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SHORT COMMUNICATION

High isolation rates of multidrug-resistant bacteria from water and carpets of mosques

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Objective: There is little information regarding the isolation of antimicrobial-resistant potentially pathogenic bacteria from water and carpets of mosques worldwide. The objective of the present investigation is to determine the bacteriological quality of water and carpets of mosques in Elkhomes city in Libya.
Methods: Potentially pathogenic bacteria were isolated from water samples ($n = 44$) and dust samples from carpets ($n = 50$) of 50 mosques in Elkhomes city, Libya, using standard bacteriological procedures. Susceptibility of isolated bacteria to antimicrobial agents was determined by the disc-diffusion method.
Results: Of the water samples examined, 12 (27.3%) were positive for *Escherichia coli*, 10 (22.7%) for *Klebsiella* spp., and 15 (34.1%) for other enteric bacteria. Of the dust samples of carpets examined, 6 (12%) were positive for *E. coli*, 33 (66%) for *Klebsiella* spp., and 30 (60%) for *Staphylococcus* spp. Multidrug resistance (MDR, resistance to three or more antimicrobial groups) was found among 48.7% (19/37) and 46.9% (30/64) of the examined enterobacteria from water and carpets, respectively, and among 66.7% (20/30) of *Staphylococcus* spp. from carpets. In addition, methicillin-resistant *Staphylococcus aureus* (MRSA) was isolated from a carpet of one mosque.
Conclusion: Presence of multidrug-resistant potentially pathogenic bacteria in examined water and carpets indicate that mosques as communal environments may play a role in the spread of multidrug-resistant bacteria in the community and pose a serious health risk to worshipers.

Keywords: *water*; *carpets*; *mosques*; *potentially pathogenic bacteria*; *multidrug resistance*; *Libya*

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Several studies reported the detection of *Escherichia coli* in holy water in temples and churches in Asia and Europe, respectively (1, 2), but studies on the presence of pathogenic and potentially pathogenic organisms in water sources and carpets of mosques are rare (3, 4). Areas of the mosque where worshipers pray are usually covered with carpets, and though shoes are left outside, prayers entail extensive contact of the legs, hands, and face with the carpet. Worshipers frequent the mosque at least once a week and for a devoted Muslim can be up to 35 times per week. Ablution with pure water is required before performing prayers. Most worshipers use the water provided by the mosque mainly for ablution. During warmer seasons of the year, worshipers, particularly those coming from distant areas, consume drinking water provided by the mosque more frequently. Nowadays, the majority of mosques in Libya use either steeliness steel containers or cold-water dispensers with exchangeable 20 L bottles to provide drinking water for worshipers.

In addition, some information is available on the isolation of bacteria in general and of antimicrobial resistant bacteria from water and carpets of mosques in Tripoli, Libya, but none in other cities. The present investigation was carried out to determine the bacteriological quality of drinking and ablution water and carpets of mosques in Elkhomes city, located on the Mediterranean coast about 100 km southeast of Tripoli with a population of around 200,000. Furthermore, the antimicrobial susceptibility of the isolated bacteria was also determined.

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Materials and methods

Drinking and ablution water samples were collected aseptically from 44 mosques in sterile glass containers. All water samples were examined within 2 hours from collection. All samples were examined for coliforms, *E. coli* and other enterobacteria and *Aeromonas* spp. as previously reported (3). Dust samples were collected from the carpets of 50 mosques in Elkhomes city. Mosques were selected randomly to cover most areas in the city. Carpet dust samples were collected and examined for *E. coli* and other enteric bacteria, *Aeromonas* spp., non-fermentative gram-negative bacilli, and staphylococci as described previously (4).

In addition, isolated enterobacteria, *Aeromonas* spp. and non-fermentative gram-negative bacilli were further identified by the BD Phoenix Automated Microbiology System (PAMS, MSBD Biosciences, Sparks, MD, USA), employing the Phoenix™ NMIC/ID Panels according to the manufacturer's instructions. Susceptibility of the isolated bacteria to antimicrobial agents was determined by the disc-diffusion methods according to the guidelines of the Clinical and Laboratory Standards Institute (CLSI) (5). Susceptibility of staphylococci to methicillin was determined by the cefoxitin disc-diffusion method. The following quality control organisms *E. coli* ATCC 25922, *K. pneumoniae* ATCC 700603, and *Pseudomonas aeruginosa* ATCC 27853 were used with gram-negative bacilli and *S. aureus* ATCC 29213 and *S. aureus* ATCC 25923 with staphylococci.

Results

The MPN (per 100 ml) of coliforms was less than 2–220 (mean = 14.5). Of the water samples from 44 mosques investigated, 12 (27.3%) were positive for *E. coli* and 10 (22.7%) for *Klebsiella* spp. Table 1 shows the enterobacteria isolated from water samples from mosques in Elkhomes city. Of the dust samples of carpets from 50 mosques examined, 6 (12%) were positive for *E. coli*, 33 (66%) for *Klebsiella* spp., and 30 (60%) for staphylococci, including one isolates identified as *S. aureus*. Gram-negative bacilli isolated from carpets of mosques in Elkhomes city are shown in Table 2. *Salmonella* spp. and *Shigella* spp. were not isolated in the present study.

Antimicrobial susceptibility testing showed that 80% (27/37) and 64.9% (24/37) of total enterobacteria from water were resistant to ampicillin and amoxicillin–clavulanic acid, respectively. Antimicrobial resistance profiles of enterobacteria isolated from water obtained from mosques are shown in Table 3. Lower resistance rates to several antimicrobials were observed among *E. coli* compared with *Klebsiella* spp. and other enterobacteria from water samples. Resistance to ampicillin and amoxicillin-clavulanic acid was observed among 67.2% (43/64) and 43.8% (28/64) of enterobacteria from carpets, respectively. Table 4 shows the antimicrobial resistance profiles of enterobacteria isolated from carpets of mosques in city of Elkhomes.

Table 1. Enterobacteria isolated from water obtained from 44 mosques in Elkhomes city

Organism	No (%) positive
Escherichia coli	12 (27.3)
Klebsiella oxytoca	2 (4.6)
Klebsiella pneumoniae	1 (2.3)
Klebsiella spp.	7 (16.9)
Citrobacter freundii	3 (6.8)
Citrobacter spp.	1 (2.3)
Enterobacter aerogenes	2 (4.6)
Serratia spp.	7 (16.9)
Proteus mirabilis	1 (2.3)
Hafnia alvei	1 (2.3)

Multidrug resistance (MDR, resistance to three or more antimicrobial groups) was found among 48.7% (19/37) and 46.9% (30/64) of enterobacteria from water

Table 2. Gram-negative bacilli isolated from carpets of 50 mosques in Elkhomes city

Organism	No (%) positive
Escherichia coli	6 (12)
Escherichia hermanii	1 (2.0)
Klebsiella pneumoniae	4 (8.0)
Klebsiella spp.	29 (58%)
Citrobacter freundii	1 (2.0)
Citrobacter spp.	2 (4.0)
Enterobacter aerogenes	2 (4.0)
Enterobacter amnigenus	2 (4.0)
Enterobacter cloacae	5 (10)
Enterobacter spp.	2 (4.0)
Hafnia alvei	9 (18)
Kluyvera ascorbata	1 (2.0)
Leclercia adecarboxylata	1 (2.0)
Pantoea agglomerans	2 (4.0)
Proteus spp.	13 (26)
Serratia fonticola	1 (2.0)
Serratia marcescens	1 (2.0)
Serratia spp.	3 (6.0)
Yersinia pseudotuberculosis	1 (2.0)
Yersinia spp.	5 (10)
Aeromonas caviae	1 (2.0)
Aeromonas hydrophila	1 (2.0)
Vibrio spp.	1 (2.0)
Pseudomonas luteola	1 (2.0)
Pseudomonas spp.	3 (6.0)
Stentrophomonas maltophila	5 (10)
Acinetobacter spp.	1 (2.0)

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Table 3. Antimicrobial resistance of enterobacteria isolated from water obtained from mosques in Elkhomes city

Antimicrobial agent	No (%) resistant to			
	Escherichia coli ($n=12$)	*Klebsiella* spp. ($n=10$)	Other enterobacteria[1] ($n=15$)	Total ($n=37$)
Ampicillin	4 (33.3)	9 (90)	14 (93.3)	27 (80)
Amoxicillin-clavulanic acid	4 (33.3)	9 (90)	11 (73.3)	24 (64.9)
Ceftriaxone	0 (0.0)	0 (0.0)	5 (33.3)	5 (13.5)
Imipenem	0 (0.0)	4 (40)	7 (46.7)	11 (29.7)
Chloramphenicol	0 (0.0)	4 (40)	11 (73.3)	15 (40.5)
Amikacin	0 (0.0)	3 (30)	9 (60)	12 (32.4)
Gentamicin	0 (0.0)	3 (30)	10 (66.7)	13 (35.1)
Streptomycin	3 (25)	8 (80)	13 (86.7)	24 (64.9)
Naladixic acid	1 (8.3)	2 (20)	10 (66.7)	13 (35.1)
Ciprofloxacin	1 (8.3)	1 (10)	0 (0.0)	2 (5.4)
Nitrofurantoin	1 (8.3)	4 (40)	11 (73.3)	16 (43.2)
Trimethoprim-sulfamethoxazole	2 (16.7)	1 (10)	9 (60)	12 (32.4)
MDR[2]	1 (8.3)	7 (70)	11 (73.3)	19 (48.7)

[1]Other enterobacteria include seven *Serratia* spp., two *Enterobacter aerogenes*, four *Citrobacter* spp., one *Proteus mirabilis* and one *Hafnia alvei*. [2]MDR: multidrug resistance (resistance to three or more antimicrobial groups).

and carpets, respectively. In addition, MDR was observed in 100% of non-fermentative bacilli isolated from carpets (Supplemental table).

Of the 30 staphylococci isolated from carpets, 25 (83.3%) were resistant to ampicillin, 17 (56.7%) to amoxicillin-clavulanic acid, 15 (50%) to ceftriaxone, 9 (30%) to imipenem, 16 (53.3%) to chloramphenicol, 1 (3.3%) to amikacin, 13 (43.3%) to streptomycin, 3 (10%) to ciprofloxacin, 14 (47.7%) to erythromycin, and 11 (36.7%) to tetracycline. Resistance to methicillin was detected among 13 (43.3%) staphylococci isolates, including the only *S. aureus* (i.e. MRSA) isolated in the present work from carpets. MDR was detected among 66.7% (20/30) of staphylococci isolates from carpets.

Discussion

Mashat (6) found *E. coli* in 13.2% of 68 water samples from small tanks in the dooryard of mosques in Makkah, Saudi Arabia. Here, *E. coli* was detected in 27.3% of water samples from mosques. Detection of *E. coli* indicates

Table 4. Antimicrobial resistance of enterobacteria isolated from carpets of mosques in Elkhomes city

Antimicrobial agent	No (%) resistant to			
	Escherichia coli ($n=6$)	*Klebsiella* spp. ($n=33$)	Other enterobacteria ($n=25$)[1]	Total ($n=64$)
Ampicillin	4 (66.7)	23 (69.7)	16 (64)	43 (67.2)
Amoxicillin-clavulanic acid	3 (50)	16 (48.5)	9 (36)	28 (43.8)
Ceftriaxone	1 (16.7)	10 (30.3)	10 (40)	21 (32.8)
Imipenem	1 (16.7)	5 (15.2)	3 (12)	9 (14.1)
Chloramphenicol	2 (33.3)	10 (30.3)	10 (40)	22 (34.4)
Amikacin	1 (16.7)	4 (12.1)	1 (64)	6 (9.4)
Gentamicin	2 (33.3)	5 (15.2)	2 (8)	9 (14.1)
Streptomycin	2 (33.3)	6 (18.2)	9 (36)	17 (26.6)
Nalidixic acid	2 (33.3)	15 (45.5)	14 (56)	31 (48.4)
Ciprofloxacin	2 (33.3)	7 (21.2)	2 (8)	11 (17.2)
Nitrofurantoin	2 (33.3)	13 (39.4)	13 (52)	28 (43.8)
Trimethoprin-sulfamethoxazole	4 (66.7)	8 (24.2)	4 (16)	16 (25)
MDR[2]	3 (50)	14 (42.4)	13 (52)	30 (46.9)

[1]Other enterobacteria include nine *Hafnia alvei*, two *Citrobacter* spp., two *Enterobacter amnigenus*, two *Enterobacter* spp., two *Pantoea agglomerans*, three *Serratia* spp. and five *Yersinia* spp. [2]MDR: multidrug resistance (resistance to three or more antimicrobial groups).

direct or indirect contamination of water by animal or human feces, which in turn means the possible presence of serious enteric pathogens that include among others *Salmonella* spp., diarrheagenic *E. coli*, and enteric viruses in such water sources.

Rahouma *et al*. isolated *Salmonella* spp. from 3.5% and *E. coli* from 28% of carpets of mosques in Tripoli, Libya (4). Contrary to their findings, no *Salmonella* spp. were isolated in the present study; however, *E. coli* was detected at a lower rate of 12% from carpets of mosques in Elkhomes city. As animals are not allowed into mosques, the presence of *E. coli* in carpets of mosques is an indicator of human fecal contamination.

Studies from Libya reported high resistance rates against ampicillin, trimethoprim-sulfamethoxazole, and cephalosporins among enteric bacteria isolated from different sources (7). We found high resistance rates among enterobacteria from water and carpet samples from Elkhomes mosques to aforementioned drugs (Tables 3 and 4). Rahouma *et al*. (4) reported lower rates of resistance for ampicillin (50%), trimethoprim-sulfamethoxazole (19%), and ceftriaxone (0.0%). They only examined *E. coli* and *Salmonella* isolates but not other enterobacteria, which may explain the lower resistance rates observed by them.

A previous study from Tripoli examined 10 *S. aureus* samples isolated from carpets of mosques and found none were MRSA (4). We found that more than 43% of staphylococci isolates were resistant to methicillin, including one MRSA. To our knowledge, this is the first report of MRSA isolated from a carpet of a mosque.

Our finding of more than 46% of enterobacteria from water and carpets, and 100% of non-fermentative bacilli and more than 66% of *Staphylococcus* spp. from carpets were MDR indicate that mosques as communal environments may play a role in the spread of multidrug-resistant bacteria in the community and pose a serious health risk to worshipers, particularly the old and individuals with compromised immunity. The mosque administration should provide good quality ablution and drinking water and frequently clean the carpets of the mosque using the expertise of local carpet-cleaning companies. In addition, the local health authorities should cooperate with administration of mosques in educating worshipers on the importance of personnel hygiene and hand washing to protect the health of worshipers and minimize the spread of multidrug-resistant bacteria in the community.

Conflict of interest and funding

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