Original Article

Methicillin-resistant *Staphylococcus aureus* colonization among healthcare workers in Oman

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Abstract

Introduction: Methicillin-Resistant *Staphylococcus aureus* (MRSA) is a *S. aureus* strain characterized by resistance to cloxacillin. Healthcare workers (HCWs), are recognized for their heightened risk for MRSA acquisition and possibly for MRSA nosocomial transmission. This cross-sectional study aimed to determine the prevalence and the associated risk factors of MRSA colonization among healthcare workers at Sultan Qaboos University Hospital (SQUH) in Oman.

Methodology: A total of 200 nasal swab samples were collected from the healthcare workers at SQUH during the period October 2nd 2018 to January 7th 2019. All nasal swab samples were examined microbiologically for the presence of MRSA using the standard method and the results were confirmed by detection of the *mecA* product (PBP2a). Data on associated risk factors for MRSA colonization was collected and analyzed.

Results: Forty-one of the 200 screened healthcare workers (20.5%) were found to have nasal carriage of *Staphylococcus aureus* of which 63.4% were Methicillin Sensitive and 36.6% were Methicillin-Resistant (MRSA). Methicillin-Resistant *Staphylococcus aureus* (MRSA)was isolated from fifteen of the 200 screened healthcare workers giving a prevalence rate of nasal colonization with MRSA of 7.5%. We found no statistical association between healthcare worker MRSA nasal colonization and age, gender, HCWs specialty, hand hygiene practices, skin condition, previous MRSA infection, and previous exposure to antibiotics.

Conclusions: Identification of the prevalence and the associated risk factors of MRSA colonization in healthcare workers mandates continuous surveillance and the implementation of all possible preventive measures to reduce re-occurrences.

Key words: Prevalence; associated risk factors; methicillin-resistant *Staphylococcus aureus*; MRSA colonization; healthcare workers; Oman.

Introduction

Staphylococcus aureus is gram positive bacteria found commensally in the skin and nasopharynx in human and animal [1]. Methicillin-resistant *S. aureus* (MRSA) is *S. aureus* with resistance to methicillin (typically with resistance to other anti-*staphylococcus* antibiotics) [2]. MRSA generates a worldwide concern particularly in hospitalized patients, especially in immunocompromised persons [3,4]. In the community, 2% of people carrying MRSA, and historically, the first MRSA infection was reported in 1961 [5].

Clinically, MRSA infected patient suffers from osteomyelitis as a form of bone infection accompanied with prosthetic joint infection. [6]. Furthermore, MRSA causes primary and secondary bacteremia [7]. Also, MRSA may result in abscess formation in the abdominal and pelvic regions [6]. Additionally, a central intravenous line infection is a common characteristic of MRSA clinical manifestations which is associated with unclear-fever [8]. In dermal tissue, MRSA can cause skin, wound and burn infections [9]. Nosocomial pneumonia is an occasional form of MRSA infection [10]. Additionally, a study conducted in Russia showed that the MRSA was proved to cause a fatal community acquired pediatric pneumonia and intensive care unit associated bacteremia [11]. Induction of sepsis and soft tissue infection also mentioned as MRSA clinical findings. [12].

Healthcare workers are particularly at risk for MRSA infection [13]. In 2012, a study conducted in India showed that 12% of Karnataka hospital healthcare workers are colonized with MRSA [13]. In Africa, a study conducted in Tanzania revealed MRSA prevalence rate of 15.6% in healthcare workers in two local hospitals [14]. In Europe, a study conducted in Hamburg geriatric nursing facilities in Germany showed MRSA prevalence of 1.6% among healthcare workers [15]. In the gulf cooperation council region, a

study conducted at King Fahad National Guard Hospital in Saudi Arabia showed MRSA prevalence of 13.5% among healthcare workers [16]. In Oman, a study from Sohar Hospital found that MRSA was prevalent among healthcare workers with a rate of 15.1% [17].

Regarding the treatment, Clindamycin is an FDA (Food and Drug Administration) approved anti-*Staphylococcus aureus*, while tetracycline is also FDA approved but only to treat *Staphylococcus aureus* skin infections [18]. Rifampin and linezolid can be used as treatment if seriously required, but only in a combined way of both linezolid and Rifampin and if only authorized by clinical consultation [19]. Furthermore, lactobacilli fermentum produces a bacteriocin against MRSA which can be used as anti-MRSA in certain cases [20].

This cross-sectional study aims to determine the prevalence and the associated risk factors of MRSA colonization among healthcare workers at Sultan Qaboos University Hospital (SQUH).

Methodology
Study Design
This study was carried out at Sultan Qaboos University Hospital, where a total of 200 non-repeat nasal swab samples were randomly collected from health care workers (HCWs), at Sultan Qaboos University Hospital from 2nd of October 2018 to 7th of January 2019. Demographic data including healthcare workers gender, age, job specialization and clinical department where he/she works were collected.

Samples collection
The collection of nasal swab samples from HCWs and the conducting of the study was authorized by the ethical committee at the College of Medicine and Health Sciences (MREC # 1688). Healthcare workers included in the study were physicians, nurses, medical orderlies, physiotherapists, radiographers and central sterilization services technicians and belong to the following clinical departments: Medicine, Surgery, Critical Care Units [neonatal ICU, Adult ICU], Emergency, Radiology, Operating Theatres, Family medicine, Physiotherapy, infection control, and Central sterilization services. The Nasal swab samples were collected from HCWs by using Sterilin™ irradiated-red-cap-general-purpose swab (Parkway, Newport, UK). A questionnaire was filled by participants to obtain demographic data detailed above. Additionally, the following information was obtained from screened healthcare workers to asses possible risk factors for

MRSA colonization including recent hospitalization history, recent antibiotic exposure, recent MRSA infection, recent skin or soft tissue infection, nose-picking habit, smoking, and compliance with standard infection control practices.

Bacteriological analysis
The identification of *Staphylococcus aureus* was performed following the standard laboratory identification protocol. Nasal swab samples were directly plated into blood agar and mannitol salt agar after collection. On blood agar colonies of *S. aureus* are frequently surrounded by zones of clear beta hemolysis with a golden appearance of colonies as well isolated *S. aureus* colonies produced the typical yellow colour on mannitol salt agar which indicates mannitol fermentation properties. Also, isolates which exhibited gram positive cocci in clusters and were positive for catalase, coagulase and DNase were identified as *S. aureus*.

Screening for antibiotic susceptibility
Antibiotic sensitivity tests were performed on Mueller-Hinton agar using the Kirby-Bauer disc diffusion method. The results were interpreted according to Clinical Laboratory Standard Institute (CLSI), performance standards for antimicrobial susceptibility testing [21]. With aid of antibiotics discs dispensers, the following antibiotic discs were applied on the streaked media: 5μg/L rifampin, 10μg/L penicillin, 30μg/L cefoxitin, 30μg/L tetracyclines 10μg/L gentamycin, 15μg/L erythromycin, 5μg/L ciprofloxacin, 2μg/L clindamycin, 25μg/L trimethoprim-sulfamethoxazole, 30μg/L linezolid.

MRSA detection criteria
Based on Clinical Laboratory Standards Institute (CLSI) 2018 criteria [21], *Staphylococcus aureus* considered as methicillin-resistant *Staphylococcus aureus* (MRSA) if it was resistant to cefoxitin by the diameter of > 20 mm, while the methicillin-sensitive *Staphylococcus aureus* (MSSA) was sensitive to cefoxitin by a diameter of < 20 mm [21].

Penicillin Binding Protein -II (PBP-II) confirmatory test
The *mecA* product (PBP2a) was detected using the Mastalex™ MRSA kit (Mast Group Ltd., Bootle L20 1EZ, UK). PBP2a latex agglutination test. This test was performed in accordance with the manufacturer's instructions. Negative and positive controls were included in each experiment.

Table 1. MRSA detection by MASTLEX PBP-II and Disc diffusion.

Test	Positive MRSA	Negative MRSA
	% (n)	% (n)
Disc diffusion	100 (15)	0 (0)
MASTALEX™ PBP-II	100 (15)	0 (0)

Data analysis

All participant's data were collected, categorized and analyzed by using of Statistical Package for Social Sciences (SPSS) version 22.

Results

Disc diffusion and MASTALEX™ Penicillin Binding Protein-II (PBP-II) tests in MRSA detection

All fifteen (100%) MRSA detected by disc diffusion test, were also positive by MASTALEX™ PBP-II test (Table 1).

The Prevalence of MRSA in healthcare workers at Sultan Qaboos University Hospital

Out of a total of two-hundred non-repeat samples, forty-one (20.5%) were positive for *S. aureus* (13% MSSA and 7.5% MRSA) (Figure 1), and out of the total

Table 2. Demographic details of the 200 participating healthcare workers.

Characteristics	% (n)
Age Group (Years)	
25-30	41.0 (82)
31-35	34.5 (69)
36-40	13.0 (26)
>40	11.5 (23)
Sex	
Female	55.0 (110)
Male	45.0 (90)

Figure 1. Prevalence of MSSA and MRSA in nasal swab obtained from 200 SQUH HCWs.

of forty-one *S. aureus* positive nasal swab samples, twenty-six samples (63.4 %) were MSSA, and fifteen (36.6%) were MRSA.

Associated risk factors of MRSA colonization in healthcare workers at Sultan Qaboos

Eighty-two healthcare workers (41.0%) were in the age group of 25-30 years, ninety-six (34.5%) within the age group of 31-35 years, twenty-six (13.0%) within the age group of 36-40 years, and twenty-three (11.5%) were within the age group of >40 years (Table 2).

With regards to the gender distribution of the two-hundred healthcare workers, hundred and ten (55%) were females and while ninety (45%) were males (Table 2).

The distribution of the participating healthcare workers in different hospital departments and job specialization

The distribution of the participating healthcare workers in different hospital departments and job specialization is depicted in Table 3.

MRSA and MSSA prevalence in relation to the age of health Care Workers (HCWs)

The highest prevalence of MRSA was in the age group: 31-35 and the lowest was in the age group: 36-40. MRSA and MSSA prevalence in association to age are summarized in Figure 2.
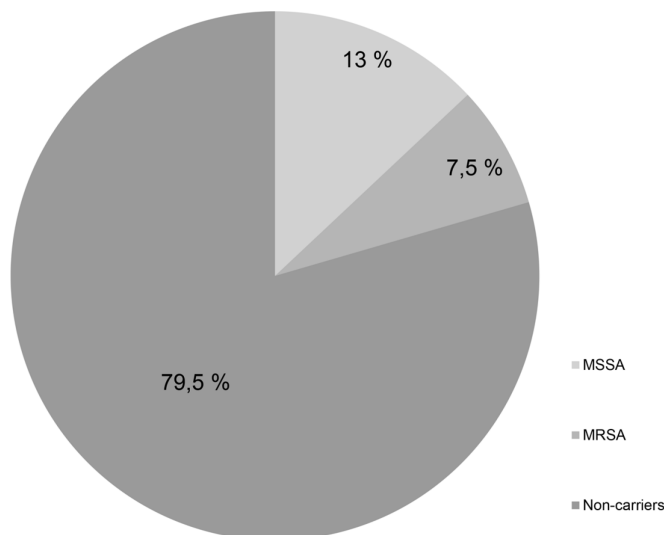
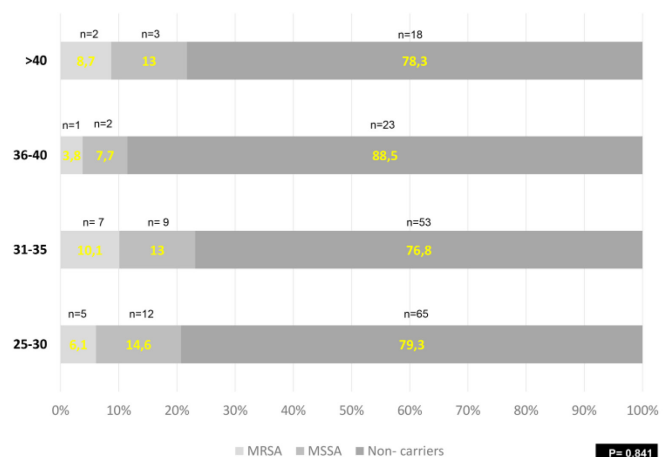**Figure 2.** MRSA and MSSA prevalence in association to age.

Table 3. The distribution of the participating healthcare workers in different hospital departments and job specialization.

Specialty	Doctor	Nurse	Medical orderly	Radiographer	Physiotherapist	Sterilization service technician	Total
Clinical area							
Infection Control	0	4	0	0	0	0	4
ENT	17	0	0	0	0	0	17
Medicine	9	8	0	0	0	0	17
Surgery	5	6	1	0	2	0	14
Neonatal ICU	2	20	0	0	0	0	22
Emergency	0	12	0	0	0	0	12
Adult ICU	6	30	0	1	0	0	37
Operating theatres	2	22	2	0	0	1	27
Family Medicine	6	3	2	0	0	0	11
Radiology	6	2	1	9	0	0	18
Physiotherapy	0	0	0	0	12	0	12
CSSD	0	0	0	0	0	9	9
TOTAL	53	107	6	10	14	10	200

ENT: ear, nose and throat; CSSD: central sterilization services department.

Table 4. MRSA prevalence in healthcare workers according to clinical areas.

Department	Number of samples tested	MRSA prevalence: MRSA % (n)
Infection Control Unit	4	25% (1)
ENT	17	0 (0)
Medicine	17	5.9% (1)
Surgery	14	21.4% (3)
Neonatal ICU	22	9.1% (2)
Emergency	12	8.3% (1)
Adult ICU	37	2.7% (1)
Operation Theaters	27	3.7% (1)
Family Medicine	11	9.1% (1)
Radiology	18	11.1% (2)
Physiotherapy	12	8.3% (1)
Central Sterilization	9	11.1% (1)
Total	200	15

Table 5. MRSA and MSSA prevalence within hand washing variable.

	Hands washing Before patient contact			Hand washing After patient contact		
	Always	often	sometimes	Always	Often	Sometimes
MSSA% (n)	13.4 (20)	15.8 (6)	0 (0)	13.0 (21)	12.9 (4)	12.5 (1)
MRSA%(n)	7.4 (11)	5.3 (2)	15.4 (2)	8.1 (13)	6.5 (2)	0 (0)
Non- carriers %(n)	79.2 (118)	78.9 (30)	84.8 (11)	78.9 (127)	80.6 (25)	87.5 (7)
Total number (100%)	149	38	13	161	31	8

MRSA and MSSA prevalence in relation to the gender of HCWs

Out of the total of ninety Males healthcare workers, ten (11.1%) were MRSA carriers while out of the hundred and ten female Healthcare workers, five (4.5%) were MRSA carriers (Figure 3). Statistically, no association was found between gender and MRSA prevalence ($p > 0.01$).

MRSA and MSSA prevalence in relation to healthcare worker specialty

3.8% of screened physicians were found to be colonized with MRSA while 7.5% of screened nursing staff were carriers for MRSA. Interestingly, 1/3 (a total of 6 screened) of the screened medical orderlies were found to be positive for MRSA. Findings on MRSA carrier rates among other specialties are detailed in Figure 4, statistically, P-value showed non-significant association ($p > 0.01$).

Prevalence of MRSA colonization in relation to clinical areas

25% (1/4) of the screened staff in infection control department were found to be carriers for MRSA. Rate of MRSA colonization in healthcare workers from other clinical areas are 5.9% (Medicine), 21.4% (Surgery), 9.1% (Neonatal ICU), 8.3% (Emergency), 2.7% (Adult ICU), 3.7% (operating theatre staff), 9.1% (Family medicine), 11.1% (Radiology), 8.3% (Physiotherapy), and 11.1% (Sterilization staff). The highest prevalence of MRSA detected among SQUH healthcare workers was in the infection control unit (25%), followed by Surgery unit (21.4%) (Table 4). Interestingly, no MRSA detection was demonstrated in screened ENT staff (Table 4). Statistically, non- significant P value

indicate no association between the clinical area and MRSA prevalence ($p > 0.01$).

Prevalence of MRSA and MSSA based on hand washing frequency

As shown in Table 5, for the variable "handwashing before patient contact", the highest level of methicillin-resistant *Staphylococcus aureus* (MRSA) was found in the group of healthcare workers (HCWs) classified as "sometimes-hand-washers" (15.4%) and the lowest was found in the group "often-hand-washers" (5.3.%). Surprisingly, for the variable "handwashing after patient contact", the highest MRSA detection rate was in the group "always-hand-washers" (8.1%), while MRSA was absent in the group "sometimes-hand-washers" (Table 5). Statistically, handwashing frequency was found to have a non-significant association with MRSA prevalence ($p > 0.01$).

Prevalence of MRSA in association with other different risk factors
Twelve months' history of skin and soft tissue infection

Out of a total of 192 nasal swab samples of HCWs with no skin and soft tissue infection (SSTHX) history, methicillin-sensitive *Staphylococcus aureus* (MSSA) was found in 26 (13.5%), MRSA in 15 (7.8%) and 151 (78.6%) showed no *S. aureus*. The eight HCWs with a history of SSTHx were not *S. aureus* carriers (Table 6). Statistically, no statistical association was found between SSTHx and MRSA prevalence ($p > 0.01$).

Figure 4. MRSA and MSSA prevalence within job specializations.
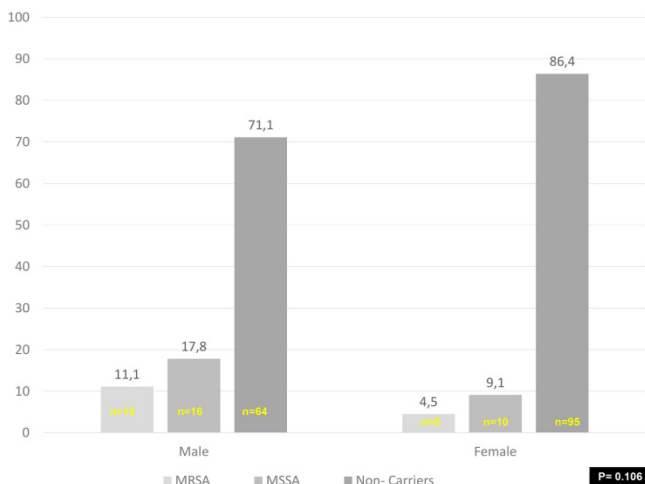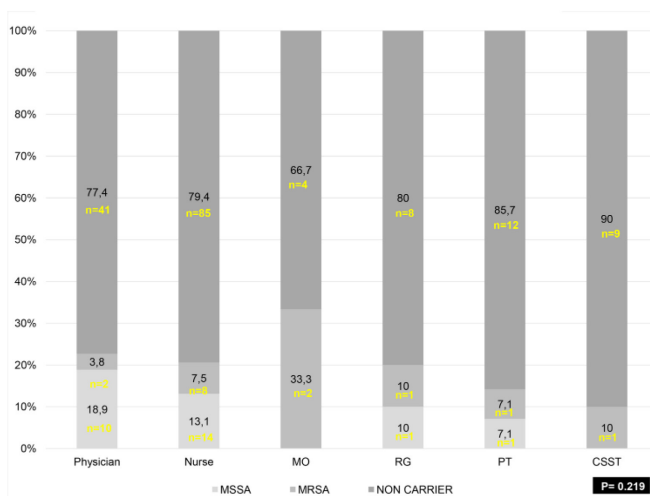

MO: medical orderly; **RG**: radiographer; **PT**: physiotherapist; **CSST**: central sterilization services technician.

Figure 3. MRSA and MSSA prevalence in relation to gender.

Twelve months' hospitalization history

For the variable hospitalization history for the previous 12 months, the 13 samples obtained from HCWs with a history of hospitalization showed two (15.4%) with MRSA, two (15.4%) with MSSA and nine (69.2%) were non-*S. aureus* carriers. Of the 187 swab samples obtained from HCWs with no hospitalization history, 13 (7.0%) had MRSA, 24 (12.8%) had MSSA and 150 (80.2%) tested negative for *S. aureus*. These results show that MRSA detection was higher in nasal swabs obtained from HCWs with a history of hospitalization (Table 6). Statistically, no association was found between a history of hospitalization in the previous 12 months and MRSA prevalence ($p > 0.01$).

Healthcare workers with a history of MRSA colonisation in the previous 12 months

Of the six samples with a history of MRSA infection in the previous 12 months (MRSA Hx), one (16.7%) had MRSA, one (16.7%) had MSSA and four (66.7%) tested negative for *S. aureus*. Of the 159 samples with no MRSA Hx, 14 (7.2%) had MRSA, 25 (12.9%) had MSSA and 155 showed no *S. aureus*. According to these results, the group with a positive MRSA Hx had a higher rate of MRSA detection (Table 6). Statistically, no association was found between MRSA Hx and MRSA prevalence ($p > 0.01$).

Healthcare workers who had taken antibiotics in the previous 12 months

Out of the 35 samples who had taken antibiotics in the previous 12 months, 3 (8.6%) had MSSA, 5 (14.3%) had MRSA and 27 (77.1%) showed no *S. aureus*. Of the 165 nasal swab samples obtained from HCWs who had not taken antibiotics, 23 (13.9%) had MSSA, 10 (6.1%) had MRSA and 132 (80.0%) tested negative for *S. aureus*. These results show a higher rate of MRSA detection in HCWs who had taken antibiotics (Table 6). Statistically, no association was found between taking antibiotics in the previous 12 months and MRSA prevalence ($p > 0.01$).

Nose-picking

For the nose-picking variable, 48 HCWs identified themselves as "nose-pickers" and 152 as "non-nose-pickers". Of the nose-pickers, 6 (12.5%) of had MSSA, six (12.5%) had MRSA and 39 (75.0%) were non-*S. aureus* carriers. Of the non-nose-pickers, 20 (13.2%) had MSSA, 9 (5.9%) had MRSA and 123 (80.9%) were non-*S. aureus* carriers. These figures show a higher MRSA detection rate in the nose-pickers group (Table 6). Statistically, no association was found between nose picking and MRSA prevalence ($p > 0.01$).

Smoking

The four nasal swab samples obtained from HCWs who smoked tested negative for *S. aureus*. Of the 196 nasal swab samples obtained from non-smokers, 26 (13.3%) had MSSA, 15 (7.7%) had MRSA and 155 (79.1%) tested negative for *S. aureus* (Table 6).

Table 6. Prevalence of MRSA in association with different risk factors.

	MSSA%(n)	MRSA%(n)	Non- carriers%(n)	Total number (100%)
Skin and soft tissue infection history in the previous 12 months (S&ST Hx)				
S&ST Hx	0 (0)	0 (0)	100 (8)	8
No- S&ST Hx	13.5 (26)	7.8 (15)	78.6 (151)	192
p-value		1.000		
Hospitalization in the previous 12 months (Hospitalization Hx)				
Hospitalization Hx	15.4(2)	15.4(2)	69.2(9)	13
No- Hospitalization Hx	12.8(24)	7.0(13)	80.2(150)	187
p-value		0.253		
MRSA infection history in the previous 12 months (MRSA Hx)				
MRSA Hx	16.7(1)	16.7(1)	66.7(4)	6
No- MRSA Hx	12.9(25)	7.2(14)	79.9(155)	159
p-value		0.377		
Antibiotic History in the previous 12 months (Antibiotic Hx)				
Antibiotic Hx	8.6 (3)	14.3(5)	77.1(27)	35
No- Antibiotic Hx	13.9(23)	6.1(10)	80.0 (132)	165
p-value		0.147		
Nose picking				
Nose picker	12.5 (6)	12.5 (6)	75.0 (39)	48
Non-nose picker	13.2(20)	5.9 (9)	80.9 (123)	152
p-value		0.204		
Smoking				
smoker	0 (0)	0 (0)	100 (4)	4
Non- smoker	13.3(26)	7.7 (15)	79.1 (155)	196
p-value		1.000		

Statistically, no association was found between smoking and MRSA prevalence (p > 0.01).

Antibiotic s susceptibility patterns in S. aureus isolates

An antibiotic sensitivity test performed on the 41 *S. aureus* isolates from HCWs at Sultan Qaboos University Hospital showed that 40 *S. aureus* isolates (97.6%) were sensitive to rifampin 5µg/ml and only one (2.4%) was resistant.

Thirty-seven *S. aureus* isolates (90.2%) were resistant to penicillin and four (9.8%) were sensitive. Fifteen *S. aureus* isolates (36.6%) were resistant to cefoxitin and 26 (63.4%) were sensitive. For 30µg/ml tetracycline, 5 *S. aureus* isolates (12.2%) were resistant, 2 (4.9%) were intermediate-sensitive and 34 (82.9%) were sensitive. For 15µg/ml erythromycin, 10 isolates (24.4%) were resistant, one (2.4%) showed intermediate sensitivity and 30 (73.2%) were sensitive. For 5µg/ml ciprofloxacin, 8 isolates (19.5%) were resistant and 33 (80.5%) were sensitive. For 2µg/mL clindamycin, only one isolate (2.4%) was resistant, and 40 (97.6%) were sensitive. All 41 *S. aureus* isolates (100%) were sensitive to 25µg/mL trimethoprim, 10µg/mL gentamycin and 30µg/mL linezolid. The highest resistance in the 41 *S. aureus* isolates was against 30µg/mL cefoxitin. The antibiotic sensitivity patterns are summarized in Table 7.

Discussion

Of the 200 samples in the present study, 41 (20.5%) tested positive for *S. aureus*. Of the 41 *S. aureus*-positive samples, only 26 (13%) had MSSA and 15 (7.5%) had MRSA. Very similar findings can be found in a previously published study conducted in Karnataka Hospital in India, which showed that out 200 samples, only 45 (43.6%) tested positive for *S. aureus*. Of these, 21 (10%) had MSSA, while 21 (10%) had MRSA [13].

Demographically, the present study found the highest MRSA prevalence in the age group 31–35 (10.1%) with lack of any association toward MRSA prevalence (*p* > 0.05). Similarly, a study conducted in a geriatric nursing unit in Hamburg, Germany found the highest MRSA prevalence in the age group 30-39 (2.5%), with no statistically significant association between age and MRSA prevalence (*p* > 0.05) [15]. A study conducted in John Radcliffe Hospital in the United Kingdom also found the highest MRSA prevalence in the age group > 30 but, in contrast to the present study, indicated a statistically significant association between MRSA prevalence and age (*p* < 0.05) [22].

In our study, males were found to have a higher prevalence of MRSA than females, but no statistically significant association was found between sex and MRSA prevalence (*p* > 0.05). Similarly, a study conducted in a geriatric nursing unit in Hamburg, Germany showed a higher MRSA prevalence in males than in females. However, that study also found a statistically significant association between sex and MRSA prevalence (*p* < 0.05) [15]. By contrast, a Tanzanian study conducted in Dar Al Salam Hospital showed that females had a higher MRSA prevalence than males. However, no statistically significant association was determined between sex and MRSA prevalence (*p* > 0.05) [14].

The present study shows no statistically significant association between job specialization and MRSA prevalence. Similarly, a study conducted in Assam Hospital in India showed no statistical association between job specialization and MRSA prevalence. However, that study found that physicians had the highest MRSA prevalence [23]. In contrast to the present study, a study conducted in the University of Maiduguri Teaching Hospital and Ahmadu Bello University in Nigeria found a statistical association between job specialization and MRSA prevalence in healthcare workers, with physicians having the highest MRSA prevalence [24].

The present study also investigated the prevalence of MRSA in different departments at Sultan Qaboos

Table 7. Antibiotic susceptibility of isolated *S. Aureus*.

Antibiotic	Code/concentration	Resistant%(n)	Intermediate%(n)	Sensitive%(n)
Rifampin	RD/5 ug/mL	2.4 (1)	0 (0)	97.6 (40)
Penicillin	P/10 ug/mL	90.2 (37)	0 (0)	9.8(4)
Cefoxitin	FOX/30ug/mL	36.6 (15)	0 (0)	63.4 (26)
Tetracycline	TE/30ug/mL	12.2 (5)	4.9 (2)	82.9 (34)
Gentamycin	CN/10ug/mL	0 (0)	0 (0)	100 (41)
Erythromycin	E /15ug/mL	24.4 (10)	2.4 (1)	73.2 (30)
Ciprofloxacin	CIP/5ug/mL	19.5 (8)	0 (0)	80.5 (33)
Clindamycin	DA/2ug/mL	2.4(1)	0 (0)	97.6 (40)
Trimethoprim-Sulfamethoxazole	SXT/25ug/mL	0 (0)	0 (0)	100 (41)
Linezolid	LZD/30 ug/mL	0 (0)	0 (0)	100 (41)

University Hospital (SQUH). The highest prevalence of MRSA detected in SQUH was in the infection control unit. However, this finding of highest MRSA detection in the infection control unit was based on the fact that only four samples were collected from this department all of these were from nurses. In contrast to our finding, a study conducted in Amana and Temeke Hospitals in Tanzania found the highest MRSA prevalence in the department of Medicine [14]. Another study conducted in Saudi Arabia at King Abdulaziz University showed the highest MRSA prevalence in the burns unit [25].

Regarding the associated risk factor history of hospitalization in the past 12 months among healthcare workers and volunteers, the present cross-sectional study revealed no statistical association between this risk factor and MRSA prevalence. A similar finding was reported in a Taiwanese study conducted in the National Taiwan University Hospital, Wan Fang Hospital and Taipei Cathay General Hospital, which showed no statistical association between healthcare workers' hospitalization history in the past 12 months and MRSA [26]. In contrast, a study conducted at Grady Memorial Hospital in the United States showed a statistical association between hospitalization history in the previous 12 months and MRSA prevalence [27]. Additionally, in the present study, no statistical association was found between soft tissue and skin infection history in the previous 12 months and MRSA prevalence. The aforementioned Taiwanese study also showed no statistical association between infections of soft tissue and skin in the previous 12 months and MRSA [26]. However, the aforementioned United States study showed a statistically significant association between this variable and MRSA prevalence ($p < 0.05$) [27]. In our study, we also assessed participants' history of MRSA colonisation in the previous 12 months and found no statistical association toward the MRSA prevalence. Conversely, the aforementioned United States study showed an association between this variable and MRSA prevalence [27]. However, another study conducted in Brooke Army Medical Center, also in the United States, showed no association between MRSA infection in the past 12 months and MRSA prevalence [28].

Regarding the associated risk factor antibiotics use in the previous 12 months, the findings of a similar study conducted at Brooke Army Medical Center found an association between that variable and MRSA prevalence, according to the significant statistical P-value ($p < 0.05$) [28]. This is inconsistent with our finding of no statistical association between MRSA prevalence and history of antibiotics use. However, the study conducted in Dar Al Salam Hospital in Tanzania also found no statistically significant association between these variables ($p > 0.05$) [14].

The present study showed no statistical association between nose-picking and nasal carriage of MRSA. This is similar to the findings of a comparative study carried out in Erasmus University Medical Center in the Netherlands [29]. In contrast, a Nigerian study conducted in Lagos Hospital showed a statistical association between nose-picking and nasal carriage of MRSA [30].

Smoking was another risk factor we analysed for the present study. We found no statistical association between nasal carriage of MRSA and smoking. This was similar to the findings of a Chinese study conducted on 33 hospitals in Guangzhou [31]. By contrast, a study conducted by the Dutch Centre for Infectious Disease Control in the Netherlands found a statistical association between smoking and nasal carriage of MRSA [32].

For the variable handwashing, a study conducted in Mubarak Al Kabir Hospital found a statistical association between handwashing and a reduction of nasal carriage of MRSA [33], which is contrary to our finding of no statistical association between these variables.

The antibiotic sensitivity patterns of the *S. aureus* isolates showed that gentamycin, trimethoprim-sulfamethoxazole and linezolid can be used to treat MRSA. Moreover, rifampin and clindamycin could also be used as treatments if their concentrations were increased, since the sensitivity percentage revealed in the present study for both of these was 97.6%. A study conducted in Dar Al Salam and Amana hospitals in Tanzania showed that the all *S. aureus* isolates were sensitive to linezolid, which is one of the treatments we suggest based on the antibiotics sensitivity pattern we identified [14]. A local study conducted in Sohar hospital and Oman Medical College Campus in Oman found MRSA sensitivity percentages of 99%, 93%, 91% and 97% to rifampicin, doxycycline, vancomycin and linezolid, respectively. While this supports our findings regarding the sensitivity of MRSA to linezolid, it differs significantly from our results for vancomycin, which indicates that MRSA may have developed a resistance to vancomycin [17].

Diagnostically, the all detected MRSA in the present study were confirmed by PBP-II test, which showed high sensitivity and specificity of the disc diffusion technique in term of MRSA diagnosis, in comparison, to a study conducted in India in the National Institute of Medical Science and Research,

showed also high sensitivity and specificity of Kirby-Bauer disc diffusion toward a high sensitive and specific CHROMagar™ method, which concluded that the disc diffusion is a highly reliable method to detect MRSA [34], however, the MASTALEX™ method consumed less time in comparison to Kirby-Bauer since disc diffusion required overnight incubation for the phenotypic results to be generated.

In conclusion, the present cross-sectional study investigated the prevalence and the associated risk factors of MRSA colonisation among HCWs at Sultan Qaboos University Hospital. This study indicate the need to implement effective preventive measures in order to control or at least to reduce the emerging of hospital and community-acquired MRSA.

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