นิพนธ์ต้นฉบับ ***Original article***

Infrastructure Changes in Critical Care Unit to Prevent Multidrug-Resistance Organisms Spreading during COVID-19 Pandemic: the Effect on Clinical Outcomes and Cost Reduction in Chaopraya Abhai Bhubejhr Hospital, Prachinburi, Thailand

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Date received: 2022 Jun 6
Date revised: 2022 Sep 20
Date accepted: 2022 Sep 30

Abstract Increasing multidrug-resistant organisms (MDROs) is one of the public health concerns. There has been an increase in many MDROs during the pandemic of COVID-19. The objectives of this study were to compare MDROs infection after implementing multimodal prevention, including infrastructure changes and control measures; and compare mortality rate, antibiotic consumption, and cost during admission. The retrospective study was conducted in the medical COVID-19 ICU of Chaopraya Abhai Bhubejhr Hospital, Prachinburi, Thailand, from 1 June 2021 to 31 October 2022. The ICU was renovated by removing unnecessary medical equipment, the old contaminated ceiling, installing the glass partition, touchless sliding door, and ventilation controlled system. Strict hospital infection and prevention control policy was applied. We collected characteristics, outcomes, and cost per admission and analyzed them by IBM SPSS Statistics version 29.0. Altogether 988 participants were included in the study with a mean age of 55.2±19.6 years; and 54 (5.5%) underwent endotracheal intubation with mechanical ventilation. There were 66 (11.3%) participants in the before-renovation group, and 6 (1.5%) participants in the after-renovation group who got MDROs colonization. The carbapenem-resistant *Acinetobacter baumannii* was the most common pathogen, 62 out of 66 (93.3%) before and 5 out of 6 (83.3%) in the after-renovation group. Hospital mortality and mean length of stay were significantly higher in the before-renovation group. The mean cost per person per admission was significantly higher before the renovation group (137,564.4±141,019.7 versus 39830.3±39599.4 Thai baht, $p<0.001$). The overall cost reduction during the study was 25,312,625.7 Thai baht. In conclusion, renovating the infrastructure, together with a comprehensive approach that includes hand hygiene, isolation precautions, environmental cleaning, antibiotic stewardship, and staff education, can prevent the spread of MDROs in the ICU, resulting in reducing the incidence of MDROs in the ICU, reducing admission cost and improving patient outcomes.

***Keywords*: multidrug-resistant organism; MDROs; infrastructure; ICU**

Introduction

Increasing multidrug-resistant organisms (MDROs) is one of the public health concerns worldwide, especially in developing countries[1-3]. MDROs cause economic burdens due to unnecessary longer hospitalization, higher readmissions, and additional disease costs[4-5]. In addition to the economic factors, the disease burden is high since mortality from healthcare-associated infection (HAI) has been up to 70% higher in patients with MDROs than those with antibiotic susceptible conditions[6]. HAIs have increased with COVID-19 worldwide[7-13]. Since the beginning of the COVID-19 pandemic, there has been an increase in many MDROs, including carbapenem-resistant Acinetobacterbaumannii (CRAB), antifungal-resistant Candida spp. ESBL-producing Enterobacterales and Vancomycin-Resistant Enterococci (VRE). The Centers for Disease Control and Prevention (CDC) reported a 78% increase in hospital-onset CRAB, a 35% increase in hospital-onset carbapenem-resistant Enterobacterales (CRE), 32% increase in hospital-onset ESBL-producing Enterobacterales, 13% increase in hospital-onset MRSA and a 14% increase in hospital-onset VRE[14]. This trend was similar among intensive care units (ICU) around the world: a national referral hospital in Indonesia noted that increase in MDROs bloodstream infections from 130.1 cases per 100,000 patient-days in 2019 to 165.5 cases per 100,000 patient-days in 2020 (incidence rate ratio 1.016 per month, p<0.001), endotracheal aspirates collected from patients in a Turkish ICU showed an increase in MDROs after March 2020 as compared with the prior year, and an ICU in Rome saw a statistically significant association between COVID-19 diagnosis and drug-resistant *A. baumannii* bloodstream infections[15-17]. ICU patients are at the highest risk of infection with MDROs due to invasive procedures, immunosuppressive therapy, several drugs (including antibiotics), and their underlying diseases. Direct contact with infected patients, carriers, medical equipment, and the contaminated environment is the main transmission route for MDROs in the ICU[18-21]. Therefore, guidelines published by the World Health Organization in 2017 proposed prevention and control measures for MDROs based on multimodal infection prevention and control (IPC) strategies[22]. The objectives of this study were to compare MDROs infection after implementing multimodal prevention, including infrastructure changes and control measures; and compare mortality rate, antibiotic consumption, and cost during admission.

Methods

This retrospective study was conducted in the Medical COVID-19 ICUs of Chaopraya Abhai Bhubejhr Hospital, Prachinburi, Thailand, and covered the period from June 2021 to October 2022. The ethics committee of Chaopraya Abhai Bhubejhr Hospital approved this study. The authors verified that all procedures contributing to this study adhere to the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

The inclusion criteria of patients were all patients admitted to Medical COVID-19 ICUs with over 15 years of age during the study time and separated into two groups; the first group was all patients admitted from 1 June 2021 to 30 November 2021 and assigned as before the renovation group and second group was all patients admitted from 1 May 2022 to 31 October

2022 assigned as after the renovation group. We started infrastructure renovation from 1 December 2021 to 20 April 2022. We renovated the medical COVID-19 ICU by removing unnecessary medical equipment, the old contaminated ceiling, installing the glass partition, touchless sliding door, and HEPA filter and ventilation controlled system. Our ICU followed infection prevention and control strategies during the study period: hand hygiene, contact isolation, and environmental surface cleaning and disinfection.

At the date of data collection, we collected (1) clinical characteristics, including gender, age, and history of drug allergy, (2) length of stay in the hospital, (3) type of infection, (4) Antibiotic and antifungal consumption, and (5) cost pre admission. Mean with standard deviation (SD), median with interquartile range (IQR), and frequencies (%) were used to describe participants' characteristics. Categorical factors between the two groups were compared using Chi-square or Fisher's exact test as appropriate. As appropriate, continuous variables were compared between the two groups using the Mann-Whitney U and Student's t-test. All statistical analyses were performed using IBM SPSS Statistics version 29.0.

Results

A total of 988 participants from the Medical COVID-19 ICUs were included in the study. Five hundred eighty-five participants were assigned to the before, and four hundred-three were assigned to the after-renovation group. The mean±SD) age was 55.2 ±19.6 years (51.1±17.9 years in the before-renovation group and 61.3±20.5 years in after renovation group), and 440 participants (44.5%) were male. There were 7 patients (0.7%) with a history of drug allergies. The baseline characteristics of both groups were significantly higher in age in the after-renovation group. There were 111 (11.2%) participants who had respiratory complications, 54 (5.5%) underwent endotracheal intubation with mechanical ventilation, and 57 (5.8%) received heated humidified high-flow oxygen therapy. The overall characteristics of the before and after renovation group are shown in Table 1.

There were 66 (11.2%) participants in the before-renovation group and infection, and 6 (1.5%) participants in the after-renovation group got MDROs colonization, respectively. In the medical COVID-19 ICU, the carbapenem-resistant *Acinetobacter baumannii* (CRAB) was the most common colonized

Table 1 Baseline characteristics between before and after the renovation group

Factors	Before renovation group (N=585)	After renovation group (N=403)	p-value
Age, years (Mean±SD)	51.1±17.9	61.3±20.5	0.001
Gender			
Male, n (%)	272 (46.5)	168 (41.7)	0.003
Body weight, Kilograms (Mean±SD)	65.9±14.5	52.5±9.3	0.311
Height, Centimeters (Mean±SD)	158.4±6.9	160.8±3.8	0.067
History of drug allergy, n (%)	6 (9.1)	1 (16.7)	0.275

pathogen, 62 out of 66 (93.3%) before and 5 out of 6 (83.3%) in the after-renovation group. Hospital mortality (8.5% versus 0.7%, p<0.001) and mean length of stay were significantly higher in the before-renovation group (13.8±7.2 versus 6.8±5.2 days, p<0.001, respectively). MDROs events, including clinical outcome, site of infection and colonization, and cost per admission between two groups, was shown in Tables 2 and 3. We invested 8 million Thai Baht for the renovation, including infra-structure and a ventilation system. The mean cost per person per admission was significantly higher in before the renovation group (137,564.4±141,019.7 versus 39,830.3±39,599.4 Thai Baht, p<0.001). The summary overall cost reduction during the study was 25,312,625.7 Thai Baht.

Table 2 Clinical outcome between before and after the renovation group

Factors	Before renovation group (N=585)	After renovation group (N=403)	p-value
MDROs event n, (%)	66 (11.3)	6 (1.5)	<0.001
In hospital mortality n, (%)	50 (8.5)	3 (0.7)	<0.001
Length of stay, days (Mean±SD)	13.8±7.2	6.8±5.2	<0.001
Cost per admission, THB (Mean±SD)	137,564.4±141,019.7	39,830.3±39,599.4	<0.001

Table 3 MDROs infection event between before and after the renovation group

Factors	Before renovation group (N=66)	After renovation group (N=9)	p-value
Receiving medical device			
Endotracheal tube, n (%)	52 (78.8)	2 (33.3)	<0.001
High flow nasal canula, n (%)	52 (78.8)	5 (83.3)	<0.001
Central venous catheter, n (%)	49 (74.2)	3 (50.0)	0.185
Foley catheter, n (%)	38 (57.6)	4 (66.7)	0.234
Site of specimen collection			
Sputum or tracheal aspiration, n (%)	54 (81.8)	5 (83.3)	0.853
Urine, n (%)	5 (7.6)	2 (33.3)	0.002
Hemoculture, n (%)	34 (51.5)	0	0.001
Tissue culture, n (%)	2 (3.0)	0	0.777
Pathogens			
Vancomycin-Resistant *Enterococci* (VRE), n (%)	1 (1.5)	0	0.370
Carbapenem-resistant *Acinetobacter baumannii* (CRAB), n (%)	62 (93.9)	5 (83.3)	0.080
Carbapenem-resistant *Pseudomonas aeruginosa* (CRPA), n (%)	12 (18.2)	1 (16.7)	0.853
Carbapenem-resistant *Enterobacterales* (CRE), n (%)	10 (15.2)	1 (16.7)	0.849
Death, n (%)	50 (75.8)	3 (50.0)	0.151
Cost per case per admission, THB (Mean±SD)	496707.7±64682.7	232442.1±248903.5	<0.001

Discussion

The cost-effectiveness analysis of prevention strategies against MDROs in ICUs was studied in China; Hand hygiene proved to be the optimal strategy because of its excellent performance with low cost, followed by contact isolation[23,24]. Intensive care units (ICUs) are particularly vulnerable to the spread of multidrug-resistant organisms (MDROs) due to the high concentration of critically ill patients and the frequent use of invasive procedures. Prevention measures to prevent the spread of MDROs in the ICU, several infrastructure measures can be implemented.

Hand hygiene: the most effective way to prevent the spread of MDROs is through proper hand hygiene. Hand hygiene includes handwashing with soap and water or using alcohol-based hand rubs before and after patient contact.

Isolation precautions: patients with MDROs should be placed in isolation to prevent the spread of the infection to other patients. Isolation precautions may involve placing the patient in a private room, using contact precautions such as wearing gowns and gloves, and limiting the patient's movement outside the room.

Environmental cleaning: regular cleaning of high-touch surfaces such as bed rails, doorknobs, and equipment is essential to prevent the spread of MDROs. Cleaning should be done with appropriate disinfectants that are effective against MDROs.

Antibiotic stewardship: appropriate use of antibiotics is crucial to prevent the development of MDROs. Antibiotics should only be used when necessary, and the duration of treatment should be limited to the minimum required to achieve clinical improvement.

Staff education: proper education and training of ICU staff on infection control measures and antibiotic stewardship are essential to prevent the spread of MDROs. Staff should be trained in proper hand hygiene, isolation precautions, and environmental cleaning.

Our study is the first to demonstrate the effectiveness of infrastructure modification in preventing the spread of MDROs in a public hospital in the Ministry of Public Health of Thailand is a great contribution to the field of infection control. Our study provides valuable insights into how hospitals can modify their infrastructure to prevent the spread of MDROs, and can serve as a model for other hospitals facing similar challenges in Thailand. By implementing our pilot model in other centers that have uncontrolled MDROs or are experiencing an MDROs outbreak, the model possible to significantly reduce the spread of these infections and improve patient outcomes. Additionally, the significant cost reduction associated with our intervention makes it a cost-effective solution for hospitals looking to improve their infection control practices.

A limitation of our study is that it was conducted in a single center, otherwise it's important for other centers to explore the root cause of theirs MDROs spreading problem and apply appropriate interventions to their setting. Additionally, the study was conducted during the COVID-19 pandemic, so it's important to consider how these findings may be impacted by the pandemic and any associated infection control measures that were implemented.

In conclusion, our study highlights the importance of implementing a comprehensive approach to infection control that includes infrastructure modifications, hand hygiene, isolation precautions, environmental cleaning, antibiotic stewardship, and staff education.

By taking a multifaceted approach, hospitals can effectively prevent the spread of MDROs in the ICU, resulting in reduced incidence of MDROs, reduced admission costs, and improved patient outcomes. Our study can serve as a pilot model for other hospitals in Thailand to implement similar interventions and improve their infection control practices.

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บทคัดย่อ: การเปลี่ยนแปลงโครงสร้างพื้นฐานในหอผู้ป่วยวิกฤติ เพื่อป้องกันการติดเชื้อแบคทีเรียดื้อยาต้านจุลชีพหลายขนานแพร่กระจายหอผู้ป่วยวิกฤตในช่วงการระบาดของโรคติดเชื้อไวรัสโคโรนา 2019: ผลกระทบต่อผลลัพธ์ทางคลินิกและการลดต้นทุนการรักษาในโรงพยาบาลเจ้าพระยาอภัยภูเบศร

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การเพิ่มขึ้นของแบคทีเรียดื้อยาต้านจุลชีพหลายขนาน (multidrug-resistant organisms - MDROs) เป็นหนึ่งในปัญหาด้านสาธารณสุข MDROs ทำให้เกิดการสูญเสียทางเศรษฐกิจ เนื่องจากการรักษาในโรงพยาบาลที่ยาวนานขึ้น การเข้ารับการรักษาใหม่ที่สูงขึ้น และค่าใช้จ่ายที่สูงขึ้น ตั้งแต่จุดเริ่มต้นของการแพร่ระบาดของโรคติดเชื้อไวรัสโคโรนา 2019 มีการเพิ่มขึ้นของ MDROs อย่างรวดเร็ว ซึ่งการแพร่กระจายของการติดเชื้อ MDROs ในหอผู้ป่วยหนักอย่างรวดเร็วนั้นเกิดจากการสัมผัสโดยตรงกับผู้ป่วยที่ติดเชื้อ พาหะนำโรค อุปกรณ์ทางการแพทย์ และสภาพแวดล้อมที่ปนเปื้อน การศึกษานี้มีวัตถุประสงค์เพื่อประเมินสถานการณ์การติดเชื้อ MDROs ผลการรักษา และค่ารักษาในหอผู้ป่วยหนักโรงพยาบาลเจ้าพระยาอภัยภูเบศรในช่วงที่มีการระบาดของโรคติดเชื้อไวรัสโคโรนา 2019 การใช้มาตรการป้องกันและการควบคุมหลายรูปแบบ โดยเปรียบเทียบก่อนและหลังปรับปรุงโครงสร้างพื้นฐานในหอผู้ป่วยวิกฤติ เป็นการศึกษาแบบย้อนหลัง ดำเนินการในผู้ติดเชื้อไวรัสโคโรนา 2019 ที่ได้รับการรักษาในหอ-ผู้ป่วยหนัก (ICU) ของโรงพยาบาลเจ้าพระยาอภัยภูเบศร ปราจีนบุรี ประเทศไทย ระหว่างวันที่ 1 มิถุนายน 2564 ถึง 31 ตุลาคม 2565 ซึ่งได้ปฏิบัติตามนโยบายการควบคุมการติดเชื้อและการป้องกันโรคของโรงพยาบาลอย่างเคร่งครัด มีการปรับปรุงหอผู้ป่วยหนัก (ICU) ได้แก่ (1) นำอุปกรณ์ทางการแพทย์ที่ไม่จำเป็นออก (2) เปลี่ยนฝ้าเพดานเก่า (3) ติดตั้งกระจกกั้น ประตูเลื่อนแบบไร้การสัมผัส และ (4) ระบบควบคุมการระบายอากาศ รวบรวมและวิเคราะห์ข้อมูลโดย IBM SPSS Statistics version 29.0. โดยผลการศึกษาจากกลุ่มตัวอย่างจำนวน 988 คน มีอายุเฉลี่ย (SD) คือ 55.2 ± 19.6 ปี กลุ่มตัวอย่างจำนวน 54 คน (ร้อยละ 5.5) ได้รับการใส่ท่อช่วยหายใจโดยใช้เครื่องช่วยหายใจ ก่อนการปรับปรุงโครงสร้างพื้นฐานในหอผู้ป่วยวิกฤติ เพื่อป้องกันเชื้อดื้อยา โดยมีกลุ่มตัวอย่างจำนวน 66 คน (ร้อยละ 11.3) ซึ่งพบติดเชื้อดื้อยาจำนวน 6 คน (ร้อยละ 1.5) โดยพบเชื้อในกลุ่ม *Acinetobacter baumannii* (CRAB) ที่ดื้อต่อ carbapenem เป็นเชื้อที่พบได้บ่อยที่สุด 62 คน จาก 66 คน (ร้อยละ 93.3) ในกลุ่มหลังปรับปรุงโครงสร้างพื้นฐานในหอผู้ป่วยวิกฤติ เพื่อป้องกันการติดเชื้อ MDROs ในกลุ่มก่อนปรับปรุง และพบติดเชื้อนี้จำนวน 5 คน จาก 6 คน (ร้อยละ 83.3) ในกลุ่มหลังการปรับปรุง จากข้อมูลพบว่าอัตราการเสียชีวิตในโรงพยาบาล และระยะเวลาการพักรักษาตัวเฉลี่ยของกลุ่มตัวอย่างก่อนปรับปรุงสูงกว่าหลังปรับปรุงอย่างมีนัยสำคัญทางสถิติ ค่าใช้จ่ายเฉลี่ยต่อคนในการเข้ารับการรักษาสูงขึ้นอย่างมีนัยสำคัญทางสถิติในกลุ่มก่อนปรับปรุง (137,564.4±141,019.7 บาท เทียบกับ 39,830.3±39,599.4 บาท, p<0.001) ค่าใช้จ่ายโดยรวมลดลงในระหว่างการศึกษาคือ 25,312,625.7 บาท โดยสรุป การใช้การปรับปรุงโครงสร้างพื้นฐาน ร่วมกับการใช้การป้องกันการแพร่กระจายของ MDROs ในหอผู้ป่วยหนัก (ICU) ต้องใช้วิธีการตามมาตรฐาน ได้แก่ การรักษาสุขอนามัย การล้างมือ หลักการการแยกผู้ป่วย การรักษาความสะอาดสิ่งแวดล้อม การควบคุมดูแลการใช้ยาปฏิชีวนะ และการให้ความรู้แก่เจ้าหน้าที่ โดยมาตรการและโครงสร้างพื้นฐานเหล่านี้ สามารถช่วยลดอุบัติการณ์ของ MDROs ในหอผู้ป่วยหนัก (ICU) และปรับปรุงผลลัพธ์ในการดูแลผู้ป่วยให้ดีขึ้น

คำสำคัญ: **เชื้อดื้อยาหลายชนิด; โครงสร้างพื้นฐาน; หอผู้ป่วยหนัก (ICU)**