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Stethoscope, Hands, and Mobile Phone: Bacterial Contamination and Infection Control among Medical and Nursing Students in Jordan

Stetoskop, El ve Cep Telefonu: Ürdün'deki Tıp ve Hemşirelik Öğrencilerinde Bakteriyel Kontaminasyon ve Enfeksiyon Kontrolü

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Abstract

Introduction: This study aimed to investigate the antibiotic susceptibility of bacterial contamination that is present on stethoscopes, mobile phones, and hands along with the level of self-reported cleaning practices among medical students.
Materials and Methods: Eighty-seven swabs from stethoscopes, mobile phones, and hands were collected from volunteering medical (n=66, 75.8%) and nursing students (n=21, 24.2%) in a hospital environment. The swabs were collected and transported to the microbiology laboratory and cultured on appropriate media. The isolated bacteria were identified as per standard microbiological procedures.
Results: Five bacterial species were isolated and identified. The highest contamination was found on hands (37%), mobile phones (32%), and stethoscopes (31%). Isolates were highly resistant to most tested antibiotics. Only seven (8%) students cleaned their stethoscopes between patients and more alarmingly, 33 (38%) did not clean their stethoscopes at all, and 58 (67%) did not know how to effectively clean their stethoscopes. The current study revealed a gap between the students' knowledge and their proper hygienic practice in hospitals.
Conclusion: The hands are a major source of pathogenic bacteria and have higher bacterial contamination than stethoscopes and mobile phones. It highlights the need for increasing awareness among students and healthcare professionals about the importance of disinfecting medical devices, mobile phones, and hands in hospitals.
Keywords: Medical students, nursing students, stethoscope, mobile phone, hand hygiene, nosocomial infection

Öz

Giriş: Çalışmanın temel amacı, tıp öğrencilerinde stetoskop, cep telefonu ve ellerde bulunan bakteriyel kontaminasyonun antibiyotik duyarlılıkları ile birlikte öğrencilerin kendi bildirdiği temizlik uygulamaları düzeyini araştırmaktır.
Gereç ve Yöntem: Hastane ortamında gönüllü tıp öğrencilerinin (n=66, %75,8) ve hemşirelik öğrencilerinin (n=21, %24,2) stetoskop, cep telefonu ve elinden 87 sürüntü örneği alındı. Sürüntü örnekleri toplanarak mikrobiyoloji laboratuvarına nakledildi ve uygun besiyerlerinde kültüre edildi. İzole edilen bakteriler, standart mikrobiyolojik prosedürlere göre tanımlandı.
Bulgular: Beş bakteri türü izole edildi ve tanımlandı. En yüksek kontaminasyon ellerde (%37) bulundu ve takiben cep telefonlarında (%32) ve stetoskoplarda (%31) bulundu. İzolatlar, test edilen çoğu antibiyotiğe karşı oldukça dirençliydi. Öğrencilerin sadece yedisi (%8) hastalar arasında stetoskoplarını temizlemekteydi ve daha da endişe verici bir şekilde 33'ü (%38) stetoskoplarını hiç temizlemiyordu. Elli sekizi (%67) stetoskoplarını

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etkili bir şekilde nasıl temizleyeceğini bilmiyordu. Mevcut çalışma, öğrencilerin bilgileri ile hastanelerdeki uygun hijyen uygulamaları arasında bir boşluk olduğunu göstermektedir.

Sonuç: Eller, patojenik bakterilerin ana kaynağıdır ve stetoskoplar ve cep telefonlarından daha yüksek bakteriyel kontaminasyona sahiptir. Hastanelerde tıbbi cihazların, cep telefonlarının ve ellerin dezenfekte edilmesinin önemi konusunda öğrenciler ve sağlık çalışanlarında farkındalığın artırılması gerekmektedir.

Anahtar Kelimeler: Tıp öğrencileri, hemşirelik öğrencileri, stetoskop, cep telefonu, el hijyeni, hastane enfeksiyonu

Introduction

Healthcare-associated infections (HCAIs) affect hundreds of millions of individuals worldwide and represent a significant threat to patient safety[1]. Healthcare-associated infections result in increased mortality and morbidity, a greater length of hospital stay, and higher healthcare costs[2]. Studies have indicated that healthcare workers' hands are the main route of cross-transmission[3], and provide convincing evidence that hand hygiene improvement reduces rates of HCAIs[4]. Hand hygiene is the simplest and most cost-effective way to reduce HCAI transmission incidences[3], especially antimicrobial-resistant pathogens[5]. A stethoscope is a medical tool that has been at the core of infection control studies and identified as a potential vector for bacterial infection transmission for over 30 years[6]. Studies from developed countries revealed that a major proportion of healthcare professionals do not maintain the proper hygiene of their stethoscopes, resulting in the transmission of serious pathogenic bacteria, such as methicillin-resistant *Staphylococcus aureus*, vancomycin-resistant *Enterococci*, *Clostridioides difficile*, *Pseudomonas aeruginosa*, and *Klebsiella species*[7].

However, the massive and widespread use of modern technology in medicine and its role in improving healthcare services could represent an additional piece of the complex puzzle of infection control in hospital wards. The methods of infection spread in healthcare facilities have been noted to become more diverse. Using mobile phones as a method of communication and a source of information in our lives is an important example to be considered. Many studies have confirmed that a mobile phone is a reservoir for nosocomial infections, including multidrug-resistant bacteria[8]. A previous study reported that >90% of the cell phones of healthcare workers were contaminated with microorganisms and >14% of them carried pathogenic bacteria that commonly cause nosocomial infections[9]. Pathogenic bacteria were detected with multiple antibiotic resistance (MAR) indices, where hands and mobile phones can act as a carrier for infectious disease transmission[10].

However, little attention has been given to the student's hygienic practice in disinfecting stethoscopes, mobile phones, and hands within the clinical or educational setting. Therefore, we investigated the relationship between the students' hand hygiene, stethoscope, and mobile phone disinfection and the rate of bacterial contamination to improve their understanding of hygiene practices. Additionally, this study aimed to determine the susceptibility to antimicrobials of bacterial isolates and associate the results with self-reported cleaning practices among medical students.

Materials and Methods

Sample Collection

From October to December 2019, a station was established to collect 261 swabs from 87 volunteers medical (n=66, 75.8%) and nursing (n=21, 24.2%) students who participated in the survey at Princess Rahmah Teaching Hospital as per standard aseptic procedures. Princess Rahmah Teaching Hospital is specialized in pediatric medicine and surgery that receives cases from the age of 1 day to 14 years. It is the referral hospital in the northern region of Jordan and is located at Princess Badiaa Hospital campus. Collectively, these two hospitals have a capacity of 400 beds. It is a teaching hospital that trains students of medicine, pharmacy, and nursing in governmental and private colleges and institutes. Additionally, the hospital has an auditorium that is equipped for educational purposes, which can accommodate nearly 100 persons. To the best of our knowledge, no previous studies have been reported in Princess Rahmah Teaching Hospital actual staff knowledge and practice of hygiene during their clinical rounds. No education has been given to the student's hygienic practice in disinfecting stethoscopes, mobile phones, and hands within the clinical or educational setting before they start their clinical ward practice.

The diaphragm of the stethoscope (n=87), the surface of the mobile phone (n=87), and the dominant hand (n=87) of each student were swabbed using a separate sterile cotton swab for each specimen. A self-administered survey was collected along with the samples to evaluate their knowledge. The study participants include medical and nursing students who are undergoing hospital clinical training.

Bacterial Isolation

The swabs were collected in Stuarts transport medium and transported to the lab within 1 hour. Each swab was enriched in 10ml Mueller-Hinton broth (Oxoid, USA) and aerobically incubated at 37 °C for 24 h. After incubation, a loopful was streaked on blood agar and MacConkey agar (Oxoid, USA) and aerobically incubated at 37 °C for 24 h. All media used

in this study were prepared according to the manufacturer's instructions and sterilized by autoclaving at 121 °C for 15 min.

Bacterial Isolate Identification

Every plate was observed after incubation. Colony morphology was examined and recorded based on the size, form, pigmentation, margin, elevation, and opacity. The pure colony of each isolate was picked and identified by cellular characteristics after gram staining. Gram-positive cocci were identified by conventional methods, i.e., catalase, coagulase, esculin hydrolysis in the presence of 40% bile, and susceptibility to novobiocin and bacitracin. Gram-negative cells that are grown on MacConkey agar were identified according to test results for motility, triple sugar iron agar, indole, methyl red, Voges proskauer, and citrate.

Preservation of Isolates

A separate colony from each identified isolate was enriched in 10 ml Mueller-Hinton broth and aerobically incubated at 37 °C. After incubation, the McFarland 2.0 turbidity standard (~$6x10^8$ CFU/ml) was taken as a reference to adjust the turbidity of bacterial suspensions. Then, 700 µl of the cultures were introduced to 300 µl sterile glycerol and kept at -70 °C until further testing.

Antimicrobial Susceptibility Tests

Susceptibility to antimicrobial agents was evaluated using the disk diffusion method, according to the Clinical and Laboratory Standard Institute (CLSI, 2016) guidelines. The following antimicrobials were tested: ciprofloxacin (5 µg), ampicillin (10 µg), norfloxacin (10 µg), erythromycin (15 µg), chloramphenicol (30 µg), gentamicin (10 µg), tetracycline (30 µg), vancomycin (30 µg), amoxicillin/clavulanic acid (20/10 µg), cefepime (30 µg), penicillin (10 µg), clindamycin (2 µg), trimethoprim-sulfamethoxazole (1.25/23.75 µg), and oxacillin (1 µg). Briefly, few colonies of the isolate to be tested were suspended in saline to density visually equivalent to that of "0.5 McFarland standards. A swab of the cell suspension was then spread in three directions on the entire surface of a Mueller Hinton Agar plate, and antibiotic disks were applied onto the agar. The agar plates were then incubated at 35 °C for 18-24 h. *S. aureus* (ATCC25923) was bought lyophilized from a local supplier and used as a control. Multidrug resistance (MDR) bacteria were considered when an isolate was resistant to 3 of the used antimicrobials in this study[11].

Statistical Analysis

The self-administered survey was analyzed using an Excel program that shows the descriptive values of responses regarding knowledge about cleaning the stethoscope, mobile phone, and hand. Data were summarized as frequencies and proportions and were compared using the chi-square test. Logistic regression models were fitted to identify the associated factors with a poor score (a score <1). All tests were two-sided, and statistical significance was considered at a p value of <0.05. The data entry and statistical analysis were performed using the Statistical Package for the Social Sciences (SPSS) (IBM SPSS Corp, SPSS Statistics ver. 25, USA).

Results

This study included 87 medical (66, 76%) and nursing (21, 24%) students. Demographic characteristics were divided as follows: 35 males (40%) and 52 females (60%) aged between 20-24 years. Only seven (8%) students cleaned their stethoscopes after every patient, whereas 33 (38%) did not. The remaining students showed a variable frequency of cleaning their stethoscopes (Table 1).

Alcohol was the most popular method of cleaning the stethoscopes in 30 (34%) students, followed by alcohol-free wet wipes 17 (20%). Surprisingly, 26 (30%) students did not use anything to clean their stethoscopes (Table 1). The stethoscopes were considered an infection hazard in 68 students (78.2%) and 67 (77%) stated the importance to have their stethoscopes always clean; however, 58 (67%) did not know how to effectively clean their stethoscopes and 11 (13%) stated that they saw others cleaning their stethoscopes. Remarkably, 51 students (59%) agreed to have enough time to clean their stethoscopes, whereas 36 (41%) agreed that cleaning equipment was available in the hospitals. Of the students, 80 (92%) students acknowledged that they did not have this experience in lectures at the university or any training online about cleaning their stethoscopes (Table 2). Most students (78%) washed their hands after the patient encounter. Most of the students (86%) used

Table 1. Cleaning stethoscopes frequency and method used by the students

How frequently do you clean your stethoscope?	
Frequency	**No (%)**
After every patient	7 (8.0)
More than once daily	2 (2.3)
Once daily	13 (14.9)
Once weekly	24 (27.6)
Once monthly	8 (9.3)
Never	33 (37.9)
Methods for cleaning stethoscope	
Method	**No (%)**
Nothing	26 (30.0)
Water	3 (3.5)
Hygiene or wet wipes	17 (19.5)
Alcohol	30 (34.4)
Dry cotton or fine or tissue	11 (12.6)

Table 2. Cross-tabulation analysis of the differences in attitudes between nursing and medical students

Variable	Specialty		p value
	Nursing (%)	Medical (%)	
I am confident that I know how to properly clean my stethoscope			**0.010**
Disagree	2 (9.5)	27 (40.9)	
Neutral	4 (19.0)	15 (22.7)	
Agree	15 (71.5)	24 (36.4)	
My cleaning equipment is readily available			**0.005**
Disagree	3 (14.3)	29 (43.9)	
Neutral	3 (14.3)	16 (24.2)	
Agree	15 (71.4)	21 (31.9)	
I regularly see others cleaning their stethoscopes			**0.001**
Disagree	10 (47.6)	57 (87.7)	
Neutral	3 (14.3)	5 (7.7)	
Agree	8 (38.1)	3 (4.6)	
I must make sure my stethoscope is clean			**0.033**
Disagree	5 (23.8)	5 (7.6)	
Neutral	0 (0.0)	10 (15.2)	
Agree	16 (76.2)	51 (77.3)	
Before completing this survey I had considered stethoscopes as an infection hazard			**0.460**
Disagree	4 (19.0)	6 (9.1)	
Neutral	2 (9.5)	7 (10.6)	
Agree	15 (71.4)	53 (80.3)	

their mobile phones during clinical rotations with only 29% of them cleaning them after the rotations (Table 2).

A cross-tabulation analysis was performed to assess the difference in attitudes between nursing and medical students and revealed significant statistical differences as shown in Table 2. Approximately, 72% of nursing students perceived being confident in knowing how to properly clean their stethoscopes compared to 36% of medical students (p value=0.010). Furthermore, approximately 71% of nursing students reported that cleaning equipment was readily available compared to 32% of medical students (p value=0.001).

Another cross-tabulation analysis was performed to assess the difference in practice and bacterial isolates from participants' stethoscopes. Interestingly, 57% of nursing students perceived knowing how to effectively clean their stethoscopes compared to approximately 26% among medical students (p value=0.008). The percentage of nursing students who have attended lectures or training sessions on how to clean stethoscopes was more than that for medical students (p value=0.33). Concerning the type of bacterial isolates, approximately 36% of medical students clean their stethoscopes (no bacterial species) compared to only approximately 5% of nursing students (p value=0.021). These results are illustrated in Table 3.

Bacterial species were isolated from 62 (71%) of the 87 tested students. A total of 131 bacterial isolates were identified and tested for their antibiotic susceptibility, and 87 mobile phones, 87 stethoscopes, and 87 dominant hands of medical and nursing students were tested. Of these, 42 (32%) mobile phones [42 bacterial isolates recovered from 87 mobile phones of students were coagulase-negative *Staphylococcus* (CoNS) (28%), followed by *S. aureus* (13%) and *E. coli* (1%)], 40 (31%) stethoscopes [40 bacterial isolates were CoNS (31%), *S. aureus* (8%) and *P. mirabilis* (1%)], and 49 (37%) dominant hands [49 bacterial isolates were CoNS (40%), *S. aureus* (8%) and *K. pneumoniae* (1%)] showed contamination with one or more types of microorganisms (Table 4). Twenty-nine *S. aureus* isolates (mobile phones 13, stethoscopes 8, and hands 8) showed a high rate of resistance to penicillin (26; 90%), ampicillin (26; 90%), methicillin (27; 93%), and erythromycin (18; 62%) (Table 4). Two *S. aureus* isolates were resistant to 8 of the 14 antibiotics tested. One of them was from a mobile phone and was resistant to methicillin, erythromycin, ciprofloxacin, norfloxacin, trimethoprim/sulphamethoxazole, tetracycline, penicillin, and ampicillin, whereas the other one was from a stethoscope and was resistant to methicillin, oxacillin, erythromycin, amoxicillin/clavulanic acid, vancomycin, cefepime, penicillin, and ampicillin. Five (17.2%) isolates were resistant to 7 out of 14 antibiotics, three of them were resistant to 7 out of 14 antibiotics: one

Table 3. Cross-tabulation analysis of the differences in practice and bacterial isolates from the stethoscope of nursing and medical students

Variable	Specialty		p value
	Nursing (%)	Medical (%)	
Do you wash your hands after you examine patients?			**0.391**
No	6 (28.6)	13 (19.7)	
Yes	15 (71.4)	53 (80.3)	
Do you know how to clean your stethoscope effectively?			**0.008**
No	9 (42.9)	49 (74.2)	
Yes	12 (57.1)	17 (25.8)	
Did you attend any lecture or training session about how to clean your stethoscope?			**0.033**
No	17 (81.0)	63 (92.0)	
Yes	4 (19.0)	3 (8.0)	
Do you use your mobile phone during rotations?			**0.940**
No	3 (14.3)	9 (13.6)	
Yes	18 (85.7)	57 (86.4)	
Do you clean your mobile phone after using it while in your rotations?			**0.593**
No	14 (66.7)	48 (72.7)	
Yes	7 (33.3)	18 (27.3)	
Type of isolate			**0.021**
None	1 (4.8)	24 (36.4)	
Gram (-)	0 (0.0)	0 (0.0)	
Gram (+)	19 (90.4)	40 (60.6)	
Both Gram (+) and Gram (-)	1 (4.8)	2 (3.0)	

from the hands and was resistant to methicillin, oxacillin, erythromycin, tetracycline, chloramphenicol, penicillin, and ampicillin; one from the phone and was resistant to methicillin, oxacillin, erythromycin, trimethoprim/sulphamethoxazole, cefepime, penicillin, and ampicillin; and one from the stethoscope and was resistant to methicillin, erythromycin, amoxicillin/clavulanic acid, trimethoprim/sulphamethoxazole, cefepime, penicillin, and ampicillin.

As shown in Table 5, isolates that are resistant to three out of 14 antibiotics in at least 25 (86%) isolates. Interestingly, four (50%) hand isolates showed resistance to at least six antibiotics, five (40%) phone isolates to at least five antibiotics, whereas three (38%) stethoscope isolates to at least five antibiotics out of 14. One isolate of the hand was resistant to ciprofloxacin antibiotic and two for trimethoprim/sulphamethoxazole. The antibiotics, which were effective against all stethoscope isolates include chloramphenicol, tetracycline, vancomycin, norfloxacin, and ciprofloxacin. The antibiotics that were effective against all mobile phone isolates include tetracycline, ciprofloxacin, and gentamicin. Contrarily, penicillin and ampicillin were not effective at all for all mobile phone isolates. The antibiotics that were effective against all hand isolates include vancomycin and gentamicin only. All hand and stethoscope isolates were resistant to methicillin. Only four antibiotics, gentamicin, vancomycin, ciprofloxacin, and norfloxacin, out of the 14 used antibiotics appeared to be effective against 28 (97%) isolates

Table 4. The distribution of the isolated bacteria from stethoscope, phone, and hands

		Stethoscope	Phone	Hand	Total
Gram-positive	*S. aureus*	8	13	8	29 (22.1%)
	CoNS	31	28	40	99 (75.6%)
Gram-negative	*E. coli*	0	1	0	3 (2.3%)
	Klebsiella	0	0	1	
	Proteus	1	0	0	
	Total	40 (30.5%)	42 (32.1%)	49 (37.4%)	131 (100%)

CoNS: Coagulase negative staphylococcus, *S. aureus: Staphylococcus aureus*

Table 5. Antimicrobial susceptibility of the isolated *S. aureus* and coagulase-negative *Staphylococcus* bacteria to 14 antimicrobials

Antibiotics	*S. aureus* (n=29)											
	Stethoscope (n=8)			Phone (n=13)			Hand (n=8)			Total (n=29)		
	S	R	I	S	R	I	S	R	I	S	R	I
P	1	7	0	0	13	0	2	6	0	3	26	0
AMP	1	7	0	0	13	0	2	6	0	3	26	0
C	8	0	0	11	2	0	6	2	0	25	4	0
T	8	0	0	13	0	0	4	4	0	25	4	0
FEP	7	1	0	11	2	0	6	0	2	25	2	2
VA	8	0	0	12	1	0	8	0	0	28	1	0
SXT	7	1	0	12	1	0	6	2	0	25	4	0
NOR	8	0	0	12	0	1	7	1	0	27	1	1
AMC	7	1	0	10	3	0	6	2	0	23	6	0
CIP	8	0	0	13	0	0	6	1	1	27	1	1
CN	7	1	0	13	0	0	8	0	0	28	1	0
E	1	7	0	7	6	0	3	5	0	11	18	0
OX	7	1	0	8	4	1	6	1	1	21	6	2
ME	0	8	0	0	11	2	0	8	0	0	27	2
Antibiotics	CoNS (n=99)											
	Stethoscope (n=31)			Phone (n=28)			Hand (n=40)			Total (n=99)		
	S	R	I	S	R	I	S	R	I	S	R	I
P	5	26	0	7	21	0	6	34	0	18	81	0
AMP	4	27	0	7	21	0	3	37	0	14	85	0
C	31	0	0	25	3	0	40	0	0	96	3	0
T	27	4	0	26	2	0	34	6	0	87	12	0
FEP	27	2	2	24	2	2	35	3	2	86	7	6
VA	30	1	0	28	0	0	37	3	0	95	4	0
SXT	20	10	1	26	0	2	30	8	2	76	18	5
NOR	28	2	1	27	1	0	38	1	1	94	4	1
AMC	25	6	0	25	3	0	34	6	0	84	15	0
CIP	24	3	4	27	1	0	38	1	1	89	5	5
CN	29	1	1	26	1	1	37	2	1	92	4	3
E	6	24	1	12	15	1	8	27	5	26	66	7
OX	17	14	0	17	11	0	19	20	1	53	45	1
ME	0	27	4	0	24	4	0	33	7	0	84	15

CoNS: Coagulase-negative staphylococcus, *S. aureus: Staphylococcus aureus*, P: Penicillin, AMP: Ampicillin, C: Chloramphenicol, T: Tetracycline, FEP: Cefepime, VA: Vancomycin, SXT: Trimethoprim/sulphamethoxazole, NOR: norfloxacin, AMC: Amoxicillin/clavulanic acid, CIP: ciprofloxacin, CN: Gentamicin, E: Erythromycin, OX: Oxacillin, ME: Methicillin

Table 6. The distribution of isolated bacteria on the stethoscope, mobile phone, and hands

	CoNS	Percent (%)	*S. aureus*	Percent (%)
Stethoscope	31	31.3%	8	27.5%
Phone	28	28.3%	13	45%
Hand	40	40.4%	8	27.5%
Total	99	100%	29	100%

CoNS: Coagulase-negative staphylococcus

Table 7. Multiple antimicrobial-resistant (MAR index) of the isolated bacteria to the tested antibiotics (n=14)

Bacterial species	Parameter		Frequency	MAR index
	No.	Type		R/S
CoNS	R1	ME	6	0.0714
		E	1	0.0714
	R2	ME, E	2	0.1429
		E,T	1	0.1429
		ME,AMP	2	0.1429
		E,FEP	1	0.1429
		P,AMP	1	0.1429
		ME,E	1	0.1429
	R3	ME,P,AMP	12	0.2143
		ME,E,AMP	1	0.2143
		E,P,AMP	4	0.2143
	R4	ME,CIP,SXT,AMP	1	0.2857
		ME,E,P,AMP	16	0.2857
		ME,OX,P,AMP	4	0.2857
		OX,E,P,AMP	1	0.2857
		E,CN,P,AMP	1	0.2857
		ME,SXT,P,AMP	1	0.2857
		E,SXT,P,AMP	1	0.2857
		E,T,P,AMP	1	0.2857
		E,C,P,AMP	1	0.2857
	R5	ME,OX,E,P,AMP	13	0.3571
		ME,E,AMC,P,AMP	1	0.3571
		ME,E,SXT,P,AMP	1	0.3571
		ME,OX,AMC,P,AMP	1	0.3571
		ME,OX,SXT,P,AMP	1	0.3571
		ME,E,SXT,P,AMP	1	0.3571
		ME,E,FEP,P,AMP	1	0.3571
		ME,E,T,P,AMP	1	0.3571
		ME,OX,C,P,AMP	1	0.3571
		ME,AMC,C,P,AMP	1	0.3571
		ME,E,CN,P,AMP	1	0.3571
	R6	ME,OX,E,AMC,P,AMP	1	0.4286
		ME,OX,E,SXT,P,AMP	3	0.4286
		ME,OX,E,VA,P,AMP	1	0.4286
		ME,OX,E,AMC,P,AMP	1	0.4286
		ME,OX,E,T,P,AMP	1	0.4286

Table 7. Continued

		ME,OX,E,SXT,P,AMP	2	0.4286
		ME,OX,AMC,FEP,P,AMP	1	0.4286
		ME,OX,E,VA,P,AMP	1	0.4286
		ME,OX,E,T,P,AMP	2	0.4286
		ME,OX,AMC,C,P,AMP	1	0.4286
		ME,E,T,C,P,AMP	1	0.4286
	R7	ME,OX,E,AMC,SXT,P,AMP	1	0.5000
		ME,OX,E,SXT,T,P,AMP	1	0.5000
		ME,OX,E,AMC,SXT,P,AMP	1	0.5000
		ME,OX,AMC,VA,FEP,P,AMP	1	0.5000
		ME,OX,E,AMC,T,P,AMP	1	0.5000
		ME,OX,E,VA,T,P,AMP	1	0.5000
		ME,OX,E,SXT,FEP,P,AMP	1	0.5000
		ME,E,AMC,SXT,FEP,P,APM	1	0.5000
	R8	ME,OX,E,AMC,SXT,T,P,AMP	2	0.5714
		ME,OX,E,XIP,NOR,SXT,P,AMP	1	0.5714
		ME,OX,E,AMC,VA,FEP,P,AMP	1	0.5714
	R10	ME,OX,E,CN,CIP,AMC,NOR,FEP,P,AMP	2	0.7143
	R11	ME,OX,E,CN,CIP,AMC,NOR,SXT,FEP,P,AMP	1	0.7857
S. aureus	R2	ME,E	1	0.1429
	R3	ME,P,AMP	3	0.2143
	R4	ME,AMC,P,AMP	2	0.2857
		ME,C,P,AMP	1	0.2857
	R5	ME,OX,E,P,AMP	1	0.3571
	R6	ME,E,SXT,T,P,AMP	1	0.4286
		ME,E,AMC,T,P,AMP	1	0.4286
	R7	ME,OX,E,T,C,P,AMP	1	0.5000
	R8	ME,E,CIP,NOR,SXT,T,P,AMP	1	0.5714

CoNS: Coagulase-negative staphylococcus, *S. aureus: Staphylococcus aureus*, P: Penicillin, AMP: Ampicillin, C: Chloramphenicol, T: Tetracycline, FEP: Cefepime, VA: Vancomycin, SXT: Trimethoprim/sulphamethoxazole, NOR: norfloxacin, AMC: Amoxicillin/clavulanic acid, CIP: ciprofloxacin, CN: Gentamicin, E: Erythromycin, OX: Oxacillin, ME: Methicillin

out of 29 isolates. None was effective against all the isolated 29 samples. Ten samples (35%) of *S. aureus* showed MDR according to the Centers for Disease Control and Prevention (CDC) MDR definition. In total, 13 samples (45%) of hospital-acquired MRSA were isolated according to Klevens et al. (2006)[12].

CoNS bacteria were isolated from 99 samples including 31 (31.3%) isolates from stethoscopes, 28 (28.3%) isolates from mobile phones, and 40 (40.4%) isolates from hands as shown in Table 6. The hands and stethoscopes were highly contaminated, forming 72% of the total samples. CoNS expressed high resistance to penicillin, ampicillin, methicillin, and erythromycin. MDR bacteria, according to the CDC definition, were 27 (27%) isolates divided as the following: 12 (44%) isolates from stethoscopes, 10 (37%) from the hands, and 5 (19%) from mobile phones.

Of the 10 stethoscope samples with MDR bacteria, 6 (12%) are resistant to at least 7 of the 14 antibiotics used. Chloramphenicol, gentamicin, vancomycin, and norfloxacin were highly effective against at least 92 (93%) isolates. Chloramphenicol appeared to be most effective with only 3 isolates showing resistance,

while vancomycin, norfloxacin, and gentamicin had only 4 isolates showing resistance from all isolated samples. Interestingly, 9 isolates were resistant to norfloxacin and ciprofloxacin antibiotics. None of the antibiotics used were effective against all isolates. Stethoscope samples showed a variable resistance profile. All stethoscopes and hand samples were sensitive to chloramphenicol. Additionally, one of the stethoscope isolates along with one of the mobile phone isolates was found to be resistant to 10 antibiotics including methicillin, oxacillin, erythromycin, gentamicin, ciprofloxacin, amoxicillin/clavulanic acid, norfloxacin, cefepime, penicillin, and ampicillin. Three stethoscope samples showed resistance to 8 antibiotics. In other stethoscope samples, vancomycin and gentamicin were effective against 30 (97%), while norfloxacin and cefepime antibiotics showed sensitivity in 29 (94%) isolates. All mobile phone samples showed sensitivity to vancomycin and trimethoprim/sulphamethoxazole. One of the hand isolates was resistant to 11 antibiotics, including methicillin, oxacillin, erythromycin, gentamicin, ciprofloxacin, amoxicillin/clavulanic acid, norfloxacin, trimethoprim/sulphamethoxazole, cefepime, penicillin, and ampicillin.

The MAR indexes of the isolated resistant bacteria were determined concerning 14 different antibiotics used in this study. The values of MAR indexes are shown in Table 7. The analysis of the MAR index of isolates revealed that most of the above-mentioned resistant bacteria, 0.2 ratios indicated the nature of high resistance of these isolates.

Discussion

The results regarding the frequency of cleaning stethoscopes in a single hospital setting in Jordan were slightly higher than those noted in other countries[13], with the most frequently used method for cleaning stethoscopes being alcohol (34%). The CDC recommends cleaning the stethoscopes with 70% alcohol after seeing each patient[14]. Interestingly, Genné et al. (1996)[15] showed that after >1 day without cleaning the stethoscope, the contamination level rose from 0% to 69%, leading to the recommendation by Saloojee and Steenhoff 2001[16] to clean stethoscopes with alcohol at least once daily. The majority of students and healthcare workers are aware of the role of stethoscopes in the transmission of infectious organisms from one patient to another[17]. Similarly, 78.2% of our students considered the stethoscope as a risk for infection transmission.

The current study revealed that 13% of students said that they saw others clean their stethoscope, which compares with 8.1% of Serbian 4th and 6th-year medical students[17] and in only 1.3% of the United Kingdom medical students[13]. Of the students, 67% are unaware of how to effectively clean their stethoscope, which is with a complete agreement with Jayarajah et al. in 2019[18] who revealed that the majority of South Asian students did not know the proper way or the recommendations for equipment hygiene. Additionally, only 8% of medical students had attended lectures or training on stethoscope cleaning, which is approximately similar to the finding of Gazibara et al.[17] in 2015 (8.5%), but more than that of Saunders et al.'s[13] findings (2.9%). Therefore, increasing the number of lectures on stethoscope hygiene is recommended, which is very effective and inexpensive, to improve stethoscope cleaning compliance among students[19]. Of the students, 78% washed their hands after a patient encounter, which is consistent with other observations that hand hygiene was good among students (69.2-78%) who had a moderate knowledge of hand hygiene practices that improved with the progression of training[16]. Studies show that hand washing is the simplest and most effective method to reduce contamination[20]. Currently, mobile phones are considered as a potential carrier of pathogenic bacteria[21]; however, 86% of the students still used their mobile phones during rotations, and only 29% clean them after rotations. CoNS belong to Staphylococci genera and are part of the human normal flora, mainly inhabiting the skin; however, they can colonize the upper respiratory tract, the gastrointestinal tract, the genitourinary tract, and mammary glands leading to serious infections associated with healthcare facilities and the community[22].

This study revealed that the majority of the isolates [99 (76%)] were identified as CoNS followed by *Staphylococcus aureus* [29 (22%)]. Isolation rates were 31.3% CoNS and 27.5% *S. aureus* from stethoscopes, 28.3% CoNS and 45% *S. aureus* from mobile phones, and 40.4% CoNS and 27.5% *S. aureus* from hands.

A study by Senthil et al. in 2017[23] revealed the isolation rate of CoNS and *S. aureus* from students' hands as 32% and 68%, respectively. A study of students' mobile phones produced almost the opposite results as regards bacterial species[21]. Regarding the stethoscopes, a study from Spain that was conducted by clinicians and nurses showed that CoNS was isolated from the diaphragms at a rate of 97% and *S. aureus* at a rate of 5%[24]. Another study on students' stethoscopes in the UK gave an isolation rate of 89% for CoNS and 12% for *S. aureus*[25]. In Greece, the isolation rate of CoNS from physicians' stethoscopes was 96.6% and that of S. aureus was 6.8%[26].

The vast majority of isolated CoNS in this study were resistant to penicillin, ampicillin, and methicillin, which is a common finding in other studies[27]. A study from Ethiopia revealed an approximately 65% of the isolated CoNS were resistant to penicillin[28]. However, a study in Greece showed that approximately 12% of the isolated CoNS were resistant to methicillin[26].

The isolation rate and antimicrobial resistance profile of CoNS are quite alarming since those isolates have more adoption

towards hospital settings, are more persistent, and can spread within and between hospitals[29]. Moreover, CoNS are identified in 33-60% of culture isolates obtained from neonates who suffered HCAIs, although no neonatal deaths were linked to CoNS; however, neonates had comorbidities, mainly congenital heart diseases[30].

Thirteen *S. aureus* isolates were considered MRSA according to their antimicrobial resistance profile. *S. aureus* is considered the leading cause of nosocomial infections, primarily causing lower respiratory tract infections, surgical site infections, pneumonia, and cardiovascular infections[31], and is the second leading cause of nosocomial bacteremia[32]. Infections with *S. aureus* are especially hard to treat due to the acquired resistance to antimicrobials. Resistance to penicillin and other narrow-spectrum β-lactamase-resistant antimicrobials, such as methicillin and oxacillin, appeared shortly after their introduction into the clinical practice[33].

The increased incidence of MRSA in hospitals is likely to increase the demand for vancomycin. Trimethoprim-sulfamethoxazole is available for MRSA treatment; however, vancomycin is still the drug of choice[34]. This pattern will complicate future control of MRSA, as resistance to vancomycin is already emerging[35]. The use of vancomycin should be restricted in MRSA infections when no other drug is effective to solve this issue[36].

The cleaning process, when correctly done, should dramatically reduce the contamination levels. When swabs were taken from 10 stethoscopes before and after the cleaning process, cultures revealed a significant drop of colony-forming units from an average of 27 to 1. Moreover, hand washing has been long shown to be the leading practice to limit the spread of HCAIs[37].

The MAR indexes of the isolated resistant bacteria were determined concerning 14 different used antibiotics in this study. The values of MAR indexes are shown in Table 6. The analysis of the MAR index of isolates showed that 97 of the total 99 CONS and 11 of 29 *S. aureus* had MAR of >0.2, indicating high resistance of these isolates. High resistance in the current study may suggest that isolates originated from highly resistant sources where antibiotics are often used without a physician's prescription. Healthcare professionals who misuse antibiotics by following non-standardized practices could be another major factor[38].

The major limitations of our study were the low number of students attending the training at the hospital due to the strict regulations applied after the coronavirus disease-2019 pandemic, as well as the lack of financial support.

Conclusion

The current study revealed a gap between the students' knowledge and their proper hygienic practice in the hospitals. Poor hand hygiene, which is routinely discussed in lectures, appeared to be a major source of infection transmission. Medical and nursing students should always be aware of the new methods of bacterial transmission and infection control; however, a high percentage of them stated that they did not have any idea about the importance of disinfecting their stethoscopes and mobile phones. The present study provides evidence that the hands are the major source of pathogenic bacteria and have higher bacterial contamination than stethoscopes and mobile phones. It highlights the need for increasing awareness among students and healthcare professionals about the importance of disinfecting medical devices, mobile phones, and hands in hospitals.

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Ethics

Ethics Committee Approval: The study protocol was approved by the Institutional Ethics Council at Yarmouk University under the number (IRB/2021/13).

Informed Consent: Consent form was filled out by all participants.

Peer-review: Externally and internally peer-reviewed.

Authorship Contributions

Concept: W.Al.M., Design: W.Al.M., L.A.-I., Data Collection or Processing: A.K., D.A.I., M.K., Analysis or Interpretation: N.B., L.A.-I., A.K., I.M., Literature Search: L.A.-I., A.K., D.A.I., M.K., Writing: N.B., W.Al.M., I.M., M.S.

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