Original article

Bacterial contamination and antibiogram of isolates from health care workers' fomites at Felege Hiwot Referral Hospital, northwest Ethiopia

Workneh Ayalew[1], Wondemagegn Mulu[2]*, Fantahun Biadglegne[3]

Abstract

Background: Health care workers' fomites are highly predisposed to bacterial contamination in the health care setting and are potential sources of hospital-acquired infections. However, there is scarcity of data on the status of bacterial contamination and antibiogram of isolates from HCWs' fomites in Ethiopia. This study determined the bacterial contamination and antibiogram of isolates from health care workers' fomites at Felege Hiwot Referral Hospital, Ethiopia.

Methods: A cross-sectional study was conducted from February to April 2017 in different wards of the hospital. From 422 health care workers' fomites, surface samples were swabbed using a simple-rinse method. Data from participants were collected by face-to-face interviews using a structured questionnaire. Bacterial colonies were counted and species were identified using standard bacteriological techniques. Drug susceptibility testing was performed using a disk diffusion technique. Chi-square test was computed to ascertain the association between variables. Regression analysis was computed to identify the independent risk factors.

Results: Overall, 243 (57.6%) fomites were contaminated with aerobic bacteria. Working in medical (AOR=5.2, 95% CI=1.85-14.8) and gynecology (AOR=3.1, 95% CI=1.5-6.43) wards and intensive care units (AOR=16, 95% CI=2.1-17.9), and poor laundering of HCWs' uniforms (AOR=1.3, 95% CI=1.34-3.72), were significantly associated with bacterial contamination. *Staphylococcus aureus* (19.2%) was the predominant pathogen, followed by *Klebsiella pneumoniae* (6.4%). The proportion of *K. pneumoniae* (P<0.001) and *E. coli* (P=0.014) was significantly highest in mobile phones and white coats, respectively. *S. aureus* isolates were resistant to penicillin (82.7%) and co-trimoxazole (53.1%). *K. pneumoniae* isolates were 100% resistant to ampicillin. *E. coli* isolates were 87.5% resistant to co-trimoxazole. Overall, 204 (88.3%) of the isolates were multidrug-resistant. The overall multidrug-resistant rates among *S. aureus, K. pneumoniae* and *E. coli* isolates were 88.9%, 92.6% and 100%, respectively.

Conclusions: Bacterial contamination of health care workers' fomites is a major health care problem in the study area. Multidrug-resistant isolates are alarmingly high in pathogenic bacteria. Therefore, hospital HCWs need to implement proper handling of fomites to reduce contamination and the spread of drug-resistant pathogens. [*Ethiop.J. Health Dev.* 2019; 33(2):128-141]

Keywords: Health care workers, bacterial contamination, antibiogram, fomites, health-care associate infections, Ethiopia

Background

Health care-associated infections (HAIs) are a significant burden both for the patient and for public health (1,2). They are major causes of death, increased morbidity and length of stay among hospitalized patients (1-3). The hospital environment is a major factor that contributes towards the development of HAIs (4-6).

Health care workers' (HCWs) contaminated hands and their movement from patient to patient, improper equipment sterilization and the emergence of resistant strains of bacteria are all reasons for the spread of HAIs (5,7). Hospital pathogens are transmitted via surfaces in the working environment su environmental surfaces and inanimate objects (5,6). Objects with frequent hand contact can serve as reservoirs from which infections can spread to the hands of HCWs and then to patients. Such inanimate objects of HCWs that become contaminated with pathogenic bacteria and then spread the infection to others are often referred to as fomites (5,9). Of these, stethoscopes, mobile phones and white coats are highly contaminated with hospital pathogens. HCWs' fomites are contaminated directly from HCWs' hands, patient shedding, settlement of airborne bacteria, and other solid objects (5,10).

Surgical site, urinary tract, respiratory tract and blood stream infections are the most common HAIs from HCWs' fomites (6,9,11). *Staphylococcus aureus*, *Escherichia coli*, *Klebsiella pneumoniae, Proteus* spp. and *Pseudomonas aeruginosa* are the most frequent isolates from HCWs' stethoscopes, mobile phones and white coats (9-12).

Mobile phones are commonly used in by HCWs in the hospital setting, not only for communication, but also for internet browsing, the calculation of infusion doses and electrolyte corrections (13). Mobile phones serve as a perfect habitat for microbes to breed (14,15). Although the stethoscope is one of the crucial items of medical equipment in hospital settings, it is highly prone to bacterial contamination from patients, environments and HCWs themselves (16).

[1]Amhara National Regional State Health Bureau, Felegehiwot referral Hospital, Medical Microbiology Department. Email: workneh_ayalew@yahoo.com
[2*]Department of Medical Microbiology, Immunology and Parasitology, College of Medicine and Health Sciences, Bahir Dar University, Ethiopia. Email: wondem_32@yahoo.com
[3] Email: fantahun.degeneh@gmail.com

HCWs wear their white coats during procedures, patient-care activities, in non-clinical rooms, libraries, cafeterias, and resting areas of their working environments (16). However, they have been shown to harbor potential nosocomial pathogens (17).

Previous similar studies in other parts of Ethiopia reported high rates of bacterial contamination on HCWs' fomites. Studies in Jimma, Gondar and Hawassa (12,15,18) reported rates of 71.2% to 98% of bacterial contamination on mobile phones. Another study in Jimma reported bacterial contamination of 85.5% on stethoscopes (16).

Previous studies in other countries confirmed that HCWs' fomites are major reservoirs of multidrug-resistant (MDR) *E. coli*, *K. pneumoniae* and *S. aureus*, and are major means of spreading, selection and subsequent development of drug-resistant species (11,19-21).

Despite continuing efforts of hospital infection containment, HAIs are still a major public health problem globally. There is a lack of surveillance, control of infection and monitoring of hygiene practices. The degree of strict adherence to hand washing, disinfection of objects and following aseptic procedures while using medical devices and attires varies with the clinical setting, from ward to ward and from health professional to health professional, resulting in a varied load of contamination of fomites from hospital to hospital and among HCWs. However, the contributions of HCWs fomites in the spread of drug-resistant bacteria isolates were not addressed in the study area. This study aimed at assessing the status of bacterial contamination of HCWs' fomites and antibiogram of the isolates at Felege Hiwot Referral Hospital (FHRH), Ethiopia. Specifically, this study determined the proportion of bacterial contamination in HCWs' fomites, identified the bacterial species, and determined their resistance profile to commonly prescribed drugs.

Methods

Study design and setting: A cross-sectional study was conducted from February to April 2017 at Felege Hiwot Referral Hospital (FHRH), which is located in Bahir Dar Town. FHRH is one of the highest patient-loaded governmental hospitals in Ethiopia, with more than 430 beds. It provides health care services for 690 patients per day. The hospital consists of an operation room, intensive care units, different wards, outpatient departments, and laboratory and pharmacy units. Currently, FHRH has medical doctors (107), nurses (174), midwives (30), pharmacists (37), medical laboratory professionals (43) and medical intern students (120) (22). The study population was health care professionals working in different wards at FHRH.

Sample size and sampling: The sample size for HCWs was determined using Epi info version 3.5.1 (public domain software, www.cdc.gov) by considering 95% confidence level and 5% degree of precision. The maximum proportion of HCWs' fomites assumed to be contaminated was 50%. The calculated sample size was 384. Considering a 10% (38) non-response rate, the total sample size (HCWs' fomites) was 422.

The sample size was allocated to different HCWs proportional to their total number. Study participants from each type of HCW were included by simple random sampling technique. Swabs – from either stethoscopes, white coats or mobile phones – were collected from medical doctors and intern students, while swabs from either white coats or mobile phones were collected from other HCWs.

Inclusion and exclusion criteria: The stethoscopes, mobile phones and white coats of medical doctors, anesthetists and medical intern students; and mobile phones and white coats of nurses, midwives, medical laboratory and pharmacy professionals working at FHRH were included. However, fomites from physiotherapists, radiologists, dermatologists, psychiatrists, dentists, ophthalmologists, department heads and matrons were excluded.

Variables: Bacterial contamination of fomites was the dependent variable, while demographic characteristics, qualifications, field of specialization, number of service years, hand washing and disinfection practices of HCWs were the independent variables.

Data collection: Demographic and other data related to HCWs' fomite bacterial contamination were collected via face-to-face interviews using a structured questionnaire. Moreover, hand hygiene practices of HCWs were collected by observation using standard checklists.

Sample collection and processing: A total of 422 HCWs' fomites samples were swabbed aseptically from stethoscopes, mobile phones and coats via moist sterile cotton swabs using a simple-rinse method. Swabs from the cuffs and pocket mouths of the dominant hand and the abdominal region of white coats were collected using sterile saline-dipped cotton swabs. The entire surface of the diaphragm and ear pieces of each stethoscope and the screen and reverse sides of mobile phones were swabbed with a sterile swab moistened in sterile saline. The collected samples were inserted into 1ml of tryptic soy broth (TSB) (23) and transported to FHRH microbiology laboratory within 15 minutes and diluted with 9ml of sterile saline.

Mesophilic colony counting: One ml of the diluted sample was aseptically inoculated to 5% sheep blood agar plates using the pour plate method. All inoculated media were incubated at 37ºC for 18 to 24 hours. After overnight incubation, aerobic mesophilic bacterial count was determined by taking discrete bacterial colonies using a colony counter. Bacterial loads were determined by dividing the total colony forming unit by that of the total area sampled. A colony count greater and less than 5 CFU per ml were considered as contaminated and non-contaminated, respectively (12,23).

Identification of bacteria isolates: Following colony count, the identification of culture isolates was done as per the standard microbiological methods (24). Staphylococcal isolates were differentiated from streptococcal isolates by catalase test. *S. aureus* isolates were differentiated from coagulase-negative staphylococci (CoNS) by coagulase test. Gram-negative isolates were identified by urease, glucose and lactose fermentation, citrate utilization, motility, and indole tests and gas production (24).

Antimicrobial susceptibility testing: The antimicrobial susceptibility testing of the isolates was performed on Mueller-Hinton agar (Oxoid, UK) using the Kirby-Bauer disk diffusion method (25). The drugs tested were penicillin (10IU), ampicillin (10µg),amoxicillin-clavulanate (30µg), chloramphenicol (30µg), norfloxacin (10µg), ciprofloxacin (5µg), tetracycline (30µg), gentamicin (10µg), trimethoprim-sulfamethoxazole(25µg), doxycycline (10µg), ceftriaxone (30µg), naladixic acid (30µg), cefoxitin (30µg), clindamycin (2µg), and erythromycin (15µg) (Oxoid, UK). They were selected based on guidelines from the Clinical and Laboratory Standards Institute (CLSI), and on the availability and prescription frequency of the drugs in the study area. The antibiotic susceptibility profiles were interpreted based on 2016 CLSI guidelines (26). MDR was defined as resistance of the isolate to two or more antibiotics of different classes (27).

Quality control: Strict bacteriological sample collection procedure was followed at the time of swabbing. American Type Culture Collection (ATCC) standard reference strains of *S. aureus* ATCC25923, *E. coli* ATCC25922 and *P. aeruginosa*ATCC27853 were used to control the quality of culture and drug susceptibility testing (24).

Statistical analysis: SPSS version 20 statistical packages were used to analyze data. Chi-square test was computed to see the association between variables. To determine independent predictors of bacterial contamination, binary logistic regression analysis was employed by taking variables whose P-value was ≤ 0.25. A P-value of <0.05 was taken as a measure of statistical significance.

Ethics approval: Ethical approval was obtained from the Ethical Review Committee, College of Medicine and Health Sciences, Bahir Dar University. Official permission was obtained from the Amhara National Regional State Health Bureau and the management committee of FHRH. We obtained written consent from each study participant. Confidentiality of the results was maintained

Results

Participants' characteristics: A total of 422 HCWs' fomites were included in the study and 212 (50.2%) were from males. The median age of the participants was 28 years (range: 20 to 55). The majority (49.8%) of HCWs had served for less than five years. From the total fomites, 165 (39.1%) were mobile phones and 194 (46%) were white coats. In terms of profession, 146 (34.6%), 87 (20.6%), 86 (20.4%) and 35 (8.3%) were nurses, medical intern students, doctors and laboratory professionals, respectively. With regard to working in wards, 58 (13.7%) and 54 (12.8%) of HCWs were from outpatient departments and operation theaters, respectively (Table 1).

Rate of bacterial contamination: Overall, 243 (57.6%) fomites were contaminated with bacteria. The proportion of bacterial contamination was 37 (58.7%) on stethoscopes and 98 (59.4%) on mobile phones. It was 23 (65.7%), 52 (60.5%) and 53 (60.9%) in fomites from medical laboratory, doctors and intern students, respectively (P=0.04). The highest proportion of contaminated fomites was found in HCWs working in ICU (94.1%) (P<0.001). Details of bacterial contamination found in different categories of HCWs are depicted in Table 1.

Table 1: Bacterial contamination status of fomites with different characteristics of HCWs at FHRH, Bahir Dar, 2017

Characteristics	Contamination status		Total	P-value
	Contaminated N(%)	Non-contaminated N(%)	N(%)	
Gender				
Female	120(57.1)	90(42.9)	210(49.8)	
Male	123(58)	89(42)	212(50.2)	0.86
Age (years)				
20-24	46 (61.3)	29 (38.7)	75 (17.8)	
25-29	94 (56)	74 (44)	168 (39)	
30-34	57 (53.8)	47 (46.2)	106 (25.1)	
≥35	46 (63)	27 (37)	73 (17.3)	0.55
Year of service (in years)				
<5	116(55.2)	94(44.8)	210(49.8)	
5-9	77(56.6)	59(43.4)	136(32.2)	
≥10	50(65.8)	26(34.1)	76(18)	0.27
HCWs' fomites type				
Mobile phone	98(59.4)	67(40.7)	165(39.1)	0.76
Stethoscope	37(58.7)	26(41.3)	63(14.9)	
White coat	108(55.7)	86(44.3)	194(46)	
Qualification of HCWs				
Diploma	20(60.6)	13(39.4)	33(7.8)	
BSc	113(54.1)	96(45.9)	209(49.5)	
Medical doctor	40(65.6)	21(34.4)	61(14.5)	
Specialist	17(53.1)	15(46.9)	32(7.4)	
Intern student	53(60.9)	34(39.1)	87(20.6)	0.49
Type of HCW				
Laboratory professional	23(65.7)	12(34.3)	35(8.3)	0.04
Nurse	85(58.2)	61(41.8)	146(34.6)	
Midwife	14(63.6)	8(36.4)	22(5.2)	
Pharmacist	12(40)	18(60)	30(7.1)	
Medical doctor	52(60.5)	34(39.5)	86(20.4)	
Intern student	53(60.9)	34(39.1)	87(20.6)	
Anesthetist	4(25)	12(75)	16(3.8)	
HCWs working in wards				
Outpatient departments	29 (50)	29(50)	58 (13.7)	
Surgical	29(55.8)	23(44.2)	52(12.3)	
Medical	41(75.9)	13(24.1)	54(12.8)	
Gynecology	25(83.3)	5(16.7)	30(7.1)	
Pediatrics	18(47.4)	20(52.6)	38(9)	
Maternity	17(58.6)	12(41.4)	29(6.9)	
Operation theater	20(37)	34(63)	54(12.8)	
Orthopedics	13(52)	12(48)	25(5.9)	
Pharmacy	12(40)	18(60)	30(7.1)	
Laboratory	23(65.7)	12(34.3)	35(8.3)	
Intensive care	16(94.1)	1(5.9)	17(4)	<0.001
Total	**243(57.6)**	**179(42.4)**	**422(100)**	

The practices of HCWs in relation to hand washing and disinfection of their fomites are illustrated in Table 2. The majority (72%) of participants had no regular washing of hands before touching a patient. The majority (80.8%) of participants also used mobile phones at bedsides for medical information and 305 (72.3%) answered calls while attending patients. However, regular disinfection of mobile phones and stethoscopes was found in 14.5% and 3.1% of participants, respectively. The proportion of contamination was higher among HCWs who used mobile phones at bedsides and answered calls while attending patients than those who did not. The proportion of bacterial contamination was significantly higher in those HCWs who had not laundered their white coats compared to those who did (P=0.015).

Table 2: Bacterial contamination of fomites versus hand washing and disinfection practices of HCWs at FHRH, Bahir Dar, 2017

Characteristics	Contaminated(%)	Non-contaminated N(%)	Participants (422), N (%)	P-Value
Regular hand washing before touching a patient				
Yes	69 (58.5)	49 (41.5)	118 (28)	
No	174 (57.2)	130 (42.8)	304 (72)	0.817
Regular hand washing before aseptic procedure				
Yes	159 (58.5)	113 (41.5)	272 (64.5)	
No	84 (56)	66 (44)	150 (35.5)	0.625
Regular hand washing after touching a patient				
Yes	144 (59)	100 (41)	244 (57.8)	
No	99 (55.6)	79 (44.4)	178 (42.2)	0.486
Regular disinfection of stethoscope				
Yes	7 (53.8)	6(46.2)	13 (3.1)	
No	236 (57.7)	173(42.3)	409 (96.9)	0.782
Regular disinfection of mobile phones				
Yes	32 (52.5)	29 (47.5)	61 (14.5)	
No	211 (58.4)	150(41.6)	361 (85.5)	0.382
Use of mobile phone at bed side for medical information				
Yes	203 (59.5)	138 (40.5)	341 (80.8)	0.098
No	40 (49.4)	41 (50.6)	81 (19.2)	
Answering phone calls while attending patients				
Yes	183(60)	122(40)	305(72.3)	0.106
No	60(51.3)	57(48.7)	117(27.7)	
Regular cleaning of all fomites				
Yes	45 (49.5)	46 (50.5)	91 (21.6)	
No	198 (59.8)	133 (40.2)	331 (78.4)	0.077
Use of laundry white coat				
Yes	31 (44.3)	39 (55.7)	70 (16.6)	
No	212 (60.2)	140 (39.8)	352 (83.4)	0.015

Frequency of bacterial isolates: Out of 422 swab samples processed, 253 (60%) aerobic bacterial species were isolated. *S. aureus* (19.2%) followed by *K. pneumoniae* (6.4%) were the most frequent isolates over other potential pathogens isolated. *S. aureus* and *K. pneumoniae* were the most frequent isolates on both stethoscopes and mobile phones. The proportion of *K. pneumoniae* was higheston mobile phones (9.7%) (P<0.001). The frequency of *E. coli* was highest (2.6%) in white coats (P=0.014). The highest frequency of pathogenic bacteria was isolated from medical laboratory professionals (65.7%) followed by intern students (60.9%) (P=0.02). The proportion of *S. aureus* was significantly higher in fomites from midwives and nurses (P<0.001). The proportion of *K. pneumoniae* was highest (28.6%) among medical laboratory HCWs (P=0.045) (Table 3).

Table 3: Isolation rates and distribution of bacteria in swabs collected from different HCWs' fomites at FHRH, Bahir Dar, 2017

Type of fomite	Isolated organism N (%)								
	CoNS	***S. aureus***	***Bacillus* spp.**	***S. pyogenes***	***K. pneumoniae***	***E. coli***	***Citrobacter* spp.**	***P. aeruginosa***	**Total**
Stethoscope (n=63)	18 (28.6)	11 (17.5)	2 (3.2)	1 (1.6)	3 (4.8)	0 (0.0)	2 (3.2)	1 (1.6)	38 (60.3)
Mobile phone (n=165)	43 (26.1)	31 (18.8)	10 (6.1)	0	16 (9.7)	3 (1.8)	0	0	103 (62.4)
White coat (n=194)	50 (25.8)	39 (20.1)	10 (5.2)	0	8 (4.1)	5 (2.6)	0	0	112 (57.7)
Total (N=422)	**111 (26.3)**	**81 (19.2)**	**22 (5.2)**	**1 (0.24)**	**27 (6.4)**	**8 (1.9)**	**2 (0.5)**	**1 (0.24)**	**253 (60)**
Source of fomite									
Nurse (n=146)	36 (24.7)	35 (24)	NA	0	9 (6.2)	2 (1.4)	0	0	82 (56.2)
Laboratory professional (n=35)	7 (20)	4 (11.4)	NA	0	10 (28.6)	2 (5.7)	0	0	23 (65.7)
Medical doctor (n=86)	27 (31.4)	12 (14)	NA	1 (1.2)	3 (3.5)	2 (2.3)	1 (1.2)	0	46 (53.5)
Intern student (n=87)	27 (31)	18 (20.7)	NA	0	5 (5.7)	1 (1.1)	1 (1.1)	1 (1.1)	53 (60.9)
Midwife (n=22)	6 (27.3)	6 (27.3)	NA	0	0	1 (4.5)	0	0	13 (59.1)
Pharmacist (n=30)	6 (20)	4 (13.3)	NA	0	0	0	0	0	10 (33.3)
Anesthetist (n=16)	2 (12.5)	2 (12.5)	NA	0	0	0	0	0	4 (25)
Total	**111 (26.3)**	**81 (19.2)**	**NA**	**1 (0.24)**	**27 (6.4)**	**8 (1.9)**	**2 (0.5)**	**1 (0.24)**	**231 (54.7)**
P-value	<0.001	<0.001	NA	NA	0.045	NA	NA	NA	0.023

NA: not applicable; CoNS: Coagulase-negative staphylococ*ci*

Drug-resistance profiles of bacterial isolates: Gram-positive bacteria isolates revealed a high rate of resistance to penicillin (79.3%) and erythromycin (54.4%). As indicated in Table 4, *S. aureus* showed a high rate of resistance to penicillin, at 82.7%. Overall, gram-negative bacteria were resistant to ampicillin (97.4%) and co-trimoxazole (73.7%). *K. pneumoniae* isolates were 100% and 67% resistant to ampicillin and co-trimoxazole, respectively. *E. coli* isolates were 87.5% resistant to ampicillin and co-trimoxazole. The overall resistance profiles of the isolates are depicted in Table 4.

Table 4: Antimicrobial resistance profiles of the bacterial isolates from HCWs' fomites at FHRH, Bahir Dar, 2017

Bacterial isolates	Antimicrobials tested N (%) of resistance									
Gram positives	C	NOR	P	CIP	TE	GEN	FOX	CD	E	DOX	SXT
S. aureus (n=81)	16 (19.8)	10 (12.3)	67 (82.7)	1 (1.2)	40 (49.4)	14 (17)	10 (12.3)	2 (2.5)	49 (60.5)	28 (34.6)	43 (53.1)
CoNS(n=111)	28 (25.2)	18 (16.2)	86 (77.5)	7 (6.3)	61 (55)	17 (15)	12 (10.8)	8 (7.2)	56 (50.5)	29 (26.1)	58 (15.3)
S. pyogenes(n=1)	0	0	0	0	0	0	0	0	0	0	1 (100)
Total N (n=193)	44 (22.8)	28 (14.5)	153 (79.3)	8 (4.1)	101 (52.3)	31 (16.1)	22 (11.4)	10 (5.2)	105 (54.4)	57 (29.5)	102 (52.8)
Gram negatives	AMC	AMP	CRO	C	NOR	CIP	TE	GEN	NAL	DOX	TS
K. pneumoniae (n=27)	3 (11.1)	27 (100)	5 (18.5)	13 (48.1)	2 (7.4)	1 (3.7)	15 (56)	8 (29.6)	3 (11.1)	7 (26)	18 (67)
E. coli (n=8)	0	7 (87.5)	0	4 (50)	1 (12)	0	6 (75)	3 (37.5)	0	2 (25)	7 (87.5)
Citrobacter (n=2)	0	2 (100)	0	0	0	0	2 (100)	0	0	0	2 (100)
P. aeruginosa (n=1)	0	1 (100)	0	1 (100)	0	0	1 (100)	1 (100)	1 (100)	1 (100)	1 (100)
Total N (n=38)	3 (7.9)	37 (97.4)	5 (13.2)	18 (47.4)	3 (7.9)	1 (2.6)	24 (63.2)	12 (31.6)	4 (10.5)	10 (26.3)	28 (73.7)

AMP: Ampicillin; CRO: Ceftriaxone; C: Chloramphenicol;CoNS: Cogaulase negative staphylococci ; NOR: Norfloxacin; P: Penicillin; CIP: Ciprofloxacin;
TE: Tetracycline; GEN: Gentamicin; FOX: Cefoxitin;
SXT: trimethoprim-sulfamethoxazole; CD: Clindamycin; E: Erythromycin; DOX: Doxycycline; AMC: amoxicillin-clavulanate ; NAL: Nalidixic acid;

Multidrug-resistance profiles of the isolates: Overall, 204 (88.3%) of the isolates were MDR. The overall MDR rate among gram-positive and gram-negative isolates were 87.5% and 94.7%, respectively. The proportion of MDR *S. aureus, K. pneumoniae* and *E. coli* isolates were 88.9%, 92.6% and 100%, respectively (Table 5).

Table 5: Antibiogram of bacterial isolates from HCWs' fomites at FHRH, Bahir Dar, 2017

Bacterial species	Degree of resistance										Overall, MDR
	R0 (%)	R1 (%)	R2 (%)	R3 (%)	R4 (%)	R5 (%)	R6 (%)	R7 (%)	R8 (%)	R9 (%)	
CoNS (n=111)	6 (5.4)	9 (8.1)	13 (12)	11 (10)	17 (15.3)	15 (13.5)	15 (13.5)	11 (10)	9 (8.1)	5 (4.5)	96 (86.4)
S.aureus (n=81)	3 (3.7)	6 (7.4)	8 (10)	13 (16)	12 (14)	9 (11.1)	13 (16)	8 (9.8)	4 (4.9)	5 (6)	72 (88.9)
K. pneumoniae (n=27)	-	2 (7.4)	3 (11.1)	3 (11.1)	5 (18.5)	2 (7.4)	3 (11.1)	2 (7.4)	4 (15)	3 (11)	25 (92.6)
E. coli (n=8)	-	-	-	1 (12.5)	1 (12.5)	3 (37.5)	2 (25)	1 (12.5)	-	-	8 (100)
Citrobacter spp. (n=2)	-	-	-	-	-	1 (50)	1 (50)	-	-	-	2 (100)
P. aeruginosa (n=1)	-	-	-	-	-	-	-	-	-	1 (100)	1 (100)
S. pyogenes (n=1)	-	1 (100)	-	-	-	-	-	-	-	-	0
Total n=231	**9 (3.9)**	**18 (7.8)**	**24 (10.4)**	**28 (12.1)**	**35 (15.2)**	**30 (13)**	**34 (14.7)**	**22 (9.5)**	**17 (74)**	**12 (5.2)**	**204 (88.3)**

R0: Susceptible to all antimicrobials tested; R1-R9: Resistance to one, two, three, four, five, six, seven, eight and nine antimicrobials, respectively.; CoNS: Coagulase negative staphylococci

Multivariate analysis: In terms of multivariate analysis, bacterial contamination was significantly associated with HCWs' fomites from medical (AOR=5.2, 95% CI=1.85-14.8) and gynecology (AOR=3.1, 95% CI=1.5-6.43) wards and the ICU (AOR=16.33, 95% CI=2.1-127.9). HCWs' fomites from the ICU were about 16 times more likely to be contaminated with bacteria compared to others. Likewise, HCWs' fomites taken from medical and gynecology wards were 5.2 and 3.1 times, respectively, more likely to be contaminated with bacteria compared to their counterparts. Not laundering white coats was 1.3 times more likely to be a risk factor for bacterial contamination of HCWs' fomites (AOR=1.3, 95% CI=1.34-3.72) (Table 6).

Table 6: Regression analysis showing the associated factors for bacterial contamination of HCWs' fomites at FHRH, Bahir Dar, 2017

Variables	AOR (95% CI)	*P-value*
Type of HCW		
Pharmacist	1	
Laboratory professional	1.7 (0.69-4.1)	0.25
Nurse	1.3 (0.295-5.8)	0.72
Midwife	0.59 (0.24-1.49)	0.268
Medical doctor	0.77 (0.4-1.48)	0.44
Intern student	0.46 (1.2-1.75)	0.255
Anesthetist	0.98 (0.54-1.76)	0.95
HCWs working in wards		
Pharmacy	1	
Outpatient departments	0.95 (0.4-2.3)	0.91
Surgical	0.84 (0.4-1.75)	0.64
Medical	5.2 (1.85-14.8)	0.002
Gynecology	3.1 (1.5-6.43)	0.002
Pediatrics	0.53 (0.24-1.17)	0.12
Maternity	1.23 (0.64-2.37)	0.54
Operation theater	0.49 (0.199-1.25)	0.14
Orthopedics	0.78 (0.33-1.85)	0.57
Laboratory	1.5 (0.65-3.47)	0.34
Intensive care unit	16.33 (2.1-127.9)	0.008
Use of laundry white coat		
Yes	1	
No	1.3 (1.34-3.72)	0.016
Regular cleaning of all fomites		
Yes	1	
No	1.4 (0.87-2.36)	0.16
Answering phone calls while attending patients		
Yes	1.53 (0.95-2.48)	0.08
No	1	
Use of mobile phone at bedside for medical information		
Yes	1.29 (0.76-2.17)	0.35
No	1	

AOR: adjusted odds ratio, [1]: Reference category

Discussion

In any hospital setting, identifying pathogens that are common contaminants of fomites and their drug-resistance profiles, are important interventions to contain HAIs and the spread of drug-resistant strains. This study showed the status of bacterial contamination of different HCWs' fomites and their antibiogram at FHRH for the first time.

The overall proportion of bacteria-contaminated HCWs' fomites (55.7%-59.4%) in this study was coherent with a report in Uganda (57.59%) (9). However, it was lower than previous reports in other parts of Ethiopia (71.2%-98%) (12,15,16,18), Egypt (100%) (13) and Iran (90%) (11). This variation might be associated with differences in qualifications, professions, proper handling of fomites and study settings. A lack of regular hand washing, the use of mobile phones and answering calls at bedside might contribute to a considerable proportion of contaminated fomites in the present study. Therefore, strict disinfection of fomites, hand washing before touching sterile and after touching contaminated fomites, restricted use of mobile phones and good compliance of HCWs to follow the standard protocol set to prevent HAIs are required to properly handle and reduce contamination of unavoidable fomites, such as stethoscopes and white coats.

The proportion of HCWs' stethoscopes contaminated with bacteria in this study (58.7%) is lower compared to a study in Jimma (85.8%), Ethiopia (16). This might be associated with variations in regular disinfection and handling of stethoscopes.

The proportion of HCWs' mobile phones contaminated with bacteria (59.4%) in the present study was higher compared to earlier studies in Iran (32%) (14), Saudi Arabia (38.3%) (21) and USA (0-20%) (11). However, it was lower than previous studies in Ethiopia – in Gondar (98%), Jimma (71.2%) and Hawassa (97.4%)(12,15,18). These variations might be due to differences in the infection prevention practices of HCWs. Non-restricted use of mobile phones and gaps in moments of hand washing practice in the clinical setting, as indicated in Table 2, could be the potential reasons for the occurrence of a considerable degree of contamination in the present study.

In the present study, the proportion of white coats contaminated with bacteria (55.7%) was lower than earlier studies in Nigeria (65.7%) (5), Tanzania (73.3%) (28) and India (69%) (17). This could be due to variations in the practice of cleaning white coats and working wards of HCWs.

The frequency of bacteria-contaminated fomites among medical doctors (60.5%) and intern students (60.9%) in the present study was lower than a study conducted in Jimma, Ethiopia (16), with a 100% contamination rate of stethoscopes from medical doctors. However, it was higher than reports among medical doctors in Tanzania (35%) (28) and Iran (50%) (14). This variation could be due to differences in hand washing and the fomite disinfection practices of HCWs.

In the current study, the proportion of bacteria-contaminated fomites among medical laboratory professionals, midwives and nurses was higher compared to reports in Iran (14) and Tanzania (28). However, it was lower than a study in Egypt (13) among laboratory personnel and nurses. This might be due to differences in the standards of hospital and hand washing practices.

Despite comparison with the findings of other studies being limited due to the lack of available data, in the current study, the highest proportion of pathogenic bacteria were isolated from medical laboratory professionals, followed by intern students (Table 3). This might be due to differences in the work loads and levels of HCWs' commitment to adhere to infection prevention protocols.

In this study, the highest number of fomites contaminated with bacteria was obtained from HCWs working in the ICU ($P<0.001$), which might be due to the frequent hand touching involved in patient care in ICU (29). This result indicates that ICU patients are an important reservoir of pathogens and epicenter of resistance development. Therefore, strict adherence to infection prevention protocol is required for proper management of patients and to monitor the spread of drug-resistant pathogens. The present finding is consistent with a study conducted in Jimma, Ethiopia (16). However, higher proportions of contaminated fomites were found at an orthopedics ward in Nigeria (10), medical ward in Iran (29), and laboratory units in Egypt (13). Likewise, in the present study, significantly higher proportions of fomites contaminated with bacteria were obtained from medical and gynecology wards compared to their counterparts. This might be due to differences in the patient load, frequency of HCWs' contact with patients, and infection prevention practices among the different wards.

In this study, the frequency of gram-positive isolates was higher than gram-negative isolates. This is consistent with earlier studies in other parts of Ethiopia (12,15,16,18). Moreover, it is comparable with studies done in Iran (14), India (17), Saudi Arabia (21) and Egypt (30). This might be due to the direct contact of fomites with human skin flora, which predominantly harbor gram-positive bacteria.

In the present study, *S. aureus* followed by *K. pneumoniae* were the most frequent isolates over other potential pathogens. This is similar to earlier studies in Ethiopia (12,15,16) and Uganda (31). The proportion of *E. coli* was significantly higher in white coats compared to other fomites ($P=0.014$). This is coherent with a study conducted in Nigeria (10). However, it differs from studies done in Iran (29) and India (17), where *Bacillus* spp. and *S. aureus*, respectively, were the most frequent.

The proportion of *K. pneumoniae* was higher in mobile phones compared to other fomites. This is consistent with previous studies in Uganda (9), Egypt (13) and India (17). The predominance of *E. coli* in white coats and *K. pneumoniae* in mobile phones could be associated with contamination from patient wounds and HCWs' hands, and their long-time survival in a wet environment (10,22).

Although comparison was not possible due to a lack of previous data, a significantly higher proportion of *S. aureus* was isolated from midwives and nurses compared to other HCWs (Table 3). This might be associated with the nurses' and midwives' frequent contact with the skin and wounds of patients during care. On the other hand, the highest frequency of *K. pneumoniae* in the present study – in medical laboratory HCWs ($P=0.045$) – might be linked with contamination of their fomites from different clinical specimens processed in the laboratory.

In this study, staphylococcal isolates showed a high level of resistance to penicillin. This is coherent with previous studies in Jimma, Ethiopia (16), India (17) and Saudi Arabia (21). However, it is higher than a study in Hawassa, Ethiopia (18) and lower than a another study in Jimma, Ethiopia (12).

In the current study, *K. pneumoniae* showed 100% and 67% resistance to ampicillin and co-trimoxazole, respectively. This is similar to previous studies in Jimma, where 66.7% and 75% resistance to ampicillin and co-trimoxazole, respectively, were reported (16). Furthermore, the 75% and 87.5% resistance rates of *E. coli* isolates to tetracycline and co-trimoxazole, respectively, in the present study, are comparable with other studies conducted in Ethiopia (6,32), and in

Nepal (33), where 66.7% to 100% resistance to co-trimoxazole was reported.

The overall MDR rate (88.3%) among bacterial isolates in the present study is comparable with a study conducted elsewhere in Ethiopia (32). However, this finding is higher compared to earlier studies in Gondar, Ethiopia (15), Egypt (30) and Saudi Arabia (71.8%) (21).

In this study, *E. coli*, *K. pneumoniae* and *S. aureus* isolates revealed 100%, 92.6% and 88.9% MDR, respectively. This is consistent with previous studies in Ethiopia (33, 35). The higher MDR resistance in both gram-positive and gram-negative bacteria reported in the present study might be due to the indiscriminate and mis-use of antibiotics, as most of the antibiotic classes were used as treatment alternatives in the study area.

Conclusions

Bacterial contamination of HCWs' fomites is a major health care problem in the study area. MDR bacterial isolates are alarmingly high in pathogenic bacteria. Therefore, HCWs in hospitals need to implement proper handling of fomites to reduce contamination and the spread of drug-resistant pathogens.

Competing interests

The authors declare that they have no any competing interests.

Authors' contributions

WA designed the study, performed the laboratory investigation, performed the statistical analysis and revised the manuscript; WM and FB conceptualized the study, supervised the data collection and laboratory work, were involved in the statistical analysis and interpretation of data, and wrote and critically edited the manuscript.

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