnupiravir. The third case was a 61-year-old woman with symptoms of sore throat, myalgia, and fever. Her chest radiograph revealed no recent focal or diffuse lung opacities. Despite this, she received paxlovid after testing positive on ATK. The fourth case was of a 67-year-old woman who presented with mild tiredness. Her chest radiograph revealed cardiomegaly and mild pulmonary congestion. The remaining case was a 57-year-old woman complaining of phlegm in her throat and rhinorrhea. Her chest radiograph was normal. Symptomatic treatment was administered to both patients.

Table 4 Adjusted odds ratio for multiple cofactors associated with COVID-19 positivity from multivariable logistic regression analysis

Cofactors	OR (95%CI)	P-value
Fever	22.32 (5.26-94.68)	< 0.001
Cough	7.39 (3.172-17.206)	< 0.001
Phlegm	3.94 (1.81-8.58)	< 0.001
Headache	7.94 (3.55-17.77)	< 0.001
Malaise	19.10 (8.1-45.06)	< 0.001
Sore throat	11.71 (4.62-29.67)	< 0.001
Rhinorrhea	6.40 (2.82-14.49)	< 0.001
Tiredness	10.00 (4.26-23.42)	< 0.001
Myalgia	16.61 (6.14-44.95)	< 0.001
Anosmia	1.67 (0.54-5.182)	0.376
Diarrhea	7.42 (3.02-18.23)	< 0.001
Rash	1.86 (0.72-4.92)	0.201
Dizziness	1.08 (0.36-3.28)	0.891
Vaccination 0-2 shots	2.22 (1.01-4.90)	0.048

Abbreviations: CI, confidence interval; OR, odds ratio

DISCUSSION

COVID-19 remains a considerable public health issue, underscoring the necessity to examine its impact on not only PUIs and high-risk populations but also non-PUIs and asymptomatic populations. High-risk individuals are those who have had unprotected close contact with confirmed patients with COVID-19. Such individuals who test negative for COVID-19 should be isolated, and symptoms should be monitored for 14 days[9]. Conversely, low-risk individuals are those exposed to high-risk contacts but not directly exposed to confirmed cases. These individuals should undergo symptom observation rather than testing or quarantine. Although these individuals are not identified as potential COVID-19 cases, they remain susceptible to infection and can act as carriers. Therefore, implementing a standard screening protocol for non-PUIs is important to ensure prompt treatment and curtail virus transmission.

Identifying COVID-19 cases is challenging because of asymptomatic or non-specific symptom presentations. Although these symptoms indicate potential cases, they also contribute to the complexity of effectively identifying COVID-19 cases. The variability in testing capacity and strategies for different groups further compounds this difficulty, affecting the accuracy and completeness of reported cases. The current protocol at out hospital does not include screening non-PUIs for COVID-19 as a standard practice. Asymptomatic patients also usually do not exhibit nasal swab abnormalities associated with COVID-19[14], necessitating additional screening, such as ATK, which is not a standard test for non-PUIs or asymptomatic individuals. Furthermore, testing every patient in the lower-risk group is impractical owing to budget constraints. Therefore, random testing of untested patients is conducted to estimate the rate of infections that are not identified through the standard screening process. Nevertheless, research focusing on patients in the low-risk category with COVID-19 is limited, warranting further research in this area. Additionally, incorporating asymptomatic COVID-19 cases into the non-PUI cohort could lead to a higher detection rate than the conventional approach that screens only PUIs. Identifying and promptly treating asymptomatic patients with COVID-19 is expected to curtail viral transmission, resulting in fewer complications. This approach allows patients to access earlier treatment compared with the standard screening methods of RT-PCR, thereby offering potential benefits that are significant to this study.

The infection rate among non-PUIs in this study was 9.9%, and they presented with common symptoms such as cough, phlegm, headache, malaise, sore throat, rhinorrhea, tiredness, and myalgia that are significantly associated with COVID-19. Moreover, despite the fewer presentations in this cohort, fever and diarrhea were highly associated with COVID-19 positivity. In contrast, symptoms such as anosmia, rash, and dizziness were not significantly associated with COVID-19 positivity. These findings indicate that these symptoms can serve as indicators for screening and reporting in all patients. These findings highlight that patients undergoing pre-admission screening, many of whom do not meet standard PUI criteria, may still harbor and potentially transmit COVID-19. This suggests a need to reassess current hospital screening policies to ensure early detection and prevention of viral spread, even among individuals not considered high-risk by conventional definitions. Conversely, chest radiographs in non-PUIs with COVID-19 showed a range of findings, from normal appearances to evident lung abnormalities. Despite the high sensitivity of chest CT in detecting COVID-19, CT abnormalities may be caused by viral diseases other than COVID-19[13]. Therefore, chest CT should not be considered a first-line screening method for COVID-19.

This study reported a correlation between a complete vaccination regimen and a reduced incidence of COVID-19. Particularly, receiving

more than two vaccination shots offered protective benefits against the infection. This finding indicates that the administration of COVID-19 vaccines decreases the risk of severe disease, ultimately lowering morbidity and mortality rates. Furthermore, the 9.9% COVID-19 positivity rate among non-PUIs underscores the importance of more rigorous screening of asymptomatic individuals. These findings are consistent with those of a previous study[15], which reported that 1.8% of healthy asymptomatic individuals tested positive for serum anti-SARS-CoV-2 Immunoglobulin G antibodies, indicating that the number of asymptomatic individuals is 6-24 times higher than that of symptomatic cases in the study area.

As the virus and disease symptoms continue to evolve, public authorities and researchers must remain vigilant in monitoring infection rates not only among high-risk populations but also within specific cohorts such as non-PUIs. This ongoing surveillance is vital for developing effective response strategies and safeguarding public health. Given the dynamic nature of the disease, updates and guidance from reputable health organizations are essential to keep the public informed about the latest developments and recommendations. Additionally, the situation may have changed since the last update, underscoring the importance of consulting up-to-date, trustworthy, and authoritative sources for the most current information and guidance.

This study has several limitations. First, the classification of participants as "non-PUIs" was based on national screening guidelines, which may have excluded individuals with mild or atypical symptoms who could meet evolving definitions of PUIs during periods of high transmission, potentially introducing misclassification bias. Second, data on symptom onset, duration, and severity were not collected, limiting the ability to evaluate clinical progression and potential infectiousness. Third, the study was conducted at a single center, which may limit the generalizability of the findings to other healthcare settings. Fourth, unmeasured demographic and behavioral factors not included in the multivariable analysis may have influenced the results. Fifth, the use of ATKs as the sole diagnostic tool—despite their convenience—carries lower sensitivity compared to RT-PCR, particularly in asymptomatic or early-stage infections. This may have led to an underestimation of the true infection rate. Lastly, as a pioneering study on COVID-19 prevalence among non-PUI individuals, there was no prior reference data specific to this population. As such, we referenced available data on asymptomatic infection rates in the general population as a surrogate, which may not fully capture the risk profile of the hospital-based non-PUI cohort.

CONCLUSION

This study found a 9.9% COVID-19 positivity rate among individuals not classified as PUIs, indicating a potential gap in current screening protocols. Significant symptoms associated with infection included fever, cough, phlegm, headache, malaise, sore throat, rhinorrhea, tiredness, myalgia, and diarrhea. Notably, individuals who received more than two vaccine doses were less likely to test positive. These findings suggest that symptom-based screening among pre-admission patients—regardless of PUI classification—could improve early detection. Policymakers should consider refining screening criteria and promoting complete vaccination coverage to reduce undetected transmission.

CONFLICT OF INTEREST

There's no conflict of interest.

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DATA AVAILABILITY STATEMENT

Data are available upon reasonable request.

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Original Article

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Scattered Radiation Dose and Safety Assessment from Mobile X-Ray Radiography

Khwanpicha Chidtakhob BSc[1], Tharitsanat Amnakmanee BSc[2], Wasin Laesan BSc[2], Panatsada Awikunprasert PhD[3], Thunyarat Chusin PhD[4]

[1] *Division of Diagnostic Radiology, Faculty of Medicine Vajira Hospital, Navamindradhiraj University, Bangkok 10300, Thailand*
[2] *Bachelor of Science in Radiological Technology, Faculty of Medicine Vajira Hospital, Navamindradhiraj University, Bangkok 10300, Thailand*
[3] *Department of Radiological Technology, Faculty of Medicine Vajira Hospital, Navamindradhiraj University, Bangkok 10300, Thailand*
[4] *Department of Radiological Technology, Faculty of Allied Health Sciences, Naresuan University, Phitsanulok 65000, Thailand*

ABSTRACT

OBJECTIVE: This study aimed to measure the scattered radiation levels that surround a mobile X-ray machine during chest radiography using adult and pediatric phantoms and to estimate the radiation exposure experienced by nearby individuals in simulated clinical ward settings.

METHODS: Scattered radiation was measured using a solid-state scatter probe at distances of 1.0, 1.5, and 2.0 meter (m), and at nine angular positions around the X-ray tube. Chest X-ray (CXR) exposures were performed using two parameter sets: 80 kilovoltage peak (kVp) and 2 milliampere-seconds (mAs) for the adult phantom, and 55 kVp and 1.6 mAs for the pediatric phantom. The data obtained regarding the dose were used to simulate and calculate the potential scattered radiation exposure in hospital wards under three different scenarios: (1) without walls or shielding, (2) using measured distances based on the experimental setup, and (3) with shielding barriers, incorporating attenuation coefficients for common building materials.

RESULTS: For the adult phantom, the highest scattered dose was 0.26 microgray (μGy) at 1.0 m and the lowest was 0.03 μGy at 2.0 m. For the pediatric phantom, values ranged from 0.107 μGy to 0.002 μGy. The calculations of radiation dose using ward layouts showed that the annual exposure to adjacent patients and health care workers, based on 730 imaging sessions per year, did not exceed the International Commission on Radiological Protection annual public dose limit of 1 millisievert.

CONCLUSION: Scattered radiation levels during mobile CXR procedures decrease with distance and remain within safe limits. However, the cumulative low-dose exposure may contribute to long-term stochastic risks. Measures to protect against radiation, such as maintaining a minimum 2-m distance and wearing lead aprons, are recommended for safety.

KEYWORDS: inverse square law, mobile X-ray, radiation attenuation, scatter probe, scattered radiation

Corresponding author: Panatsada Awikunprasert, panatsada@nmu.ac.th
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INTRODUCTION

For critically ill patients or those who cannot be transported to the X-ray department, mobile or portable X-ray radiography is particularly valuable. It also helps to reduce disease transmission during outbreaks such as COVID-19[1]. Portable chest X-rays (CXRs) are commonly used to assess lung and chest cavity abnormalities, monitor treatment progress, and evaluate preoperative conditions. However, CXRs use ionizing radiation, which can ionize atoms in its path, including the human body, thus exposing nearby staff members (radiographers, nurses, other health care workers) as well as patients to scattered radiation. Studies have shown that the intensity of the scattered radiation from portable X-ray machines decreases with distance from the patient and the use of radiation shielding[2,3]. In addition, scattered radiation levels are influenced by imaging parameters such as kilovoltage and milliampere-seconds (mAs)[3,4]. Unlike standard X-ray rooms, mobile X-ray units lack fixed protective barriers. During mobile CXR procedures, operators often need to stand close to patients to ensure proper positioning and to monitor factors such as respiration. In clinical practice, mobile X-ray is frequently performed in high-occupancy inpatient wards, intensive care units, and isolation rooms, where both health care workers and adjacent patients may remain in close proximity to the imaging area. These ward conditions, characterized by limited space and the presence of multiple individuals near the radiation source, can increase the likelihood of scattered radiation exposure. Although research suggests that the scattered radiation dose received by radiographers during CXRs is generally within safe limits[5], prolonged or repeated exposure without adequate protection could pose a long-term health risk to health care workers.

Scattered radiation can be measured by determining the air kerma using gas-filled detectors such as ionization chambers[3], or Geiger Mueller detector[6] as well as solid-state detectors such as scatter probes[5]. These measurements can be made using acrylic phantoms in experimental setups, in real clinical environments, or through computational simulations[7,8].

In practice, it is often impractical to place radiation-measuring devices throughout a hospital ward due to space limitations and the high patient occupancy. Therefore, in this study, we aimed to measure the scattered radiation levels around mobile CXR units at various positions in a controlled laboratory environment. The dose data we collected were used to estimate the exposure to scattered radiation of health care personnel, including nurses and other individuals who may be present in the patient rooms during CXR examinations.

METHODS

Because this study did not involve human participants, the Institutional Review Board of the Faculty of Medicine Vajira Hospital granted an exemption (exemption No. COE: 030/2023X), specifically pertaining to the use of phantoms and simulated radiation measurements.

We placed an adult anthropomorphic phantom (PBU-50, Kyoto Kagaku Co., Ltd, Japan) on a bed in a semi-upright position to simulate an anteroposterior CXR procedure. The X-ray tube was positioned 100 centimeter (cm) from the image receptor, with exposure parameters set to 80 kilovoltage peak (kVp) and 2 mAs. To measure the scattered radiation dose, we used a 100-centimeter square (cm^2) RTI scatter probe (RTI Group, Mölndal, Sweden). The probe was calibrated by the manufacturer according to ISO standards, with a measurement accuracy of ± 10% or ± 0.3 microgray per hour (μGy/h). For consistency, the probe was mounted on a tripod at a height of 80 cm above the floor (representing the level of reproductive organs for an average adult male height of 175 cm). The radiation doses were measured at distances of 1.0, 1.5, and 2.0 meters (m) from the phantom's centerline, at angles of 0°, 45°, 90°, 135°, 180°, 225°, 270°, 315°, and 360° relative to the central axis (Figure 1). We recorded both air kerma (μGy) and air kerma rate (μGy/h). To ensure accuracy and account for variability, each measurement was repeated three times at every distance and angle.

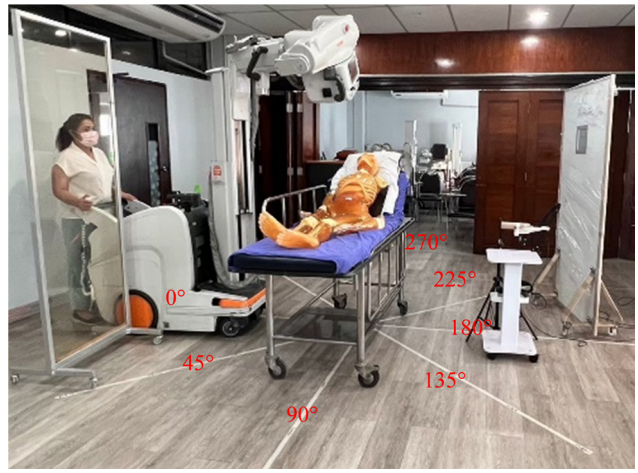

Figure 1 Experimental setup for measuring scattered radiation during chest X-ray imaging using a mobile X-ray unit

To simulate chest imaging of a pediatric patient in a supine position, we used a 10-cm thick acrylic sheet to approximate the body thickness of the pediatric patient. The exposure parameters were set to 55 kVp and 1.6 mAs to reflect the lower dose typically used in pediatric imaging. The source-to-image distance (SID) was maintained at 100 cm. Consistent with the adult protocol, the RTI scatter probe was positioned at a height of 80 cm from the ground. The radiation doses were measured at distances of 1.0, 1.5, and 2.0 m, using the same angular positions used in the adult measurements. Based on the consistency of the results obtained from the adult phantom, only one measurement per distance and angle was performed in the pediatric setup to confirm the radiation distribution trend and to reduce unnecessary repetition.

We conducted a quantitative analysis of all collected data. The maximum and minimum radiation doses recorded at each distances and angles were calculated. We used the mean values and standard deviations (SD) to summarize the central tendency and variability of the measurements. The results were presented in tables to illustrate the distribution of the scattered radiation around the mobile X-ray unit.

We estimated the scattered radiation doses in hospital wards using detailed floor plans and actual room dimensions. Comprehensive information on room materials, medical equipment, and patient bed locations was collected to ensure simulation accuracy. To enable precise spatial analysis, we used SketchUp software to model the ward layouts. The exposure of staff and patients in adjacent beds to radiation was evaluated under three simulation scenarios. In the first scenario, which assumed an open space without walls or partitions, we applied the inverse square law using a reference point 1 m from the X-ray source (point A), and calculated the scattered dose at a secondary point (point B) accordingly (Figure 2a). In the second scenario, in which the measured distances and angles from the X-ray machine matched the experimental setup (i.e., 1.0, 1.5, or 2.0 m), we assumed the radiation dose at point A to be equal to the experimentally measured value at the corresponding distance (Figure 2b). In the third scenario, which involved walls or shielding partitions, we initially applied the inverse square law from a 1-m reference point, followed by the Lambert Beer law to calculate the attenuation of radiation through materials. The resulting attenuated value was then used in a second inverse square law calculation to estimate the dose at point C (Figure 2c). The linear attenuation coefficients used in the simulations were 0.28 cm^{-1} for acrylic glass[9], 0.66 cm^{-1} for plate glass [9], 0.127 cm^{-1} for wood [10], 0.136 cm^{-1} for aluminum [11], and 1.45 cm^{-1} for concrete[12].

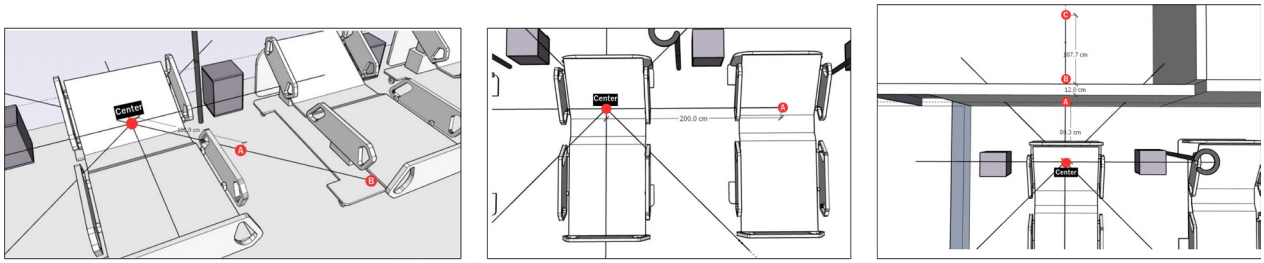

Figure 2 Estimation of scattered radiation doses received by staff and adjacent patient beds under three scenarios: (a) without walls or partitions; (b) with measured distances; and (c) with walls or partitions

RESULTS

We measured the scattered radiation values around the mobile X-ray unit using an adult phantom at distances of 1.0, 1.5, and 2.0 m from the X-ray tube, and at angles of 0°, 45°, 90°, 135°, 180°, 225°, 270°, 315°, and 360° relative to the central axis. The exposure parameters were set to 80 kVp and 2 mAs, with an SID of 100 cm. The variability in scattered radiation values is presented as mean ± SD in Table 1, reflecting the reproducibility of repeated measurements. These error estimates demonstrate consistency across most positions, with slightly higher variability observed at angular positions where scatter was less uniform. We observed the highest scattered radiation dose at a distance of 1.0 m, with an average air kerma of 0.26 µGy at angles of 0°, 45°, and 180°, primarily adjacent to the patient's bed. In contrast, the lowest dose, with a value of 0.03 µGy, was recorded at the head side of the bed (270°). Radiation values consistently decreased as distance increased (Table 1).

We conducted scattered radiation measurements using the pediatric phantom at distances of 1.0, 1.5, and 2.0 m from the X-ray tube, using the same nine angular positions as in the adult setup. The exposure parameters were set to 55 kVp and 1.6 mAs, and the results are included in Table 1. We recorded the highest scattered dose at 45° and 1.0 m, measuring 0.107 µGy. In contrast, the lowest dose occurred at 270° and 2.0 m, with a value of 0.002 µGy.

Table 1 Measured scattered radiation dose (in µGy) at varying distances (1.0 m, 1.5 m, and 2.0 m) from the X-ray source using adult and pediatric phantoms. Values represent the mean of three measurements ± SD.

			Adult CXR (80 kVp and 2 mAs)			Pediatric CXR (55 kVp and 1.6 mAs)	
No.	Angle (Degrees)	Distance (meter)	Air kerma rate	Air kerma (µGy)		Air kerma rate	Air kerma
			(mGy/h)	Average	SD	(mGy/h)	(µGy)
1	0, 360	1.0	48.44	0.26	0.01	0.01	0.036
2	0, 360	1.5	43.62	0.18	0.00	4.47	0.019
3	0, 360	2.0	23.49	0.10	0.00	2.51	0.010
4	45	1.0	54.20	0.26	0.04	26.33	0.107
5	45	1.5	38.72	0.17	0.01	7.94	0.038
6	45	2.0	19.89	0.08	0.00	2.78	0.018
7	90	1.0	N/A	N/A	N/A	N/A	N/A
8	90	1.5	6.39	0.04	0.00	5.17	0.027
9	90	2.0	7.04	0.04	0.01	3.48	0.015

Table 1 Measured scattered radiation dose (in μGy) at varying distances (1.0 m, 1.5 m, and 2.0 m) from the X-ray source using adult and pediatric phantoms. Values represent the mean of three measurements ± SD. (continued)

			Adult CXR (80 kVp and 2 mAs)			Pediatric CXR (55 kVp and 1.6 mAs)	
No.	Angle (Degrees)	Distance (meter)	Air kerma rate	Air kerma (μGy)		Air kerma rate	Air kerma
			(mGy/h)	Average	SD	(mGy/h)	(μGy)
10	135	1.0	35.77	0.23	0.12	16.69	0.070
11	135	1.5	31.94	0.18	0.01	6.70	0.028
12	135	2.0	20.13	0.10	0.00	3.84	0.016
13	180	1.0	47.72	0.26	0.02	6.82	0.031
14	180	1.5	37.44	0.18	0.01	4.10	0.017
15	180	2.0	22.06	0.11	0.00	1.53	0.010
16	225	1.0	35.38	0.24	0.01	3.57	0.015
17	225	1.5	29.03	0.12	0.00	1.72	0.008
18	225	2.0	15.85	0.08	0.00	1.08	0.005
19	270	1.0	6.56	0.03	0.00	2.15	0.008
20	270	1.5	13.84	0.07	0.01	0.97	0.004
21	270	2.0	9.99	0.04	0.00	0.05	0.002
22	315	1.0	21.80	0.10	0.08	3.88	0.016
23	315	1.5	29.93	0.13	0.00	2.13	0.008
24	315	2.0	18.55	0.08	0.01	1.07	0.005

Abbreviations: CXR, chest X-ray; h, hour; kVp, kilovoltage peak; mAs, milliampere-seconds; mGy, milligray; SD, standard deviation; μGy, microgray
"N/A" denotes "Not Applicable," indicating areas where data could not be collected due to issues with the scatter probe installation.

We used the floor plan of the adult patient ward to estimate the scattered radiation doses at key locations during the mobile X-ray procedures (Figure 3). In the isolation room, scattered radiation reached adjacent beds at angles of 270° and 180°, with calculated doses of 0.013 μGy and 0.042 μGy, respectively. For the standard patient bed location, we found that scattered radiation affected both the left and right adjacent beds, particularly at angles of 0°, 45°, 135°, and 180°. The estimated doses were approximately 0.153 μGy on the right side and 0.154 μGy on the left side. At the nurse's station, which was located near another patient bed, the scattered radiation reached the work area at 45°, 90°, 135°, and 180°, with a calculated dose of approximately 0.04 μGy.

We also used the pediatric ward layout to estimate the scattered radiation levels under clinical scenarios (Figure 3). At nurse station 1, scattered radiation reached the work area at angles of 45°, 90°, and 135°, resulting in a cumulative dose of 0.051 μGy. At nurse station 2, radiation exposure occurred at angles of 225° and 270°, with a much lower estimated dose of 0.001 μGy. In the area between the adjacent patient beds, scattered radiation again reached the nurse's station at 45°, 90°, and 135° angles, with a total dose of 0.051 μGy. In addition, we measured radiation at the adjacent beds themselves, with estimated doses of 0.016 μGy at 0° for the bed on the right and 0.014 μGy at 180° for the bed on the left.

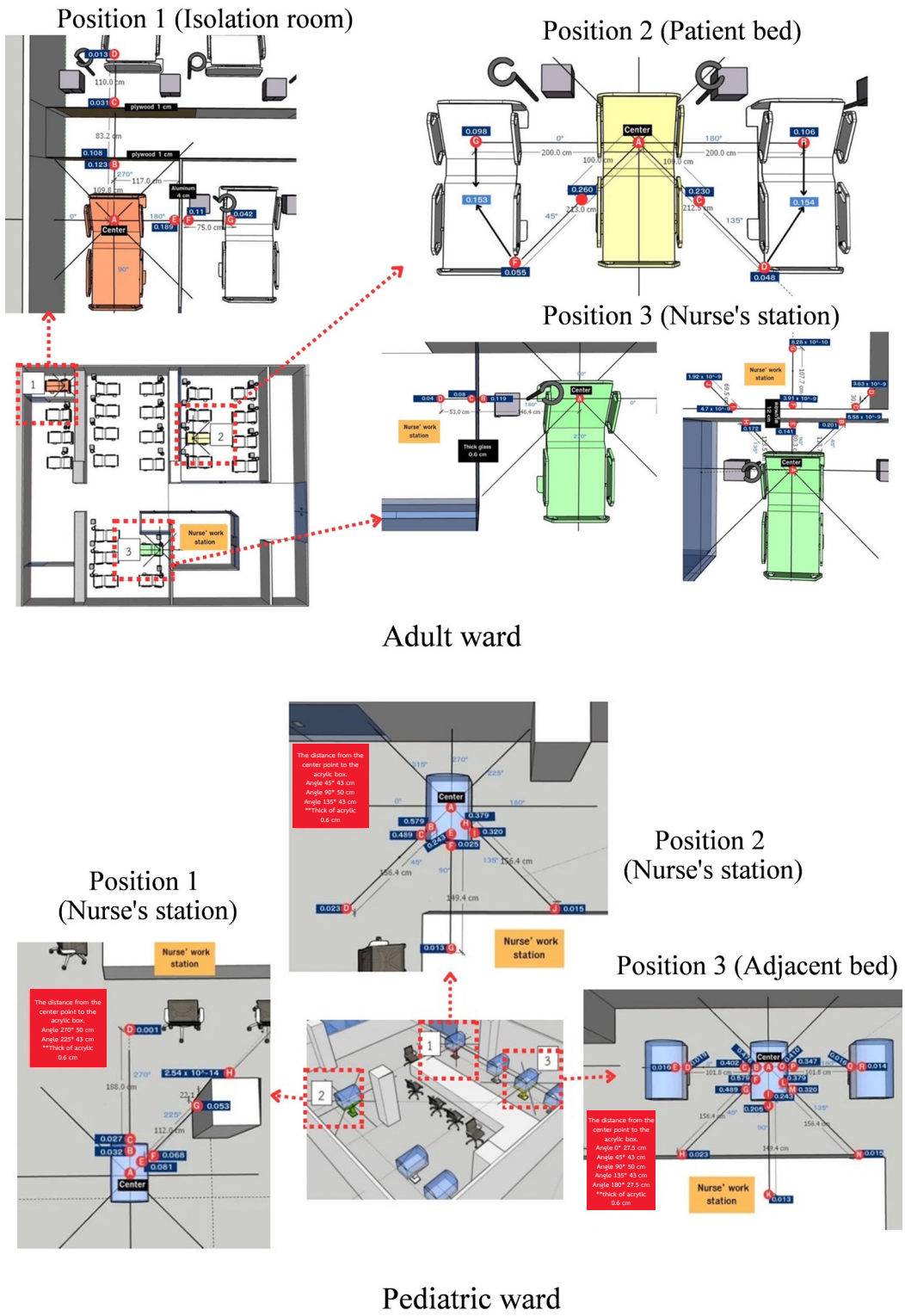

Figure 3 Floor plans of the adult ward (top) and pediatric ward (bottom), illustrating scattered radiation dose calculations (μGy) based on X-ray imaging positions and surrounding bed and nurse station locations

We evaluated the annual radiation exposure resulting from the use of mobile X-ray units in hospital wards in relation to the dose limits recommended by the International Commission on Radiological Protection (ICRP)[13]. The ICRP sets an annual dose limit of 1 millisievert (mSv) for the general public, a standard that applies to both patients in adjacent beds and health care workers who are routinely present in the ward environment. Based on an estimated frequency of two CXR examinations per bed per day, we calculated the annual number of exposures per bed to be approximately 730. The results indicate that, under these usage conditions, the cumulative radiation doses received by nearby patients and health care personnel remained well below the 1 mSv threshold, as detailed in Tables 2 and 3. These findings support the safety of routine mobile radiography in inpatient settings when appropriate protocols and distancing measures are followed.

Table 2 Estimated annual scattered radiation dose (in mSv) to adjacent patients and healthcare workers in the adult ward, based on 730 chest radiography sessions per year. Values were calculated using measured scattered radiation data and simulated ward layouts.

The location where the X-ray is performed	Angle (degrees)	Area receiving radiation	Radiation dose calculated per exposure (μSv)	Radiation dose per year (mSv)
Isolation room	270	adjacent bed 1	1.3×10^{-2}	9.3×10^{-3}
	180	adjacent bed 2	4.2×10^{-2}	3.1×10^{-2}
Observation bed	0	adjacent bed 3	9.8×10^{-2}	7.2×10^{-2}
	45	adjacent bed 3	5.5×10^{-2}	4.0×10^{-2}
	135	adjacent bed 4	4.8×10^{-2}	3.5×10^{-2}
	180	adjacent bed 4	1.1×10^{-1}	7.7×10^{-2}
Patient bed near the nurse's station	45	nurse workstation	3.6×10^{-9}	2.7×10^{-9}
	90	nurse workstation	8.3×10^{-10}	6.1×10^{-10}
	135	nurse workstation	1.9×10^{-9}	1.4×10^{-9}
	180	nurse workstation	4.0×10^{-2}	2.9×10^{-2}

Abbreviations: mSv, millisievert; μSv, microsievert

Table 3 Estimated annual scattered radiation dose (in mSv) to adjacent patients and healthcare workers in the pediatric ward, based on 730 chest radiography sessions per year. Values were calculated using measured scattered radiation data and simulated ward layouts.

The location where the X-ray is performed	Angle (degrees)	Area receiving radiation	Radiation dose calculated per exposure (μSv)	Radiation dose per year (mSv)
Patient bed near the nurse's station 1	45	nurse workstation	2.3×10^{-2}	1.7×10^{-2}
	90	nurse workstation	1.3×10^{-2}	9.5×10^{-3}
	135	nurse workstation	1.5×10^{-2}	1.1×10^{-2}
Patient bed near the nurse's station 2	225	nurse workstation	2.5×10^{-14}	1.8×10^{-14}
	270	nurse workstation	1.0×10^{-3}	7.3×10^{-4}
Between patient bed	0	adjacent bed 1	1.6×10^{-2}	1.2×10^{-2}
	45	nurse workstation	2.3×10^{-2}	1.7×10^{-2}
	90	nurse workstation	1.3×10^{-2}	9.5×10^{-3}
	135	nurse workstation	1.5×10^{-2}	1.1×10^{-2}
	180	adjacent bed 2	1.4×10^{-2}	1.0×10^{-2}

Abbreviations: mSv, millisievert; μSv, microsievert

DISCUSSION

Scattered radiation levels measured in this study consistently decreased with increasing distance from the radiation source, in line with the inverse square law. This pattern was observed for both adult and pediatric phantom setups, confirming that distance remains the most effective factor in reducing scatter exposure. Although radiation doses were generally low, the measurements also showed variability across angles, reflecting the non-uniform distribution of scatter around the patient and X-ray tube.

In the adult ward simulations, scattered radiation reached adjacent beds and nurse workstations, with certain positions receiving higher exposure than others. These estimates provide insight into the spatial distribution of scattered radiation and help identify areas where exposure control may be most critical. In pediatric ward conditions, radiation levels remained lower overall; however, the proximity and orientation of patients and staff to the X-ray source still resulted in measurable exposure. These findings highlight the importance of considering clinical ward layouts when planning radiation protection strategies.

Scattered radiation around a mobile X-ray machine during CXR imaging can be measured using either a physical phantom[5] or computational simulation such as the Monte Carlo method with the Particle and Heavy Ion Transport code System[7]. Scattered radiation exhibits uncertain and non-uniform directional patterns. Using a phantom with a radiation detector enables practical data collection through relatively straightforward procedures; however, it requires measurements from multiple positions surrounding the X-ray source. In contrast, Monte Carlo simulations—although more complex—offer a more comprehensive assessment of the spatial distribution and probability of scattered radiation as compared with phantom-based methods.

The spatial variability of scattered radiation requires the use of appropriate detectors to assess radiation levels across different cross-sectional areas. Survey meters, which use gas-filled detectors for air ionization, are portable, highly sensitive to moderate-to-high radiation levels, and can provide accurate readings across a broad range. However, these instruments measure radiation omnidirectionally (from both the front and sides), which makes it difficult to determine the exact direction of the scattered radiation. Survey meters are particularly suitable for environments with radioactive sources and for occupational radiation monitoring. In contrast, a scatter probe is a solid-state (semiconductor) detector specifically designed to measure scattered or leakage radiation. It has a flat, one-sided detection surface that enables directional detection, minimizing the interference from off-axis radiation. This design allows for more accurate and precise measurements of low-dose scattered radiation. Therefore, the choice of detector is critical to ensure the accurate assessment of scattered radiation in clinical environments.

Scattered radiation generally decreases with increasing distance from the X-ray source, which is consistent with the inverse square law, that states that the intensity of radiation decreases proportionally to the square of the distance. However, we noted exceptions at certain positions, such as the head of the patient's bed, where the measured radiation at 1 m was lower than that at 1.5 m. This anomaly may be attributed to the directional nature of the scatter, probe orientation, and attenuation caused by the bed structure or surrounding materials. Such factors can lead to deviations from the theoretical model.

Scattered radiation levels were higher in the adult ward as compared with the pediatric ward due to the greater patient body thickness of the adults and the use of greater technical factors in adult imaging. This increase in scatter corresponds with the shift from photoelectric absorption to Compton scattering at higher kVp settings. These findings are consistent with previous studies by Tam et al.[5] and Renger et al.[14], who demonstrated that the scattered radiation increases with higher tube potential.

In this study, we applied the Lambert Beer attenuation equation and the inverse square law to assess the distribution of radiation across hospital wards. To estimate the potential exposure received by adjacent patients and health care workers, we obtained the reference doses from actual measurements. Assuming the use of mobile X-ray twice per day per bed (approximately 730 times per year), the estimated scattered radiation doses remained well below the ICRP's recommended public exposure limit of 1 mSv per year. These findings are in agreement with the reports by Moonkum et al.[4] and Chiang et al.[3], who reported that radiation levels beyond 2 m fall to near-background values. Although the measured radiation doses in this study were well below the deterministic thresholds, there remains a theoretical risk of stochastic effects from cumulative exposure over time.

This study has several strengths. It included both adult and pediatric phantoms, allowing comparison under two relevant clinical conditions. Systematic measurements at different distances and angles, together with the use of a calibrated scatter probe, provided reliable low-dose data. The integration of measurements with ward simulations further enhanced the practical value of the findings by reflecting real hospital settings. However, some limitations should be noted. Only one adult and one simplified pediatric phantom were used, which may not represent the full range of patient anatomies. The study was performed with a single mobile X-ray unit and limited exposure protocols, and scatter was measured only at selected positions and heights. Ward simulations relied on specific floor plans and material assumptions, which may differ from real environments. Moreover, the controlled setup did not account for clinical factors such as staff movement, patient variability, or repeated exposures. Future studies should include a wider range of mobile X-ray units, diverse ward environments, and phantoms of varying sizes, and may benefit from simulation techniques such as Monte Carlo methods to provide more comprehensive, three-dimensional assessments of scatter distribution and risk.

Future studies should consider evaluating a broader range of mobile X-ray machines and expanding the measurements to include more diverse hospital environments. Because scattered radiation is influenced by patient anatomy and body size, future research should include phantoms of various sizes to improve the generalizability of the findings. We used a single phantom model in this study, which limits its applicability to the full range of patient populations. In additional, although we measured scattered radiation at multiple angles and distances, it was not possible to capture all directions of the scattered radiation emission. Future studies using simulation techniques, such as Monte Carlo methods, may provide more complete and three-dimensional assessments of the distribution and risk of scatter.

CONCLUSION

We found that the scattered radiation doses measured around a mobile X-ray machine during chest radiography using adult and pediatric phantoms at a distance of 1 m were within the recommended exposure limits for the general public. Although these levels are not sufficient to cause deterministic effects, they might still pose a potential risk of stochastic effects with long-term, repeated exposure. To minimize unnecessary exposure, radiologic technologists should consistently wear lead aprons, and other individuals—including patient relatives or caregivers—should maintain a minimum distance of 2 m from the X-ray unit during imaging procedures.

CONFLICT OF INTEREST

The authors declare no conflict of interest relevant to this study.

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DATA AVAILABILITY STATEMENT

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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Jitti Hanprasertpong MD

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