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Prevalence of antibiotic resident bacteria in intensive care units at Hodeida City, Yemen

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ABSTRACT

Hospital-acquired infection in intensive care units (ICUs) is considered a major healthcare problem that has a detrimental effect on the patients through increasing their morbidity, mortality, and hospitalization rates. Environmental surfaces contamination plays a major role in the transmission of microorganisms and causes such infections. This study was designed to scrutinize the frequency and antimicrobial pattern of the most common bacteria in ICUs in hospitals in Hodeida, Yemen. A cross-sectional, descriptive study was conducted in six hospitals in Hodeida City, Yemen, between March and June 2019. A total of 240 samples collected from 6 hospitals were cultured and examined, including 142 (59.2%) samples that yielded positive bacterial growth. Surfaces with the highest contamination rate were door handles (76.5%), followed by IV holders (71.4%) and medical tables (66.7%). From the findings, *Staphylococcus aureus* had the highest frequency rate (37.2%), whereas *Proteus* spp. showed the lowest frequency rate (2.8%). Gram-negative isolates demonstrated higher resistance compared with Gram-positive isolates. Moreover, it was observed that *Escherichia coli* isolates were resistant to the majority of the tested antibiotics. The high prevalence of environmental bacteria in ICUs was alarming. Antibiotic resistance was extremely high, which demonstrates the need to develop and implement surveillance programs in these hospitals to address the causes of antibacterial-resistant pathogens.

INTRODUCTION

Hospital-acquired infection (HAI), also called nosocomial infection, is one of the most critical healthcare challenges, particularly in intensive care units (ICUs) (Ababneh, *et al*., 2022; Hu *et al*., 2015). It can lead to higher patient morbidity, mortality, and healthcare costs and prolong hospital stay (Ababneh *et al*., 2022). Contaminated environmental surfaces play an important role in the transmission of HAIs, specifically when patients come into direct contact with them or when they are handled by healthcare professionals' hands or gloves (Boyce, 2007). Studies have shown the significance of contaminated environmental surfaces in HAI transmission as they found a reduction in the percentage of illnesses when suitable cleaning and

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disinfection measures for these surfaces were used (Quinn *et al*., 2015; Rutala *et al*., 2012; Rutala and Weber, 2016).

Moreover, previous studies reported that patients who were admitted to the rooms that were occupied by previously contaminated patients with vancomycin-resistant *Enterococcus* (VRE), methicillin-resistant *Staphylococcus aureus* (MRSA), *Clostridium difficile*, or *Acinetobacter baumannii* infection had a higher risk of getting these pathogens from contaminated environmental surfaces of up to threefold (Carling and Bartley, 2010; Otter *et al*., 2013; Rutala and Weber, 2016).

The severity and volatility of clinical conditions for patients in ICUs expose them to many invasive medical procedures such as intubation, mechanical ventilation, intravenous lines, central venous lines, and urine catheterization, which can all contribute to this high percentage of HAIs (Brusselaers *et al*., 2011; de Oliveira and Damasceno, 2010). In addition, ICUs are considered the most crowded areas in the hospitals with equipment and apparatuses for monitoring and support of critically ill patients, which leads to difficulties in their cleaning and disinfection (de Oliveira and Damasceno, 2010; Russotto *et al*., 2015). Panhotra *et al*., (2005) reported that the records in ICUs were more infected with pathogenic microorganisms than those in surgical units in research (85.2% *vs.* 25%, respectively) (Panhotra *et al*., 2005).

Environmental surfaces can be classified into two groups: those that are frequently touched by hands (e.g., beds, bed rails, and doorknob) and those that are rarely touched by hands (e.g., floors and walls) (Saka *et al*., 2016). The frequently touched surfaces and those closer to the infected or colonized patients have more infective pathogens, such as MRSA and VRE, which have been identified as the most pathogens found on contaminated surfaces in ICUs (de Oliveira and Damasceno, 2010; Quinn *et al*., 2015).

Infective bacteria, particularly those that are multiresistant to antibiotics, are more likely to infect the environment's surfaces (Montero *et al*., 2015). Pathogens such as MRSA, VRE, and *C. difficile* can stay alive for long periods on hospital surfaces and medical devices (i.e., hours, days, or months) (Kramer *et al*., 2006; Rutala and Weber, 2013). Consequently, regular monitoring of these surfaces could help in increasing the infection control team and healthcare leadership awareness to design policy and intervention measures that may improve healthcare workers' (HCWs) practices, disinfection procedures, and HAI prevention strategies (Tajeddin *et al*., 2016; Yusuf *et al*., 2017). Carling *et al*. (2010) emphasized the importance of environmental monitoring systems in giving quantitative and objective data to healthcare organizations to help them offer a clean and healthy environment for patients and healthcare providers (Carling and Bartley, 2010). In Yemen, no previous research has attempted to describe the prevalence of bacteria on surfaces in ICUs. As a result, this study was designed to investigate the frequency and antimicrobial pattern of the most common bacteria in ICUs at hospitals in Hodeida, Yemen.

METHODOLOGY

Design and setting

A cross-sectional descriptive study was conducted at six hospitals (Al-Thawrah, Al-Olafi, Al-Amal, Al-Aqsa, Al-Rasheed, and Al-Hodeida) in Hodeida City, Yemen, between March and June 2019. Hodeida City is considered one of the most populated cities after Sana'a, the capital of Yemen (Abdul-Ghani *et al*., 2021).

Sampling and data collection

Samples were collected from the environmental surfaces in ICU units of the six hospitals. The environmental surfaces include mechanical ventilators, oxygen masks, suctions, cardiac monitors, walls, bed rails, door handles, floors, medical tables, medical records, trolleys, electrocardiogram leads, and intravenous holders. The samples were taken with a sterile swab humidified in sterile normal saline and rolled along the surfaces several times before being deposited in a 1 ml tube.

After being properly capped and labeled, they were transported to the Microbiology Department at Al-Amal Hospital Laboratories for analysis. Blood and MacConkey agar were used to culture the swab samples, which were incubated aerobically at 35°C–37°C for 18–24 hours (Yusuf *et al*., 2017). Following aerobic incubation, Gram staining was used to assess the morphology of the bacteria, followed by routine biochemical assays to determine the bacteria's species (Tajeddin *et al*., 2016).

Antimicrobial susceptibility testing

The Clinical and Laboratory Standard Institute recommended using the disk diffusion technique in the Mueller-Hinton agar to detect antibiotic susceptibility (Akhtar, 2010). Antibiotic discs such as piperacillin/tazobactam, co-amoxiclav (AMC), amikacin, gentamycin, erythromycin, ciprofloxacin, lomefloxacin, cephalexin, cefuroxime, ceftazidime, cefepime, and imipenem (IMP) were used for the antibiotic susceptibility test. In particular, data such as the hospital's name, sampling date, surface type, and equipment or device name were collected for each sample.

Ethical approval

The study was permitted by the Ethics Committee in the Faculty of Medicine and Health Sciences, Hodeida University, under Ethical Approval no. 272-2019. A written approval was introduced to the head managers of the involved hospitals before the conduction of this study.

Statistical analysis

The data was analyzed using Statistical Package for the Social Sciences version 21, and the values were displayed in frequency and percentages.

RESULTS

A total of 240 samples collected from the 6 hospitals mentioned earlier were cultured and tested. Of them, 142 (59.2%) samples yielded positive bacterial growth. The results exhibited that the highest contamination rate was recorded with door handles (76.5%), followed by IV holders (71.4%), medical tables (66.7%), walls (65.0%), and suctions (64.3%). However, the lowest rate was recorded with heart monitors (33.3%) (Table 1).

From the overall swab samples' positive growth, *S. aureus* had the highest frequency rate (37.2%), whereas *Proteus* spp. showed the lowest frequency rate (2.8%). Furthermore, *S. aureus* was the most predominant isolate across the surfaces, except for walls and IV holders, which were majorly contaminated

Table 1. Type of isolates and their frequency according to the sample location.

No.	Sample location	Samples number	Positive sample	(%)[a]	Isolates	Microorganisms							
						Gram-positive bacteria			Gram-negative bacteria				
						S. aureus	CoNS	*Streptococcus pneumoniae*	*Pseudomonas aeruginosa*	*Acinetobacter* sp.	*Escherichia coli*	*Proteus* spp.	*K. pneumoniae*
1	Mechanical ventilators	24	12	50.0	16	6	3	1	2	0	0	0	4
2	Oxygen masks	20	11	55.0	14	6	2	1	1	1	0	0	3
3	Suctions	14	9	64.3	11	4	1	1	0	1	0	1	3
4	Cardiac monitors	15	5	33.3	6	3	1	0	0	0	0	0	2
5	Walls	20	13	65.0	15	4	6	0	2	0	1	0	2
6	Bed rails	32	18	56.3	22	8	5	1	2	1	2	1	2
7	Door handles	17	13	76.5	16	5	3	0	1	1	2	1	3
8	Floors	14	10	71.4	14	6	3	0	1	0	0	1	3
9	Medical tables	21	14	66.7	18	8	3	1	1	1	1	0	3
10	Medical records	23	14	60.9	17	5	4	0	2	1	2	0	3
11	Trolleys	16	9	56.3	13	5	4	0	1	0	1	0	2
12	ECG	10	4	40.0	5	2	1	1	0	0	0	0	1
13	IV holders	14	10	71.4	13	5	2	0	2	0	1	1	2
	Total (%)	240	142	59.2	180	67 (37.2)	38 (21.2)	6 (3.3)	15 (8.3)	6 (3.3)	10 (5.6)	5 (2.8)	33 (18.3)

[a] Positive sample/samples taken * 100.

S. aureus: *Staphylococcus aureus*, CoNS: coagulase-negative *Staphylococcus*, *Acinetobacter* sp.: *Acinetobacter* species, *Proteus* spp.: *Proteus* species, and *K. pneumoniae*: *Klebsiella pneumoniae*.

with coagulase-negative *Staphylococci* (CoNS.) and *Klebsiella pneumoniae*, respectively. On the other hand, various species of bacteria were found on room surfaces and medical equipment, bringing the total number of isolates to 180 (Table 1).

In antibiotic susceptibility testing, *S. aureus* had the highest rate of resistance to piperacillin associated with tazobactam (89.6%), followed by amoxiclav (67.2%) and cefepime and cephalexin (65.7%), while it had the lowest resistance rate to amikacin (14.9%). The isolated CoNS had the highest ciprofloxacin resistance rate (89.5%) and the lowest gentamycin resistance rate (26.3%). On the other hand, Gram-negative isolates showed higher resistance compared with Gram-positive ones. *Escherichia coli* isolates were found to be multidrug resistant to the majority of antibiotics tested: piperacillin/tazobactam (80%), AMC, gentamycin, lomefloxacin, and cephalexin (70%), ceftazidime and amikacin (60%), and ciprofloxacin and cefepime (50%). Moreover, the results of this study revealed that *P. aeruginosa* isolates were resistant to piperacillin/tazobactam (80.0%), ciprofloxacin (73.3%), cefepime (73.3%), and gentamycin (66.7%) (Table 2).

Acinetobacter species showed higher resistance to AMC, whereas the lowest resistance rate was for cefepime (83%) and IMP (33%). From the findings, it was clarified that *E. coli* were mostly resistant to piperacillin/tazobactam (80%) and less resistant to IMP (40%). In addition, *Proteus* species were most resistant against AMC, ciprofloxacin, and ceftazidime (80%), while amikacin, cefuroxime, and IMP were observed to be of the lowest resistance (40%). AMC had the highest resistance impact against *K. pneumoniae* (78.9%), while IMP had the lowest resistant effect (36.4%).

DISCUSSION

The hospital ambient surfaces in ICUs play a crucial role in HAI because they are deemed a major reservoir of microbes, such as multidrug-resistant bacteria, which adversely affect patients and hospitals (Bitew *et al*., 2021). Continuous screening and understanding of the prevalence of the bacteria in the environment of the ICUs are highly advised, and they represent one of the most important techniques for increasing HCWs' awareness thereof. The present study intended to disclose the prevalence of bacteria on the environmental surfaces in ICUs and their antimicrobial susceptibility among six different hospitals in Hodeida City, Yemen.

In this study, the average of the positive samples revealed bacterial contamination of the environmental surfaces in ICUs was 59.2%. This rate is considered dangerous and alarming, and it requires immediate attention and action to resolve the problem and reduce it to a very low level. A prior study in Wille *et al*. (2018), Austria, revealed a contamination rate of 10%, describing it as "extensive" and "requiring more attention," which is deemed relatively low when compared to the contamination rate in our study. Alternatively, earlier investigations have found contamination rates as high as the current study (62.8% and 57%) (Ekrami *et al*., 2011; Yusuf J, 2017) or even higher as in Brazil and Saudi Arabia (94.7% and 85.2%, respectively) (Rodrigues *et al*., 2019).

The presence of a high contamination rate in the current study could be attributed to many factors such as the transmission of contamination by the hands of HCWs, patients, and visitors, improper cleaning and disinfectant practices, inappropriate cleaning and disinfection methods, and inadequate adherence to HCWs to hand hygiene (Faires *et al*., 2013). Furthermore, our country's economic position has a direct impact on the infrastructure and equipment of institutions, including hospitals. As a result, the ICUs in the hospitals under investigation were consistently overloaded with patients, resulting in easy pathogen shedding, difficulty cleaning and disinfecting, and HCWs overload.

This was one of the reasons mentioned in a previous study that documented a significant relationship between HAI development and nurses' workload or overload due to understaffing in ICUs (Aycan *et al*., 2015). The findings of this study showed more contamination on surfaces that are frequently touched by the HCWs, patients, or visitors. The most contaminated surfaces in our samples were the door handles (76.5%), IV holders (71.4%), and floors (71.4%), followed by medical tables, suctions, and medical documents. This could be because the majority of these surfaces are routinely touched by HCWs' hands.

In the current study, all the intended units are not singular, which means they are not subject to appropriate disinfection. In addition, contamination of patients' personal objects, bed linens, and bedsides may be related to the normal flora because almost 106 skin squamous contains viable microorganisms are shed every day from human's skin. (Tajeddin *et al*., 2016). Failure to strictly adhere to the local infection control guidelines or the production of biofilms could lead to inappropriate surface cleaning, which eventually results in high contamination (Carling *et al*., 2010; Wille *et al*., 2018; Zuberi and Ptashnick, 2011). These findings highlight the necessity of implementing a plan for disinfecting and cleaning all surfaces in ICUs, as well as providing HCWs with ongoing education and training courses to improve their health hygiene awareness.

This study revealed that Gram-positive organisms are more prevalent than the Gram-negative ones; however, previous literature produced contradicting findings (Lemmen *et al*., 2004; Tan *et al*., 2014; Wille *et al*., 2018). *Staphylococcus aureus* was found to be the most isolated organism in the current study (58.4%). This could be due to the high frequency of *S. aureus* in the human body as normal flora, as well as their resistance to drying and heating, which is consistent with earlier research (Saka *et al*., 2016; Wille *et al*., 2018). Conversely, *S. aureus* was detected in low-frequency levels compared with other screened bacteria (Huang *et al*., 2006; Tajeddin *et al*., 2016; Tan *et al*., 2014; Zuberi and Ptashnick, 2011). This study found a high resistance pattern to routinely used antibiotics such as piperacillin/tazobactam, AMC, cefepime, ciprofloxacin, and cephalexin, which is consistent with previous findings in the literature (Akhtar, 2010; Tajeddin *et al*., 2016; Yusuf *et al*., 2017). In addition, worrying rates of medication resistance in microorganisms inhabiting various surfaces of the ICUs evaluated were discovered. These locations appear to be potential sources of common HAIs resistant to antibiotics employed in these hospitals.

Finally, infection control committees in hospitals should strictly follow the guidelines and maintain strong, effective infection control programs that focus on preventing and reducing bacterial contamination by implementing preventive techniques on the ambient surfaces in ICUs and restricting the random use of antibiotics to minimize antibiotic resistance.

Table 2. Pattern of antibiotic resistance among pathogenic bacteria isolated from ICUs environment (%).

No.	Antibiotic	Sym.	Gram-positive bacteria			Gram-negative bacteria				
			S. aureus ***N* = 67**	**CoNS** ***N = 38***	***S. pneumoniae*** ***N* = 6**	***P. aeruginosa*** ***N* = 15**	***Acinetobacter* sp.** ***N* = 6**	***E. coli*** ***N* = 10**	***Proteus* spp.** ***N* = 5**	***K. pneumoniae*** ***N* = 33**
1	Piperacillin/tazobactam	PIT	60 (89.6)	47 (70.2)	4 (66.7)	12 (80.0)	3 (50.0)	8 (80.0)	3 (60.0)	25 (75.8)
2	Co-amoxiclav	AMC	45 (67.2)	20 (52.6)	4 (66.7)	9 (60.0)	5 (83.3)	7 (70.0)	4 (80.0)	26 (78.9)
3	Amikacin	AK	10 (14.9)	9 (23.7)	2 (33.3)	7 (46.7)	3 (50.0)	6 (60.0)	2 (40.0)	17 (51.5)
4	Gentamycin	GN	31 (46.3)	10 (26.3)	3 (50.0)	10 (66.7)	4 (66.7)	7 (70.0)	3 (60.0)	21 (63.6)
5	Erythromycin	ER	40 (61.2)	16 (42.1)	3 (50.0)	NA	NA	NA	NA	NA
6	Ciprofloxacin	CIP	38 (56.7)	34 (89.5)	2 (33.3)	11 (73.3)	4 (66.7)	5 (50.0)	4 (80.0)	18 (54.5)
7	Lomefloxacin	LOM	25 (37.3)	12 (31.6)	4 (66.7)	9 (60.0)	3 (50.0)	7 (70.0)	3 (60.0)	20 (52.6)
8	Cephalexin	CPX	40 (59.7)	15 (39.5)	4 (66.7)	8 (53.3)	4 (66.7)	7 (70.0)	3 (60.0)	18 (54.5)
9	Cefuroxime	CFX	33 (49.3)	17 (44.7)	5 (83.3)	9 (60.0)	3 (50.0)	5 (50.0)	2 (40.0)	16 (48.5)
10	Ceftazidime	CFM	ND	ND	ND	7 (46.7)	4 (66.7)	6 (60.0)	4 (80.0)	23 (69.7)
11	Cefepime	CFP	44 (65.7)	21 (55.3)	3 (50.0)	11 (73.3)	2 (33.3)	5 (50.0)	3 (60.0)	22 (66.7)
12	Imipenem	IMP	22 (32.8)	18 (47.4)	1(16.7)	4 (26.7)	2 (33.3)	4 (40.0)	2 (40.0)	12 (36.4)

Sym.: symbol, PIT: piperacillin/tazobactam, AMC: co-amoxiclav, AK: amikacin, GN: gentamycin, ER: erythromycin, CIP: ciprofloxacin, LOM: lomefloxacin, CPX: cephalexin, CFX: cefuroxime, CFM: ceftazidime, CFP: cefepime, IMP: imipenem, and NA: not applicable.

S. aureus: *Staphylococcus aureus*, CoNS: coagulase-negative *Staphylococcus*, *S. pneumoniae*: *Streptococcus pneumoniae*, *Acinetobacter* sp.: *Acinetobacter* species, *E. coli*: *Escherichia coli*, *Proteus* spp.: *Proteus* species, *K. pneumoniae*: *Klebsiella pneumoniae*, and *P. aeruginosa*: *Pseudomonas aeruginosa*.

CONCLUSION

According to the findings of the current study, the prevalence of environmental bacteria in ICUs was extremely high and alarming. Gram-positive bacteria were found to be more common than Gram-negative bacteria, with *S. aureus* being the most common isolated organism in the current investigation. Environmental surfaces contributed to more than 50% of the contamination. Antibiotic resistance was found to be extremely high, which is a concerning finding. Thus, there is an urgent need to develop and implement surveillance programs in these hospitals to tackle the origin and emerging pathways of resistant pathogens.

AUTHOR CONTRIBUTIONS

All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; agreed to submit to the current journal; gave final approval of the version to be published; and agree to be accountable for all aspects of the work. All the authors are eligible to be an author as per the international committee of medical journal editors (ICMJE) requirements/guidelines.

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CONFLICTS OF INTEREST

The authors report no financial or any other conflicts of interest in this work.

ETHICAL APPROVALS

The study was permitted by the Ethics Committee in the Faculty of Medicine and Health Sciences, Hodeida University, under Ethical Approval no. 272-2019

DATA AVAILABILITY

All data generated and analyzed are included within this research article.

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