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After-action Review of Hospital Environments Exploring the 'New Normal,' Focusing on Structural Management Aspects and Bacterial Culture in Thai Hospitals Amid the COVID-19 Pandemic

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ABSTRACT

OBJECTIVE This study aimed to explore the management of hospital environments during the COVID-19 pandemic, focusing on the structural aspects of 'new normal' health services delivery practices and bacterial culture in hospital rooms.

METHODS This study employed a cross-sectional design that involved the evaluation of hospital environment management, the detection of indoor bacterial colonies in hospitals, and interviews with healthcare administrators on the 'new normal' measures.

RESULTS The evaluation form was completed by 543 healthcare division heads from 30 hospitals. Respondents in each group reported that hospitals where they worked had effectively implemented new normal measures, making changes to the structure, processes, and personnel management components in line with the 'new normal' concept. The majority of the hospitals investigated, accounting for 71.7%, were found to have pathogenic bacterial counts lower than the permissible limits. The statistical analysis identified a significant association between ventilation, structural management under the 'new normal', and bacterial counts ($p < 0.05$).

CONCLUSIONS The incorporation of the structural aspects of new normal practices for managing the workplace environment should be a routine and integral part of efforts to control healthcare-associated infections in hospitals.

KEYWORDS hospital environment, the new normal, COVID-19, bacterial culture

INTRODUCTION

The COVID-19 pandemic is an important event affecting most of mankind. The COVID virus can evolve into other new variants. The incubation period of the virus is about 6.6 days after an individual is infected (1). Transmission of COVID-19 between people occurs primarily through respiratory droplets, known as droplet spread. Laboratory studies have found that the droplets can remain suspended in the air and continue to be infectious for up to 16 hours (2). The virus can also be transmitted through contact with contaminated surfaces (3). Environmental factors such as ventilation, temperature, humidity, and airborne infection isolation rooms can dilute and remove pathogens (4) which can reduce the risk of infection if these conditions are managed appropriately (4, 5). To control the transmission of the disease, the Thai government has implemented measures to prevent and control its spread throughout the

country. Individual preventive measures, encompassing 'D' for distancing from social interactions, 'M' for mask-wearing, and 'H' for hand washing, were the primary preventative measures prior to the availability of COVID-19 vaccines in February 2021 (6-8). The WHO also recommends the implementation of protective measures for health workers (6). The rapid increase in COVID-19 cases during the pandemic also represents a heightened risk for healthcare workers, intensifying the challenges in the battle against COVID-19 (9, 10). Healthcare workers are at a higher risk of infection than the general population due to their close contact with colleagues, fellow workers, and family members who may already be infected by the virus (9, 10). Additionally, their occupational exposure to patients, particularly while performing medical procedures which involve potential exposure to droplets, further heightens the risk (9). As a consequence, healthcare workers can potentially contribute to a high rate of COVID-19 transmission. The prevalence of COVID-19 among healthcare workers was found to be 11% in Italy and 20% in England (10). In China, 1,716 healthcare workers were infected in the early stages of the epidemic (9). As a consequence, setting up measures to prevent the spread of infectious microbes in hospital areas became an urgent priority for virtually all healthcare facilities in response to COVID-19. As part of the immediate response to the pandemic, the Thai healthcare community considered adopting a 'new normal' medical service system, which involves changing or adapting various components of hospital environments and facilities in the areas of structure, process, and personnel (11). The 'new normal' healthcare services management adopted has demonstrated its effectiveness, aligning with the concept of providing healing environments and prioritizing environmental quality for healthcare buildings. This approach creates pleasant, functional, and comfortable spaces (12, 13), and serves as a crucial measure for preventing hospital staff from contracting contagious diseases. The term 'new normal,' widely used during the COVID-19 event, refers to the altered state of affairs or lifestyle that emerges following an unfamiliar experience, situation, or sudden crisis, ultimately evolving into new standards and typical practices (14). In healthcare facilities in Thailand, the new normal is evident in structural changes such as the installation of wall dividers for separated spaces and improvements to ventilation systems. Additionally, there have been modifications to screening methods, communications, and measures to ensure the well-being of hospital personnel, all in response to the surge in COVID-19 cases and hospital patients. Importantly, the new normal healthcare system can serve as a lasting mechanism which can continue to operate even after COVID-19 subsides, helping to prevent the spread of infections and diseases caused by other contagious pathogens present in hospital areas (15).

The present study, conducted following the first wave of COVID-19 in Thailand, serves as an exploration of the environmental management measures implemented by Thai healthcare facilities within the new normal framework. Additionally, the study investigated bacteria cultures in hospitals to identify contamination, aiding preparedness in the ongoing fight against the epidemic. The findings lead to the proposal to apply the new normal healthcare services delivery system used during the COVID-19 crisis as a preventive measure against future healthcare-associated infections. This initiative aims to enhance safety and health concerns for both personnel and patients.

METHODS

This investigation employed a cross-sectional design involving provincial hospitals, general hospitals, community hospitals, and private hospitals in the Bangkok metropolitan area as well as the Central and Eastern regions of Thailand. The research received approval from the Ethics Committee at Nopparat Rajathanee Hospital, with funding support provided by the Thailand Science Research and Innovation (TSRI).

The participating hospitals were identified by purposive sampling and the sample included 543 healthcare division heads from 30 healthcare facilities which consented to participate in the research. The necessary data and information were collected between April and December 2021 which was after the first wave of COVID-19 had come to an end. The investigation was undertaken in three parts employing different study tools as follows.

1. The evaluation of the use of new normal measures to prevent the spread of COVID-19

incorporated guidance from Guidance on Preparing Workplaces for COVID-19 and the COVID-19 Healthcare Planning Checklist (16). The evaluation covered three aspects of the new normal, with 11 questions on physical structure aspects, 16 questions on process management aspects, and 15 questions on personnel aspects, plus 4 questions related to policies. Responses were categorized into three levels: 0 for 'no,' 1 for 'yes but not comprehensive coverage,' and 2 for 'yes, covering the entire hospital'. An evaluation form was developed and reviewed by three experts. The evaluation form then underwent reliability test using the Cronbach's alpha method. That test yielded a calculated alpha coefficient value of 0.75. Subsequently, the form was distributed to 550 personnel division heads for online evaluation.

2. Inspection of air quality and bacterial culture tests were conducted in 150 hospital rooms across 15 healthcare facilities, covering various spaces including offices, examination rooms, and hospital wards. The equipment used included the universal Indoor Air Quality (IAQ) measurement following the ASHRAE 55 Standard (17). Air samples were collected using suction, and assessments of bacterial cultures were conducted according to the NIOSH method number 0800 standard (18).

3. Structured interviews were conducted with hospital administrators holding positions such as director, deputy director, member of the occupational health team, and member of contagious disease control and prevention teams. The interviews used a questionnaire containing items related to policies and structural organization, the arrangement of the healthcare provision system for COVID-19-infected patients, healthcare workers and professionals, and information on the implementation of measures to protect healthcare personnel and transitioning towards new normal practices.

Statistical analysis

The data processing and analysis used the Statistical Package for the Social Sciences to calculate frequencies and arithmetic means. Relationships between scores of the new normal management and the bacteria colonies groups were explored using odds ratio (OR) along with their 95% confidence intervals (95% CIs), with a $p < 0.05$ considered statistically significant. The data analysis employed the Generalized Linear Model (GLM) which can address confounding effects from factors such as room type, cleaning procedures, air movement, air temperature, relative humidity, CO, and CO_2.

RESULTS

The study found an average score of 16.3 (out of 20) for hospitals implementing the structural aspect management of the new normal measures. Implementation primarily took the form of setting up isolation rooms for COVID-19-infected patients in both ARI clinics and cohort wards, designating a room for swab collection, optimizing open-air spaces, improving ventilation systems, and other measures as detailed in Table 1.

Table 1. Scores for implementing 'new normal' structural management measures

Structural Management	Score		
	0	1	2
1. Provide isolated areas for suspected infectious groups	9 (1.7)	129 (23.8)	405 (74.6)
2. Provide adequate hand sanitizer	2 (0.4)	79 (14.5)	462 (85.1)
3. Support in providing rooms for cohort wards	21 (3.9)	89 (16.4)	433 (79.7)
4. Support in providing rooms for swabs	46 (8.5)	131 (24.1)	366 (67.4)
5. Limiting access in hospital buildings	7 (1.3)	163 (30.0)	373 (68.7)
6. Promoting space distancing between persons in hospital (waiting rooms and cafeterias)	42 (7.7)	149 (27.4)	352 (64.8)
7. Partitioning areas	6 (1.1)	135 (24.9)	402 (74.0)
8. Setting areas for isolation and quarantine of high-risk personnel	33 (6.1)	121 (22.3)	389 (1.6)
9. Improving ventilation in the hospital	16 (2.9)	172 (31.7)	355 (65.4)
10. Separate accommodation facilities for COVID team members	94 (17.3)	170 (31.3)	279 (1.4)
11. Separate bathing and clothes changing areas for COVID team members	30 (5.5)	131 (24.1)	382 (70.3)

0, no; 1, yes but not comprehensive coverage; 2, yes, covering the entire hospital

The study also calculated a score of 28.9 (out of 34) for the new normal measures in the area of process management, which included the establishment of an ad hoc committee to review policy development, and the determination to develop a healthcare management system for COVID-19-infected patients. This new normal system involved screening of symptomatic patients, maintaining patient medical records, and providing telemedicine delivery services to reduce hospital congestion. A score of 25.3 (out of 30) was achieved for the personnel aspects, encompassing the provision of knowledge and guidelines for healthcare workers (HCWs) dealing with COVID-19 patients to prevent virus spread and for protection against the disease. Support for the use of personal protective equipment (PPE), the designation of isolated working areas, and the monitoring of the safety and well-being of HCWs with high-risk exposure to COVID-19 were also included. In essence, the various new normal measures were assessed to be crucial contributors to controlling the spread of COVID-19, consistent with the results obtained from interviews with hospital administrators.

The culture test of bacteria in the indoor environment of a total of 150 rooms across 15 hospitals was compared with general data, ventilation data, and new normal data, covering those three aspects. The results revealed that in the majority of areas (70%), total bacterial counts were within acceptable limits, as detailed in Table 2. To account for confounding effects, a statistical test evaluated the relationship between various factors among groups with total bacterial counts exceeding acceptable levels as detailed in Table 3. Interestingly, the office and OPD/Ward areas demonstrated the strongest association with exceeding acceptable total bacterial counts (AOR 76.1; 95% CI: 4.0-1,449.3 and AOR 18.9; 95% CI: 1.4-259.0) (Table 2). An increase of 1 unit in air movement correlated with a decrease of approximately 38% in total bacterial counts for groups that exceeded acceptable levels (95% CI: 0.4-0.9). Additionally, relative humidity and carbon monoxide (CO) gas were associated with groups exceeding acceptable bacterial counts (AOR 1.1, 3.0; 95% CI: 1.01-1.2, 1.2-7.5, respectively). Moreover, higher scores on structural aspects were associated with a decrease in groups with unacceptable total bacterial counts (AOR 0.56; 95% CI: 0.34-0.92)."

Through interviews with hospital administrators at 30 locations, it was found that they deemed certain 'new normal' practices, outlined in Table 4, as suitable for continued and routine use. These practices, especially those aimed at reducing the spread of infectious microorganisms in the hospital environment, include the establishment of an isolated acute respiratory infection (ARI) clinic, improvement of ventilation systems, development of a screening system for acute respiratory infection symptoms, utilization of telemedicine technology to alleviate hospital congestion, and the implementation of a wellness system for the healthcare workforce to protect healthcare workers from virus infections and from becoming vectors of disease transmission.

DISCUSSION

The research findings reveal that the management of hospital environments, particularly physical structure components, included in the new normal measures, is highly effective. The mean

Table 2. The relationship between bacterial colony and hospital factors

Hospital factors	Bacterial colony (SD)	*p*-value	Hospital factors	Bacterial colony (SD)	*p*-value
Room type		0.01	Frequency of cleaning		0.14
Clean (50)	119.4 (141.5)		1 time/day (38)	216.7 (141.5)	
Ward/OPD (83)	275.4 (275.6)		2 time/day (102)	294.0 (275.6)	
Office (15)	429.3 (313.4)				
Structural management		0.35	System management		0.99
≤ 80% (35)	313.0 (306.9)		≤ 80% (45)	273.9 (287.6)	
> 80% (115)	262.7 (267.2)		> 80% (105)	274.6 (273.3)	
Staff management		0.87			
≤ 80% (65)	270.0 (257.5)				
> 80% (85)	277.8 (292.0)				

Table 3. Odds ratios (OR) of exceeding permissible bacteria counts and their 95% confidence intervals for each variable adjusted for all other factors using GLMs

Variable	N (%)	SE	OR	AOR	95% CI		*p*-value
					Lower	Upper	
Office	15 (10.1)	1.5035	32.667	76.099	3.996	1,449.347	< 0.01
OPD/Ward	83 (56.1)	1.3360	11.701	18.884	1.377	258.992	< 0.05
Clean room	50 (33.8)		1.000	1.000			
Cleaning: 1 time/day	38 (25.7)	0.7112	0.563	0.696	0.173	2.805	> 0.05
Cleaning: 2 times/day	110 (74.3)		1.000	1.000			
Air movement	148 (100.0)	0.2089	0.894	0.619	0.411	0.932	< 0.05
Air Temperature	148 (100.0)	0.1978	1.214	1.200	0.814	1.769	> 0.05
Relative humidity	148 (100.0)	0.0417	1.033	1.098	1.012	1.192	< 0.05
Carbon monoxide (CO)	148 (100.0)	0.4633	1.628	3.026	1.220	7.502	< 0.05
Carbon dioxide (CO_2)	148 (100.0)	0.0018	1.004	1.006	1.003	1.010	< 0.01
System management score	148 (100.0)	0.3106	1.057	1.555	0.846	2.858	> 0.05
Structural management score	148 (100.0)	0.2512	0.927	0.559	0.342	0.915	< 0.05

Adjust for room type, cleaning, air movement, air temperature, relative humidity, CO, CO_2, system management score, structural management score

Table 4. The 'new normal' measures to prevent the spread of infection which are normally practiced in 30 hospitals

Measures to prevent the spread of infection	Percent
• Restructured hospital administration and management systems to fight against new and re-emerging diseases	90.9
• Set up an ARI clinic as a medical examination room outside the main hospital buildings	18.2
• Adjusted the ventilation system throughout the hospital to better care for infected patients	100.0
• Set up and/or added AIIR rooms for isolating patients with contagious respiratory infections	27.3
• Organized a screening system to be used before conducting some important services, e.g., surgery and obstetrics	100.0
• Use Telemedicine and other online services to reduce hospital congestion	18.2
• Providing occupational health services to help prevent infection of healthcare personnel	100.0
• Provided training on how to care for infected patients, PPE use and universal precautionary measures	100.0

score of 16.3 out of 20, while the lowest among the new normal aspects, indicates that most hospitals have dedicated efforts and resources to manage hospital environments comprehensively. This includes not only the physical structure component but also the linkages and relationships among various parts of healthcare facilities. Even though a hospital operates as an organization with many self-contained departments or work units, it must also function as a complex adaptive system (19) which can effectively respond to the rapidly increasing demand for healthcare services with the new normal setting. This new normal endeavor represents a comprehensive concept of managing hospital facilities and environments, encompassing the components of people, places, and processes (20). According to the present study, the majority of hospitals were found to have implemented changes to various elements of the structural component, particularly the management or establishment of ARI clinics, cohort wards, and swab collection rooms, at 98.3%, 79.0%, and 54.0%, respectively. These changes are aimed at isolating suspected or confirmed COVID-19 cases from the main hospital buildings and/or confining them to designated places. The implementation of physical isolation methods (4, 21) to restrict the presence of COVID-19-infected patients to certain areas within the hospital premises is a practical measure to minimize pathogen contamination in other hospital areas. This study observed that all hospitals had restructured their screening procedures in ARI clinics to expedite initial diagnosis, serving as a preventive measure for contagious disease control and the spread of COVID-19 to healthcare personnel and patients (21). Notably, 98.4% of the hospitals in this study set up ARI clinics outside the main hospital buildings to maximize outdoor

air flow and solar radiation (22), thereby isolating ARI patients. Although the use of open-air space for routine ARI clinic services during normal times might result in some level of discomfort for both service users and healthcare personnel. Interviews with hospital administrators also revealed that 68.2% had considered improving the ventilation system to generate negative pressure in hospital rooms. This measure is aimed at preventing airborne contaminants from COVID-19 patients in one room from flowing out into the surrounding area.

These changes align with CDC recommendations advocating for the use of negative pressure rooms and respirators with HEPA filters to accommodate confirmed COVID-19 patients in healthcare facilities. The establishment of negative pressure rooms for swab collection to confirm viral infections also conforms with these guidelines (4, 21). Regarding physical distancing measures, 22.7% of hospitals utilized fixed or movable partitions or room dividers, while the majority, 92.2%, promoted the use of face shields. This approach aims to reduce the transmission risk of the virus from COVID-19 patients to healthcare personnel engaged in activities with close contact (within one meter) (21) and exposure times longer than 15 minutes (23). Hospitals also implemented various strategies for physical distancing, including widening the space between seats in waiting rooms, providing remote clinical and non-clinical services through online communication technologies like telehealth and telemedicine, sending prescribed medicines via post, and enforcing a no visitation policy. These arrangements collectively contributed to lowering the number of patients visiting the hospital and reducing hospital congestion (24).

Protecting the health and safety of healthcare personnel, especially those providing care to COVID-19 patients and those facing high exposure risks, is paramount to reducing hospital-acquired virus dispersion. Some healthcare facilities have established special COVID response teams dedicated to handling COVID-19 patient care. These teams are provided with housing accommodations that allow isolation from other individuals, including their families, and undergo rigorous health monitoring before returning to their respective work units or offices. The protocols for these COVID response teams mirror those applied to other healthcare professionals with high exposure risk (25, 26) which aim to minimize healthcare-associated infections among medical staff. This proactive approach helps mitigate the risk of staff shortages and helps ensure the continuous provision of services to patients. The majority of hospitals in this study have designated specific shower rooms and clothes changing areas exclusively for the use of personnel caring for COVID-19 patients. This strategic arrangement aims to diminish the likelihood of these healthcare workers becoming vectors of virus transmission to their colleagues, patients, and family members, thereby contributing to the prevention and control of virus spread (27).

Environmental quality also plays a crucial role in reducing contamination and preventing the spread of pathogens in hospitals (28), thereby preventing hospital outbreaks. This study conducted laboratory tests of air-borne pathogenic bacteria using culture techniques, revealing that in the majority of hospitals studied (71%), the number of bacterial colonies did not exceed the permissible limit. Factors found to be associated with exceeding acceptable bacteria counts included lower air movement, higher humidity, and higher CO_2 levels. Notably, carbon monoxide (CO) was found to triple the risk of exceeding acceptable bacteria counts. When the scores for the structural aspects of the new normal were equal to or exceeded 80%, there was a 44.1% decrease in the risk of exceeding permissible bacteria counts ($p < 0.05$). Furthermore, no relationship was detected between indoor bacterial colonies and air changes per hour. This finding aligns with the results of a study by Memarzadeh, which suggests that the critical factor in the spread of bacterial droplet contamination is the path between the contaminant source and the exhaust system rather than the ventilation airflow rate (29). Through interviews with hospital administrators, it was confirmed that adjustments in structural practices are being made for continued and routine use in an effort to reduce the spread of infectious microorganisms in the hospital environment. These strategic changes have been recommended as a preparation for the potential next wave of the pandemic.

This study has a few limitations. First, the questionnaire on the 'new normal' was not derived directly from guidelines, but was adjusted based

on practices during the pandemic situation. Additionally, the bacteria culture analyses were conducted in only 15 hospitals, as this study commenced during the onset of the second wave of the pandemic.

Modification of the management of hospital environments and facilities in response to COVID-19 should be a top priority. Implementing structural measures, such as the establishment of isolation rooms and improvement of ventilation systems, is crucial for effectively reducing the spread of contagious agents in the hospital environment. Implementation of these actions, in addition to the re-arrangement of healthcare service provision and delivery systems and the establishment of measures to protect healthcare personnel in accordance with the 'New Normal' medical services policy of the Thai Ministry of Public Health, has indeed proven to be effective in curbing healthcare-associated COVID-19 infections. Thus, the new normal practices should continue to be adopted and/or adapted as guidelines for use in times of normality to control the occurrence of future healthcare-associated infections and disease spread which represent a major risk to healthcare, business and industry.

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CONFLICTS OF INTEREST

The authors have no conflicts of interest to report.

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