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Isolation of antibiotic-resistant pathogenic and potentially pathogenic bacteria from carpets of mosques in Tripoli, Libya

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Objective: Isolation of potentially pathogenic bacteria from carpets in hospitals has been reported earlier, but not from carpets in mosques. The aim of the present study is to determine the pathogenic and potentially pathogenic bacteria that may exist on the carpets of mosques in Tripoli, Libya.

Methods: Dust samples from carpets were collected from 57 mosques in Tripoli. Samples were examined for pathogenic bacteria using standard bacteriological procedures. Susceptibility of isolated bacteria to antimicrobial agents was determined by the disc-diffusion method.

Results: Of dust samples examined, *Salmonella* spp. was detected in two samples (3.5%, 1 in group B and 1 in group C1), *Escherichia coli* in 16 samples (28.1%), *Aeromonas* spp. in one sample (1.8%), and *Staphylococcus aureus* in 12 samples (21.1%). Multiple drug resistance was observed in >16.7% of *E. coli* and in 25% of *S. aureus*.

Conclusion: Contamination of carpets in mosques of Tripoli with antibiotic-resistant pathogenic and potentially pathogenic bacteria may pose a health risk to worshippers, particularly, the very young, the old and the immunocompromised. Worshippers are encouraged to use personal praying mats when praying in mosques.

Keywords: *pathogenic bacteria; antibiotic resistance; carpets; mosques; Tripoli; Libya*

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Al-Qur'an, Islam's holy book, commands Muslims to pray five times a day (1). The act of praying can be performed at any place (i.e. at home, at workplace, etc.), as long as it is clean. However, whenever it is possible, Muslims are encouraged and required to pray in the mosque, particularly, for the Friday prayer. Nowadays, mosques in Libya are usually covered with wall-to-wall carpets. The act of prayer is performed on the carpet covering the prayer hall of the mosque.

In addition to safety (reduced slips and falls), wall-to-wall carpeting can offer advantages both technically and with regard to comfort when compared with other flooring materials (i.e. tile and wood) (2). Isolation of potentially pathogenic bacteria from carpets in hospitals has been reported earlier (2, 3). However, there is a dearth of information in regard to the isolation of bacteria from carpets in residential and communal environments.

The aim of the present study is to determine the pathogenic and potentially pathogenic bacteria that may

exist on the carpets of mosques in Tripoli, Libya. The number of mosques in Tripoli is 647 by mid-August 2010 according to the General Authority of Mosques in Tripoli.

Materials and methods

Dust samples

Dust samples (57 in total) were collected from carpets of 57 mosques in Tripoli during December 2009 and January 2010. Mosques were selected randomly to cover most areas in Tripoli. Carpet dust samples were collected using a 2,000 W household vacuum cleaner. Sampling covers more than 20 m² of the carpet surface area of each mosque for at least 15 min. After each sample is collected and the bag is removed, the vacuum cleaner was left working for at least 10 min before a new bag is replaced for the next sample collection to reduce the possibility of

carryover. The collected samples were transferred to the laboratory and processed within 24 h of collection.

Bacteriology

A suspension was prepared from each sample by adding 10 g of dust to 90 ml of sterile PBS, vortexed for 2 min and left to settle for 10 min. Loopfuls from the surface of each suspension were inoculated onto plates of MacConkey agar and *Salmonella-Shigella* agar (SSA), to isolate members of the family *Enterobacteriaceae* and other Gram-negative bacilli, and onto mannitol-salt agar to isolate *Staphylococcus* spp. In addition, 1 ml from each suspension was added to 10 selenite F broth (SFB) for the enrichment of *Salmonella* and *Shigella* spp. All media were incubated at 37°C. After overnight incubation, a loopful from SFB was inoculated onto SSA and incubated at 37°C overnight.

Isolation of *Aeromonas* spp. was carried out by placing 1 ml of each bacterial suspension being tested into 10 ml alkaline peptone water (pH 8.6) and incubated at 37°C. After an overnight incubation, a loopful of peptone water was inoculated onto ampicillin blood agar (15 mg ampicillin/l) and incubated at 37°C for 18–24 h. Colonies from the agar plates were identified using standard bacteriological procedures (4, 5) and, whenever appropriate, the API 20E system (bioMe'rieux, Marcy l'Etoile, France) was used. Susceptibility of the isolated bacteria to antimicrobial agents was determined according to the guidelines of the Clinical and Laboratory Standards Institute (CLSI) (6). Susceptibility of *Staphylococcus aureus* isolates to methicillin was determined by the cefoxitin disc-diffusion method and the E-test (AB Biodisk, Solna, Sweden). Isolates identified biochemically as *Salmonella* spp. were serotyped at NAMRU#3, Cairo, Egypt. Unless otherwise stated, all media and antibiotics discs used in the present work were obtained from Oxoid, UK.

Results

Of the 57 dust samples examined, from carpets of mosques in Tripoli, *Salmonella* spp. was detected in two samples (3.5%, 1 group B and 1 group C1), *Escherichia coli* in 16 samples (28.1%), *Aeromonas* spp. in one sample (1.8%), and *S. aureus* in 12 samples (21.1%). Table 1 shows the bacteria isolated from dust samples of carpets of mosques in Tripoli, Libya. *Shigella* spp. was not detected in the present study.

Antimicrobial resistance profiles of the isolated bacteria are shown in Table 2. Multiple drug resistance (resistance to three or more antibiotics) was observed in 16.7% of *E. coli* and in 25% of *S. aureus* isolated from carpets of mosques. All (100%) tested bacteria were susceptible to ciprofloxacin.

Table 1. Bacteria isolated from 57 dust samples of carpets of mosques in Tripoli, Libya

Bacteria	No. (%) detected
<i>Escherichia coli</i>	16 (28.1)
<i>Escherichia vulneris</i>	3 (5.3)
<i>Leclercia adecarboxylata</i>	5 (8.8)
<i>Salmonella</i> spp.	2 (3.5)
<i>Enterobacter</i> spp.	29 (50.9)
<i>Pantoea</i> spp.	8 (14)
<i>Klebsiella</i> spp.	8 (14)
<i>Citrobacter</i> spp.	3 (5.3)
<i>Serratia</i> spp.	2 (3.5)
<i>Proteus</i> spp.	2 (3.5)
<i>Providencia</i> spp.	1 (1.8)
<i>Morganella morganii</i>	1 (1.8)
<i>Acinetobacter</i> spp.	3 (5.3)
<i>Pseudomonas</i> spp.	6 (10.5)
<i>Aeromonas</i> spp.	1 (1.8)
Other Gram-negative bacilli	3 (5.3)
<i>Staphylococcus aureus</i>	12 (21.1)
<i>Staphylococcus epidermidis</i>	37 (64.9)

Discussion

There is very little published research on the presence of microorganisms in carpets. Raboobee et al. (8) examined the role of mosque carpets and ablution areas in the spread of tinea pedis and tinea unguium among adult Muslims regularly attending five mosques in Durban, South Africa. They found significantly high prevalence rate of tinea pedis and tinea unguium in the adult Muslims when compared with non-Muslim control group and concluded that this can be attributed to the spread of the fungal organisms in the ablution areas and prayer carpets of the mosques.

In the present study, *Salmonella* spp., *E. coli*, *Aeromonas* spp., and *S. aureus* were detected in carpets from the mosques in Tripoli. *Salmonella* spp. are important foodborne pathogens worldwide. They are the most important cause of bacterial diarrhea among Libyan children (9). Although *E. coli* is part of the normal intestinal flora of humans and animals, several types (i.e. diarrheagenic *E. coli*) are major causes of diarrheal disease, particularly, in children (10). However, the presence of *Salmonella* spp. and *E. coli* on the carpets of mosques is an indicator of fecal contamination. *Aeromonas* spp. are recognized as causative agents of a wide spectrum of diseases in human and animals (11). Studies have shown that some of these organisms are emerging food- and water-borne pathogens of increasing importance (12). Although *Aeromonas* spp. were detected only in a single mosque, their presence, in addition to *Salmonella* and *E. coli*, indicates that a wide variety of

Table 2. Antimicrobial resistance profiles of pathogenic and potentially pathogenic bacteria isolated from carpets of mosques in Tripoli, Libya

Antibiotics	No. (%) resistance				
	<i>Escherichia coli</i> (n = 18) ^a	<i>Salmonella</i> spp. (n = 2)	<i>Aeromonas</i> spp. (n = 1)	Total enteric bacteria (n = 21)	<i>Staphylococcus aureus</i> (n = 12)
Amp	9 (50)	1 (50)	1 (100)	11 (52.4)	7 (58.3)
AMC	NT	NT	NT	NT	4 (33.3)
CTX	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (8.3)
C	1 (5.6)	0 (0.0)	0 (0.0)	1 (4.8)	0 (0.0)
CN	1 (5.6)	0 (0.0)	0 (0.0)	1 (4.8)	0 (0.0)
NA	1 (5.6)	1 (50)	0 (0.0)	2 (9.5)	NT
Cip	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
SXT	3 (16.7)	1 (50)	0 (0.0)	4 (19)	1 (8.3)
Te	14 (77.8)	2 (100)	1 (100)	17 (81)	0 (0.0)
Meth	NT	NT	NT	NT	0 (0.0)
E	NT	NT	NT	NT	3 (25)
FD	NT	NT	NT	NT	2 (16.7)
Van	NT	NT	NT	NT	0 (0.0)

^aTwo different *E. coli* strains isolated in two samples.

Note: NT, not tested; Amp, ampicillin; AMC, amoxicillin/calvulanic acid; CTX, ceftriaxone; C, chloramphenicol; CN, gentamicin; NA, nalidixic acid; Cip, ciprofloxacin; SXT, sulfamethoxazole/trimethoprim; Te, tetracycline; Meth, methicillin; E, erythromycin; FD, fusidic acid; Van, vancomycin.

enteric pathogenic bacteria can be found on carpets in communal environments.

A wide variety of other enteric bacteria were detected in dust samples from carpets of mosques that included *Klebsiella* spp., *Enterobacter* spp., etc. These organisms are found in soil and water and considered as non-pathogenic in healthy individuals.

Most popular carpets today are made of synthetic fibers including nylon, polypropylene, polyester, and polytrimethylene terephthalate (PTT) (13). These fibers do not support bacterial growth and retain little humidity. However, if food is spilled or tracked on the carpet, bacteria will bind and act on it (7). It appears that some of the worshipers performing the prayers introduced the isolated enteric pathogens (i.e. *E. coli*, *Salmonella*, and *Aeromonas* spp.) onto the carpets of the mosques included in the study. Although worshipers are commanded to perform ablution before entering the praying hall, such an act will have no significant effect if the general hygiene of the individual is low and/or suffering from infectious diarrhea, particularly if the individual is very young or old. Animals (i.e. dogs, cats, etc.) may introduce such organisms to carpets, however, their presence in mosques is not allowed in the Islamic tradition.

S. aureus can potentially cause infections that vary from relatively minor skin infections to life threatening systemic illnesses, in both healthy and immunocompromised individuals. The isolation of *S. aureus* from carpets

was expected, as the organism is carried by 25–33% of normal individuals in the anterior nares and skin (14). Recently, de Boer et al. (15) reported the isolation of methicillin-resistant *S. aureus* (MRSA) from environmental samples (including one from a carpet) obtained from the house of a nurse who had persistent MRSA colonization.

No MRSA was isolated in the present study. However, multiple-antimicrobial resistance (resistance to three or more antibiotics) was observed in 25% of *S. aureus* and in 19% of total isolated enteric bacteria (i.e. *E. coli*, *Salmonella*, and *Aeromonas*). No data is available in the literature on the isolation of antimicrobial-resistant pathogenic and potentially pathogenic bacteria from carpets in mosques. Ghenghesh et al. (16) examined 50 drinking water samples collected from 50 mosques in Tripoli. They detected *E. coli* in 14%, *Aeromonas* spp. in 19%, and *Klebsiella* spp. in 26%. In addition, they reported that >79% of the isolated bacteria were resistant to at least one antimicrobial agent.

Bacteria can be transferred to humans and cause disease either by ingestion, inhalation, or transfer to the skin. Leonas (7) carried out a study to determine if transfer of bacteria (*E. coli* and *S. aureus*) and fungi from carpet to human skin does occur. The preliminary findings of the study showed that transfer of bacteria and fungi from carpet to human fingertips does occur. In addition, more *E. coli* are transferred than *S. aureus*. During the process of praying, a Muslim is obliged to go

down to the floor and prostrate by pressing his bare forehead, and putting his palms, knees, and pads of the toes on the floor (17). Therefore, there are possibilities that the pathogenic bacteria detected in the present study may be transmitted to worshippers performing their prayers in mosques examined.

To our knowledge, this study is the first to report on the isolation of antimicrobial-resistant pathogenic and potentially pathogenic bacteria from carpets in mosques. The present study clearly demonstrates that >33% of carpets in mosques examined are contaminated with these bacteria. Such contamination may pose a health risk to worshippers, particularly, the very young, the old, and the immunocompromised. The health and environmental authorities may play an important role in providing guidance and supervision to authorities in charge of mosques in Libya to ensure that carpets in mosques are properly maintained and cleaned. However, it is important to realize that cleaning should not replace basic hygiene practices (e.g. frequent hand washing) but complement it. In addition, the use of personal praying mats may be another alternative for individual worshippers. More studies are required in the future on the hygiene of the environment in mosques, as well as of worshippers in Libya.

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Conflict of interest and funding

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