



Awareness of Bacterial Resistance to Antibiotics among Healthcare Providers in Sana'a City, Yemen

Abdulsalam M. Halboup^{1,*}, Karem H. Alzoubi², Gamil Q. Othman¹

¹Department of Clinical Pharmacy and Pharmacy Practice, Faculty of Pharmacy, University of Science and Technology, Sana'a, Yemen

²Department of Clinical Pharmacy, Faculty of Pharmacy, Jordan University of Science and Technology, Irbid, Jordan

ABSTRACT

Objectives: To assess the awareness of healthcare providers in Sana'a city of the most frequently antibiotic-resistant bacterial isolates encountered in clinical settings, the factors associated with the emergence of such resistance and the strategies to counteract antibiotic resistance.

Methods: This cross-sectional study included 416 healthcare providers; namely, 167 physicians, 61 pharmacists and 188 nurses, from four public and two private hospitals in Sana'a. Data about demographics, awareness of the most frequently isolated antibiotic-resistant bacteria in clinical settings, the factors possibly associated with such resistance and the best strategies to counteract antibiotic resistance were collected using a pre-designed questionnaire. Data were then analyzed using suitable statistical tests.

Results: The majority of healthcare providers were aware of methicillin-resistant *Staphylococcus aureus* and *Pseudomonas aeruginosa* as the two most frequently encountered bacterial species in clinical practice, with non-statistically significant differences in the awareness level among physicians, pharmacists and nurses. However, a statistically significant difference was found among healthcare providers regarding their awareness of the most possible factors contributing to antibiotic resistance. In this regard, pharmacists were significantly more aware of the contribution of the extensive use of newer generations of antibiotics ($P = 0.030$), inappropriate prescribing of antibiotics ($P = 0.010$) and use of antibiotics without prescription ($P = 0.045$) to the emergence and spread of antibiotic resistance than physicians and nurses. On the other hand, physicians and nurses were significantly more aware of the role of reducing the length of hospital stay ($P = 0.005$), limiting the use of medical instrumentation ($P = 0.036$), use of narrow-spectrum antibiotics ($P = 0.005$), surveillance for antibiotic resistance ($P = 0.004$), development of infection control policies and procedures ($P < 0.001$) and consultation with infectious disease specialists ($P = 0.010$) as key strategies to minimize the emergence of antibiotic-resistant bacteria compared to pharmacists. Moreover, nurses showed significantly higher awareness of the use of narrow-spectrum antibiotics ($P = 0.005$) and surveillance of antibiotic resistance ($P = 0.003$) as key strategies to reduce the emergence and spread of antibiotic resistance.

Conclusions: There is a discrepancy in the awareness of Yemeni healthcare providers' of the most frequently encountered antibiotic-resistant bacteria in clinical practice, the factors possibly contributing to such resistance and the key strategies to counteract it. Therefore, continuing medical education of physicians, pharmacists and nurses is recommended to keep them updated on antibiotic resistance and the best strategies and approaches to its containment. In addition, there is a need for the development of infectious disease protocols for hospitals to optimize the selection and treatment with antibiotics, to reduce side effects and costs and to minimize the development of antibiotic resistance.

Keywords: Awareness, Antibiotic-resistant bacteria, Healthcare provider, Hospital, Sana'a

* Corresponding author: A. M. Halboup (a.halboob@ust.edu)



1. Introduction

Antibiotics are one of the most commonly prescribed medications worldwide, and the majority of such medications are mainly prescribed outside the hospital setting in community pharmacies (1, 2). Treatment of infectious diseases caused by resistant microorganisms contributes to a considerable increase in treatment costs, disease spread, illness duration and mortality rate (3). Therefore, the emergence of bacterial strains resistant to antibiotics represents a major public health problem (4).

Multidrug resistance (MDR) in bacteria refers to their resistance to three or more agents from different categories of antibiotics, mainly antipseudomonal penicillin, aminoglycosides, cephalosporins, carbapenems, and quinolones (5, 6). MDR bacteria of special concern to healthcare facilities include methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant *Enterococcus*(VRE), extended-spectrum beta-lactamase (ESBL)-producing Gram-negative bacteria, *Pseudomonas aeruginosa* and *Acinetobacter baumannii* (7). Several risk factors have been linked to the emergence and spread of MDR bacteria. These include prolonged hospitalization, invasive procedures, exposure to broad-spectrum antibiotics, non-adherence to infection control guidelines, inadequate surveillance system and unhygienic conditions (8–12). In addition, irrational use of antimicrobials is one of the major drivers for antibiotic resistance, especially in developing countries (13). In Yemen, easy over-the-counter obtaining of antibiotics from pharmacies (14,15) and physicians non-adherence to rational prescribing of antibiotics (16, 17) are among the factors that contribute to the emergence of resistant bacteria.

Therefore, the present study aimed to assess healthcare providers' awareness of the most frequently encountered antibiotic-resistant bacteria, the factors contributing to such resistance and the key strategies to counteract it in Sana'a city.

2. Methods

2.1. Study design, setting and sample size calculation

This was a cross-sectional study among physicians, pharmacists and nurses working in public and private hospitals of Sana'a city during April 2016. Healthcare providers were recruited from four public hospitals; namely, Al-Thawra Modern General Hospital (TMGH), Al-Jomhori Teaching Hospital (GTH), Kuwait University Hospital (KUH) and Al-Sabeen Maternal Hospital (SMH) and two private hospitals, University of Science and Technology Hospital and Saudi German Hospital. A sample size of 383 was calculated using OpenEpi (<http://www.openepi.com/SampleSize/SSPropor.htm>) after applying the default parameters and their values such as population size, anticipated % frequency, confidence limit and design effect were used. A number of 167 questionnaires were added to overcome non-respondents healthcare providers and to give a better chance to collect the required sample size.

2.2. Data collection

Data was collected using a pre-designed questionnaire composed of four sections (18). Modifications were made by the authors and then distributed to five PhD holders from the Faculty of Pharmacy, Al-Nasser University and University of Science and Technology as part of validation. All comments were considered before starting the study. Questionnaires were administered and collected through hospital visits, where participants were approached at their offices or rest areas and asked to complete the four questionnaire sections. The first section included questions about the respondent's demographic data including gender, age, occupation, level of education and specialty. In the second section, the participants were asked to answer questions regarding the most likely encountered antibiotic-resistant



bacterial species. The participants had to rate six different bacterial strains known to have the ability to develop resistance to antibiotics including MRSA, VRE-*faecium*, VRE-*faecalis*, ESBL-producing Gram-negative bacteria, *P. aeruginosa* and *A. baumannii*. In the third and fourth sections, the respondents were asked to rate 12 factors that contribute to the emergence of bacterial resistance to antibiotics and 12 strategies that may reduce the development of such resistance. A four-level scale was used to rate responses as follows: 1, very unlikely; 2, somewhat unlikely; 3, somewhat likely; 4, very likely.

2.3. Statistical analysis

Data were analyzed using IBM SPSS Statistics version 21.0 for Windows® (IBM Corp., Armonk, NY, USA). One-way analysis of variance (ANOVA) followed by Bonferroni post-hoc test was used to compare between the mean scores of independent groups for normally distributed data. On the other hand, non-normally distributed data were analyzed using Kruskal-Wallis test.

3. Results

3.1. Characteristics of participating healthcare providers

Out of 550 healthcare providers invited to participate, 518 (94%) responded to the study. However, only 416 questionnaires were filled properly and subsequently used in the study. Table (1) shows that the majority of participants were males (56.7%; 236/416), working in public hospitals (78.8%; 318/416) and aged less than 30 years (51.9%; 216/416). Details of the education levels and medical specialties of the participants are shown in Table (1).

3.2. Healthcare providers' awareness of the most frequent antibiotic-resistant bacterial strains and the factors possibly associated with antibiotic resistance

There were no statistically significant differences among physicians, pharmacists and nurses regarding their awareness of the most frequently encountered antibiotic-resistant bacteria in clinical practice (Table 2). However, there were statistically significant differences among physicians, pharmacists and nurses with respect to their awareness of the probable contribution of the extensive use of newer generations of antibiotics ($P = 0.036$), inappropriate prescribing of antibiotics ($P = 0.020$), use of antibiotic without prescription ($P = 0.015$) and economic and political factors ($P = 0.043$) to the development of antibiotic resistance (Table 3). The Bonferroni post-hoc test revealed that pharmacists were significantly more aware of the contribution of the extensive use of newer generations of antibiotics ($P = 0.030$), inappropriate prescribing of antibiotics ($P = 0.010$) and the use of antibiotics without prescription ($P = 0.045$) to antibiotic resistance than physicians and nurses. On the other hand, physicians showed statistically higher awareness of the probable contribution of using antibiotics without prescription ($P = 0.009$) and economic and political factors ($P = 0.040$) to the development of antibiotic resistance compared to nurses and pharmacists.

3.3. Healthcare providers' awareness of the strategies to counteract antibiotic resistance

Regarding the appropriate strategies to limit the development of antibiotic resistance, Table (4) shows statistically significant differences among physicians, pharmacists and nurses with respect to their awareness of the utility of the following strategies to counteract the emergence of antibiotic resistance: reducing the length of hospital stay ($P = 0.005$), limiting the use of medical instrumentation ($P = 0.036$), use of narrow-spectrum antibiotics ($P = 0.005$), surveillance for antibiotic resistance ($P = 0.004$), development of infection control policies and procedures ($P < 0.001$) and consultation with infectious disease specialists ($P = 0.010$). Bonferroni post-hoc test



revealed that physicians had significantly higher awareness of the following strategies to reduce the risk of the emergence of antibiotic-resistant bacterial strains: reducing the length of hospital stay ($P = 0.005$), development of infection control policies and procedures ($P = 0.001$) and consultation with infectious disease specialists ($P = 0.032$). On the other hand, nurses were significantly more knowledgeable than pharmacists re-

garding the following strategies: reducing the length of hospital stay ($P = 0.007$) and development of infection control policies and procedures. Moreover, nurses showed significantly higher awareness of the use of narrow-spectrum antibiotics ($P = 0.005$) and surveillance of antibiotic resistance ($P = 0.003$) as key strategies to reduce the emergence and spread of antibiotic resistance.

Table 1: Characteristics of participating healthcare providers working in hospitals of Sana'a city, Yemen in 2016 ($N = 416$)

Characteristic		Physicians	Pharmacists	Nurses	Total
		<i>n</i> (%)	<i>n</i> (%)	<i>n</i> (%)	<i>n</i> (%)
Hospital	TMGH	51 (30.5)	14 (23.0)	58 (30.9)	123 (29.6)
	GTH	39 (23.4)	20 (32.8)	26 (13.8)	85 (20.4)
	SMH	30 (18.0)	6 (9.8)	28 (14.9)	64 (15.4)
	KUH	10 (6.0)	10 (16.4)	36 (19.1)	56 (13.5)
	USTH	17 (10.2)	6 (9.8)	20 (10.6)	43 (10.3)
	SGH	20 (12.0)	5 (8.2)	20 (10.6)	45 (10.8)
Hospital type	Public	130 (62.3)	50 (82.0)	148 (78.7)	328 (78.8)
	Private	37 (37.7)	11 (18.0)	40 (21.3)	88 (21.2)
Gender	Male	104 (62.3)	40 (65.6)	92 (48.9)	236 (56.7)
	Female	63 (37.7)	21 (34.4)	96 (51.1)	180 (43.3)
Occupation	< 30	59 (35.3)	28 (45.9)	129 (68.6)	216 (51.9)
	30-40	66 (39.5)	29 (47.5)	54 (28.7)	149 (35.8)
	> 40	42 (25.1)	4 (6.6)	5 (2.7)	51 (12.3)
	Physician (consultant)	20 (12.0)	-	-	20 (4.8)
Physician (specialist)	53 (31.7)	-	-	53 (12.7)	
Physician (resident)	37 (22.2)	-	-	37 (8.9)	
Physician (general practitioner)	57 (34.1)	-	-	57 (13.7)	
Pharmacist (diploma)	-	16 (26.2)	-	16 (3.8)	
Pharmacist (bachelor)	-	42 (68.9)	-	42 (10.1)	
Pharmacist (master)	-	3 (4.9)	-	3 (0.7)	
Nurse (diploma)	-	-	107 (56.9)	107 (25.7)	
Nurse (bachelor)	-	-	75 (39.9)	75 (18.0)	
Nurse (master)	-	-	6 (3.2)	6 (1.40)	
Total	-	167 (40.1)	66 (14.7)	188 (45.2)	416 (100)

TMGH, Al-Thawra Modern General Hospital; GTH, Al-Jomhori Teaching Hospital; KUH, Kuwait University Hospital; SMH, Al-Sabeen Maternal Hospital; USTH, University of Science and Technology Hospital; SGH, Saudi German Hospital.



Table 2. Healthcare providers' awareness of the most frequently encountered antibiotic-resistant bacterial strains in clinical practice in Sana'a city, Yemen in 2016 (N = 416)

Bacterial strain	Category of healthcare provider	n (%)	Awareness score (mean ± SD)	F-statistic	P-value
MRSA	Physician	167 (40.1)	207 ^a ± 0.748	3.11 ^b	0.211 [#]
	Pharmacist	61 (14.7)	230 ^a ± 0.719		
	Nurse	188 (45.2)	202 ^a ± 0.838		
VRE-faecium	Physician	167 (40.1)	1.86 ± 0.965	1.208	0.300
	Pharmacist	61 (14.7)	1.80 ± 0.853		
	Nurse	188 (45.2)	1.98 ± 0.901		
VRE-faecalis	Physician	167 (40.1)	204 ^a ± 0.883	0.501 ^b	0.778 [#]
	Pharmacist	61 (14.7)	215 ^a ± 0.885		
	Nurse	188 (45.2)	209 ^a ± 0.848		
ESBL-producing Gram-negative bacilli	Physician	167 (40.1)	1.92 ± 0.776	1.134	0.323
	Pharmacist	61 (14.7)	1.92 ± 0.759		
	Nurse	188 (45.2)	1.80 ± 0.893		
<i>Pseudomonas aeruginosa</i>	Physician	167 (40.1)	2.26 ± 0.830	2.055	0.129
	Pharmacist	61 (14.7)	2.23 ± 0.783		
	Nurse	188 (45.2)	2.09 ± 0.898		
<i>Acinetobacter baumannii</i>	Physician	167 (40.1)	1.80 ± 0.983	0.428	0.652
	Pharmacist	61 (14.7)	1.67 ± 0.870		
	Nurse	188 (45.2)	1.75 ± 0.968		

[#], Analyzed using Kruskal-Wallis test; ^a, mean rank; ^b, value for chi-square; MRSA, methicillin-resistant *S. aureus*; VRE, Vancomycin-resistant *Enterococcus*; ESBL, extended-spectrum β-lactamase-producing Gram-negative bacilli; SD, standard deviation.

4. Discussion

The awareness of the majority of healthcare providers in the present study about MRSA and *P. aeruginosa* as being the most frequently isolated antibiotic-resistant bacteria in clinical settings is consistent with previous findings that both species are the most frequently isolated bacteria among Yemen patients with otitis media (19, 20). It is worth mentioning that the European Antimicrobial Resistance Surveillance Network specifies these two species among the seven resistant microorganisms commonly reported in several European countries (21). In addition, a recent study among Iraqi pharmacists revealed that MRSA was the most frequently isolated resistant bacterial strain (22).

In Yemen, the pattern of antibiotic prescription in the ambulatory care of public hospitals was high compared to the incidence of infectious diseases, where up to 51% of all prescriptions include antibiotics (16). Moreover, antibiotics in Yemen can be easily obtained from pharmacies

without prescription (23), and such over-prescription of antibiotics is one of the major risk factors for the development of resistance. The present study revealed that healthcare providers conceived that the extensive use of antibiotics, inappropriate antibiotic prescribing and use of antibiotics without prescription are major factors contributing to the emergence of antibiotic-resistant bacterial strains. This result is consistent with other studies reporting that inappropriate and over-prescription of antibiotics are leading causes of bacterial resistance to antibiotics (18,24–28). Similarly, a recent study in hospital and community pharmacies in Iraq showed that the use of antibiotics without prescription is a significant reason for the development of bacterial resistance to antibiotics (22). On the other hand, the awareness of Yemeni physicians of the contribution of economic and political situations to the emergence and spread of antibiotic resistance is in agreement with a study conducted in 28 European countries, which indicated that corruption and poor governance are contributors to the development of antibiotic resistance (29).



Table 3. Healthcare providers' awareness of the most probable factors contributing to the emergence and spread of antibiotic resistance in Sana'a city, Yemen in 2016 (N = 416)

Risk factors associated with antibiotic resistance		Awareness score			
		N (%)	Mean± SD	F-statistic	P-value
Prolonged hospitalization	Physician	167 (40.1)	217 ^a ± 0.650	2.537 ^b	0.281 [#]
	Pharmacist	61 (14.7)	198 ^a ± 0.808		
	Nurse	188 (45.2)	204 ^a ± 0.831		
Exposure to contaminated medical instruments	Physician	167 (40.1)	2.23 ± 0.890	1.548	0.214
	Pharmacist	61 (14.7)	2.34 ± 0.772		
	Nurse	188 (45.2)	2.39 ± 0.880		
Extensive use of newer generations of antibiotics	Physician	167 (40.1)	194 ^a ± 0.809	6.642 ^b	0.036 ^{*#}
	Pharmacist	61 (14.7)	230 ^a ± 0.544		
	Nurse	188 (45.2)	214 ^a ± 0.756		
Inappropriate infection control practice	Physician	167 (40.1)	2.14 ± 0.778	1.181	0.308
	Pharmacist	61 (14.7)	2.15 ± 0.771		
	Nurse	188 (45.2)	2.27 ± 0.830		
Inappropriate prescribing of antibiotics	Physician	167 (40.1)	207 ^a ± 0.778	7.813 ^b	0.020 ^{*#}
	Pharmacist	61 (14.7)	245 ^a ± 0.629		
	Nurse	188 (45.2)	199 ^a ± 0.929		
Ineffective surveillance system	Physician	167 (40.1)	2.06 ± 0.819	0.116	0.890
	Pharmacist	61 (14.7)	2.05 ± 0.784		
	Nurse	188 (45.2)	2.02 ± 0.951		
Use of antibiotics without prescription	Physician	167 (40.1)	220 ^a ± 0.798	8.400 ^b	0.015 ^{*#}
	Pharmacist	61 (14.7)	227 ^a ± 0.788		
	Nurse	188 (45.2)	192 ^a ± 1.033		
Crowding and unhygienic conditions	Physician	167 (40.1)	2.04 ± 0.894	4.262 ^b	0.119 [#]
	Pharmacist	61 (14.7)	1.89 ± 0.915		
	Nurse	188 (45.2)	2.12 ± 0.985		
Non-adherence of practitioners to treatment guidelines	Physician	167 (40.1)	2.07 ± 0.899	0.677	0.509
	Pharmacist	61 (14.7)	2.07 ± 0.814		
	Nurse	188 (45.2)	2.17 ± 0.949		
Inappropriate hand hygiene	Physician	167(40.1)	204 ^a ± 0.813	4.217 ^b	0.121 [#]
	Pharmacist	61(14.7)	187 ^a ± 0.904		
	Nurse	188(45.2)	219 ^a ± 0.941		
Patient non-compliance	Physician	167 (40.1)	211 ^a ± 0.711	0.402 ^b	0.818 [#]
	Pharmacist	61 (14.7)	201 ^a ± 0.859		
	Nurse	188 (45.2)	208 ^a ± 0.862		
Economic and political factors	Physician	167 (40.1)	218 ^a ± 0.926	6.270 ^b	0.043 ^{*#}
	Pharmacist	61 (14.7)	176 ^a ± 0.989		
	Nurse	188 (45.2)	210 ^a ± 1.002		

*, Statistically significant at P < 0.05; #, analyzed using Kruskal-Wallis test; SD, standard deviation; ^a, mean rank; ^b, value for chi-square.

Nosocomial infections continue to be a major health problem in both developed and developing countries. The significance of such infections is not only attributed to the increase in morbidity and mortality rates but also to the emergence of antimicrobial resistance, prolonged hospitalization, increased healthcare cost and reduced treatment success (30–32). In this context, the present study revealed statistically non-

significant differences among various categories of healthcare providers regarding their awareness of the major role of prolonged hospitalization as a contributing factor possibly associated with the emergence of antibiotic resistance. Similarly, awareness of prolonged hospitalization as a contributor to antibiotic resistance was also reported among Ethiopian physicians, pharmacists and nurses (27).



Table 4: Healthcare providers' awareness of the strategies to counteract the development of antibiotic resistance in Sana'a city, Yemen in 2016 (N = 416)

Strategies to counteract bacterial resistance		Awareness scores			
		n (%)	Mean ± SD	F-statistic	P-value
Appropriate infection control practice	Physician	167 (40.1)	211 ^a ± 0.558	2.902 ^b	0.234 [#]
	Pharmacist	61 (14.7)	190 ^a ± 0.696		
	Nurse	188 (45.2)	212 ^a ± 0.589		
Reducing the length of hospital stay	Physician	167 (40.1)	2.49 ± 0.629	5.370	0.005*
	Pharmacist	61 (14.7)	2.20 ± 0.726		
	Nurse	188 (45.2)	2.49 ± 0.633		
Limiting the use of medical instrumentation	Physician	167 (40.1)	2.12 ± 0.849	3.351	0.036*
	Pharmacist	61 (14.7)	2.08 ± 0.666		
	Nurse	188 (45.2)	2.31 ± 0.809		
Use of narrow-spectrum antibiotics	Physician	167 (40.1)	2.04 ± 0.809	5.357	0.005*
	Pharmacist	61 (14.7)	2.26 ± 0.603		
	Nurse	188 (45.2)	2.30 ± 0.787		
Surveillance for antibiotics resistance	Physician	167 (40.1)	2.18 ± 0.965	5.716	0.004*
	Pharmacist	61 (14.7)	2.43 ± 0.787		
	Nurse	188 (45.2)	2.48 ± 0.763		
Review of antibiotic utilization and its relationship to local antibiotic resistance patterns	Physician	167 (40.1)	2.29 ± 0.838	1.679	0.188
	Pharmacist	61 (14.7)	2.36 ± 0.817		
	Nurse	188 (45.2)	2.45 ± 0.733		
Encouragement of the practice of bacterial isolation and susceptibility testing	Physician	167 (40.1)	2.54 ± 0.742	2.609	0.075
	Pharmacist	61 (14.7)	2.28 ± 0.819		
	Nurse	188 (45.2)	2.49 ± 0.777		
Better adherence to treatment guidelines	Physician	167 (40.1)	201 ^a ± 0.656	3.196 ^b	0.202 [#]
	Pharmacist	61 (14.7)	190 ^a ± 0.766		
	Nurse	188 (45.2)	218 ^a ± 0.673		
Discouragement of self-treatment with antibiotics	Physician	167 (40.1)	209 ^a ± 0.926	3.829 ^b	0.147 [#]
	Pharmacist	61 (14.7)	185 ^a ± 0.767		
	Nurse	188 (45.2)	216 ^a ± 0.781		
Educational programs for healthcare providers and the community	Physician	167(40.1)	2.29 ± 0.777	1.268	0.282
	Pharmacist	61(14.7)	2.23 ± 0.739		
	Nurse	188(45.2)	2.39 ± 0.797		
Development of infection control policies and procedures	Physician	167 (40.1)	211 ^a ± 0.610	18.124 ^b	<0.001**
	Pharmacist	61 (14.7)	157 ^a ± 0.703		
	Nurse	188 (45.2)	223 ^a ± 0.665		
Consultation with infectious disease specialists	Physician	167 (40.1)	2.58 ± 0.643	3.752	0.010*
	Pharmacist	61 (14.7)	2.31 ± 0.672		
	Nurse	188 (45.2)	2.44 ± 0.761		

*, Statistically significant at $P < 0.05$; #, analyzed using Kruskal-Wallis test was used; SD, standard deviation; ^a, rank; ^b, value for chi-square.



Variations in responses of various categories and specialties of healthcare providers regarding the factors possibly contributing to the emergence of antibiotic resistance in the present study might be attributed to different educational backgrounds and practice settings. Pharmacists, for example, reported that using antibiotics without prescription, inappropriate prescribing of antibiotics and extensive use of newer generations of antibiotics are the most likely factors contributing to the emergence of resistant bacteria. In the present study, physicians reported that using antibiotics without prescription in addition to economic and political factors are the factors contributing to antibiotic resistance. On the other hand, physicians and nurses indicated that prolonged hospitalization is the leading cause of antibiotic resistance, reflecting their close contact during clinical practice (order and implementation relationship). Physicians also reported that using antibiotics without prescription contributes to such resistance, highlighting the importance of taking a medication after obtaining the right diagnosis and legal drug prescription from a physician.

Identifying the factors responsible for the emergence of bacterial resistance to antibiotics is critical to the adoption of effective strategies to minimize or slow down the emergence of such resistance. Since nosocomial infections are associated with high mortality rates, poor clinical outcomes and development of antibiotic resistance, hospitals should take serious actions to minimize the emergence of antibiotic resistance. In this context, healthcare providers in the present study suggested that the implementation of appropriate infection control practice, encouragement of bacterial isolation in culture and susceptibility testing, better adherence to treatment guidelines, reducing the length of hospital stays, surveillance for antibiotic resistance and consultations with infectious disease specialists as the most likely strategies to

control the emergence of nosocomial antibiotic resistance. In line with these findings, it is well documented that appropriate use of antimicrobials, reinforcement of basic infection control measures, improved hand hygiene, surveillance for antibiotic resistance and consultation with infectious disease specialists are key strategies for counteracting antimicrobial resistance (28, 31, 33–42).

The differences in the levels of healthcare providers' awareness according to their specialties in the present study could be generally attributed to the differences in their educational backgrounds and the working environments. In this regard, physicians and nurses were significantly more aware than pharmacists of the role of reducing the lengths of hospital stay, practice of infection control policies and procedures and consultation with infectious disease specialists as key strategies to minimize the development of antimicrobial resistance. This finding is consistent with those reported in other studies, which revealed a number of discrepancies in the awareness level between healthcare providers with respect to the most isolated resistant bacteria, factors that contribute to such resistance and the strategies that can be used to counteract such resistance (18, 27).

5. Conclusions

Healthcare providers in Yemen show a discrepancy in their awareness of the most frequently encountered antibiotic-resistant bacteria in clinical practice. In addition, their awareness is variable regarding the factors possibly contributing to the emergence and spread of bacterial resistance to antibiotics as well as the key strategies that can help to counteract such resistance. Therefore, continuing medical education of physicians, pharmacists and nurses is recommended to keep them updated on antibiotic resistance and the best strategies and approaches to its containment. In addition, there is a need for the



development of infectious disease protocols for hospitals to optimize the selection and treatment with antibiotics, reduce side effects and cost and minimize the development of bacterial resistance to antibiotics.

Acknowledgments

The authors thank the final-year pharmacy students in Al-Nasser University for their assistance during data collection as well as the respective administrations of the public and private hospitals for their collaboration.

Authors' contributions

AMH & GQO proposed the idea and collected the data of the study. KHA analyzed and interpreted the collected data. AMH & GQO wrote the first draft of results and discussion. All authors revised and approved the final draft of the manuscript.

Competing interests

The authors declare that they have no competing interests associated with this article.

Ethical approval

Ethical approval was obtained from the Research Ethics Committee of the Faculty of Medicine and Health Sciences, University of Science and Technology, Sana'a, Yemen (MECA No.: 2016/16). Each consenting participant was provided with appropriate information about the study before participation in the study.

References

1. Col NF, O'Connor RW. Estimating worldwide current antibiotic usage: report of Task Force 1. *Rev Infect Dis* 1987; 9 (Suppl 3): S232–43. [PubMed](#) • [Google Scholar](#)
2. Carbon C, Bax RP. Regulating the use of antibiotics in the community. *BMJ* 1998; 317: 663–5. [PubMed](#) • [Google Scholar](#)
3. Okeke IN, Laxminarayan R, Bhutta ZA, Duse AG, Jenkins P, O'Brien TF, et al. Antimicrobial resistance in developing countries. Part I: recent trends and current status. *Lancet Infect Dis* 2005; 5: 481–93. [PubMed](#) • [DOI](#) • [Google Scholar](#)
4. Hancock RE. The complexities of antibiotic action. *Mol Syst Biol* 2007; 3: 142. [PubMed](#) • [DOI](#) • [Google Scholar](#)
5. Magiorakos AP, Srinivasan A, Carey R, Carmeli Y, Falagas M, Giske C, et al. Multidrug-resistant, extensively drug-resistant and pandrug-resistant bacteria: an international expert proposal for interim standard definitions for acquired resistance. *Clin Microbiol Infect* 2012; 18: 268–81. [PubMed](#) • [DOI](#) • [Google Scholar](#)
6. Defez C, Fabbro-Peray P, Bouziges N, Gouby A, Mahamat A, Daures J, et al. Risk factors for multidrug-resistant *Pseudomonas aeruginosa* nosocomial infection. *J Hosp Infect* 2004; 57: 209–16. [PubMed](#) • [DOI](#) • [Google Scholar](#)
7. Siegel JD, Rhinehart E, Jackson M, Chiarello L, Healthcare Infection Control Practices Advisory Committee. Management of multidrug-resistant organisms in health care settings, 2006. *American J Infect Control* 2007; 35: S165–93. [PubMed](#) • [DOI](#) • [Google Scholar](#)
8. Maragakis LL, Perl TM. *Acinetobacter baumannii*: epidemiology, antimicrobial resistance, and treatment options. *Clin Infect Dis* 2008; 46: 1254–63. [PubMed](#) • [DOI](#) • [Google Scholar](#)
9. Kollef MH. Inadequate antimicrobial treatment: an important determinant of outcome for hospitalized patients. *Clin Infect Dis* 2000; 31(Suppl 4): S131–8. [PubMed](#) • [DOI](#) • [Google Scholar](#)
10. Alanis AJ. Resistance to antibiotics: are we in the post-antibiotic era? *Arch Med Res* 2005; 36: 697–705. [DOI](#) • [Google Scholar](#)
11. Falagas ME, Kopterides P. Risk factors for the isolation of multi-drug-resistant *Acinetobacter baumannii* and *Pseudomonas aeruginosa*: a systematic review of the literature. *J Hosp Infect* 2006; 64: 7–15. [PubMed](#) • [DOI](#) • [Google Scholar](#)
12. Okeke IN, Lamikanra A, Edelman R. Socioeconomic and behavioral factors leading to acquired bacterial resistance to antibiotics in developing countries. *Emerg Infect Dis* 1999; 5: 18–27. [PubMed](#) • [DOI](#) • [Google Scholar](#)
13. Belkina T, Al Warafi A, Hussein Eltom E, Tadjieva N, Kubena A, Vlcek J. Antibiotic use and knowledge in the community of Yemen, Saudi Arabia, and Uzbekistan. *J Infect Dev Ctries* 2014; 8: 424–9. [PubMed](#) • [DOI](#) • [Google Scholar](#)
14. Mohanna M. Self-medication with antibiotic in children in Sana'a City, Yemen. *Oman Med J* 2010; 25: 41–3. [PubMed](#) • [DOI](#) • [Google Scholar](#)
15. Afady S, Ballaswad MR, Amra AS, alghadeer SM, Wajid S, Al-Arifi MN, et al. Self-medication with antibiotic amongst adults attending community pharmacies in Mukalla district, Yemen. *Lat Am J Pharm* 2017; 36: 224–8. [Google Scholar](#)
16. Al-Shami AM, Ibrahim MIM, Abdo-Rabbo A. Evaluation of the quality of prescriptions with antibiotics in the government hospitals of Yemen. *JCDR* 2011; 5: 808–12. [Google Scholar](#)
17. Alshakka M, Said K, Babakri M, Ansari M, Aldhubhani A, Hassali MA, et al. A study on antibiotics prescribing pattern at outpatient department in four hospitals in Aden - Yemen. *JPPCM* 2016; 2: 88–93. [DOI](#) • [Google Scholar](#)
18. Alzoubi K, Ayoub N, Al-Sakaji S, Al-Azzam S, Mhaidat N, Masadeh M. Awareness of bacterial resistance among physicians, pharmacists and nurses. *Int J Occup Med Environ Health* 2009; 22: 363–72. [PubMed](#) • [DOI](#) • [Google Scholar](#)
19. Al-Alousi M, Mayas N. Bacteria causing otitis media in some private and public centers in Tamar governorate - Yemen. *Yemeni J Med Sci* 2012; 6: 7–15. [Google Scholar](#)
20. Bin Mohannan MA, Bahannan AA. Bacterial profile and antibiogram of otitis media among children in Yemen. *J Ayub Med Coll Abbottabad* 2016; 28: 480-3. [PubMed](#) • [Google Scholar](#)
21. European Centre for Disease Prevention and Control (ECDC). Antimicrobial resistance surveillance in Europe 2015: Annual Report of the European Antimicrobial Resistance Surveillance Network (EARS-Net). Stockholm: ECDC; 2017.
22. Alrodhan MA, Alziyad N. Assessment the role of Iraqi pharmacists in antimicrobial resistance. *IJRPS* 2018; 9: SPL1. [DOI](#) • [Google Scholar](#)



23. Al-Worafi YMA. Pharmacy practice in Yemen. In: Fathelrahman AI, Ibrahim MIM and Wertheimer AI, editors. Pharmacy practice in developing countries: achievements and challenges. Elsevier; 2016. p. 267–87. [DOI](#) • [Google Scholar](#)
24. US Department of Health and Human Services. Antibiotic resistance threats in the United States, 2013 [update 9 April 2018; [June 18, 2018]Centres for Disease Control and Prevention. 2013 Apr 23. Available from: <https://www.cdc.gov/drugresistance/threat-report-2013/index.html>
25. Laxminarayan R, Duse A, Wattal C, Zaidi AK, Wertheim HF, Sumpradit N, et al. Antibiotic resistance - the need for global solutions. *Lancet Infect Dis* 2013; 13: 1057–98. [PubMed](#) • [DOI](#) • [Google Scholar](#)
26. Durkin MJ, Jafarzadeh SR, Hsueh K, Sallah YH, Munshi KD, Henderson RR, et al. Outpatient antibiotic prescription trends in the United States: a national cohort study. *Infect Control Hosp Epidemiol* 2018; 39: 584–9. [PubMed](#) • [DOI](#) • [Google Scholar](#)
27. Berha AB, Amin D, Alebachew A. Awareness and beliefs of antimicrobial resistance among health professionals working at Tikur Anbessa Specialized Hospital, Addis Ababa: Ethiopia. *J Bioanal Biomed* 2017; 9: 123–9. [DOI](#)
28. Abera B, Kibret M, Mulu W. Knowledge and beliefs on antimicrobial resistance among physicians and nurses in hospitals in Amhara Region, Ethiopia. *BMC Pharmacol Toxicol* 2014; 15: 26. [PubMed](#) • [DOI](#) • [Google Scholar](#)
29. Collignon P, Athukorala PC, Senanayake S, Khan F. Antimicrobial resistance: the major contribution of poor governance and corruption to this growing problem. *PLoS One* 2015; 10: e0116746. [PubMed](#) • [DOI](#) • [Google Scholar](#)
30. Taiwo S, Onile B, Akanbi II A. Methicillin-resistant *Staphylococcus aureus* (MRSA) isolates in Ilorin, Nigeria. *Afr J Clin Exper Microbiol* 2004; 5: 189–97. [DOI](#) • [Google Scholar](#)
31. Weinstein RA. Controlling antimicrobial resistance in hospitals: infection control and use of antibiotics. *Emerg Infect Dis* 2001; 7: 188–92. [PubMed](#) • [DOI](#) • [Google Scholar](#)
32. Cosgrove SE. The relationship between antimicrobial resistance and patient outcomes: mortality, length of hospital stay, and health care costs. *Clin Infect Dis* 2006; 42(Suppl 2): S82–9. [PubMed](#) • [DOI](#) • [Google Scholar](#)
33. Derde LPG, Cooper BS, Goossens H, Malhotra-Kumar S, Willems RJ, Gniadkowski M, et al. Interventions to reduce colonisation and transmission of antimicrobial-resistant bacteria in intensive care units: an interrupted time series study and cluster randomised trial. *Lancet Infect Dis* 2014; 14: 31–9. [PubMed](#) • [DOI](#) • [Google Scholar](#)
34. Johnson AP. Surveillance of antibiotic resistance. *Phil Trans R Soc London B Biol Sci* 2015; 370: 20140080. [PubMed](#) • [DOI](#) • [Google Scholar](#)
35. Esposito S, Leone S. Antimicrobial treatment for Intensive Care Unit (ICU) infections including the role of the infectious disease specialist. *Int J Antimicrob Agents* 2007; 29: 494–500. [PubMed](#) • [DOI](#) • [Google Scholar](#)
36. Zillich AJ, Sutherland JM, Wilson SJ, Diekema DJ, Ernst EJ, Vaughn TE, et al. Antimicrobial use control measures to prevent and control antimicrobial resistance in US hospitals. *Infect Control Hosp Epidemiol* 2006; 27: 1088–95. [PubMed](#) • [DOI](#) • [Google Scholar](#)
37. Salgado CD, O'Grady N, Farr BM. Prevention and control of antimicrobial-resistant infections in intensive care patients. *Crit Care Med* 2005; 33: 2373–82. [PubMed](#) • [DOI](#) • [Google Scholar](#)
38. Bischoff S, Walter T, Gerigk M, Ebert M, Vogelmann R. Empiric antibiotic therapy in urinary tract infection in patients with risk factors for antibiotic resistance in a German emergency department. *BMC Infect Dis* 2018; 18: 56. [PubMed](#) • [DOI](#) • [Google Scholar](#)
39. Ridhorkar R, Nagdeo NV. Knowledge and beliefs on antimicrobial resistance among clinicians: step towards antibiotic stewardship. *J Health Sci* 2018; 8: 4–11. [Google Scholar](#)
40. Mamhidir AG, Lindberg M, Larsson R, Fläckman B, Engström M. Deficient knowledge of multidrug-resistant bacteria and preventive hygiene measures among primary healthcare personnel. *J Adv Nurs* 2011; 67: 756–62. [PubMed](#) • [DOI](#) • [Google Scholar](#)
41. WHO Regional Office for South East Asia/WHO Regional Office for the Western Pacific. Practical Guidelines for Infection Control in Health Care Facilities. Manila/ New Delhi: WHO; 2004.
42. Baur D, Gladstone BP, Burkert F, Carrara E, Foschi F, Döbele S, et al. Effect of antibiotic stewardship on the incidence of infection and colonisation with antibiotic-resistant bacteria and *Clostridium difficile* infection: a systematic review and meta-analysis. *Lancet Infect Dis* 2017; 17: 990–1001 [PubMed](#) • [DOI](#) • [Google Scholar](#)

