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Contents lists available at ScienceDirect

## American Journal of Infection Control

journal homepage: [www.ajicjournal.org](http://www.ajicjournal.org)

## Major Article

## Acquisition of respiratory and gastrointestinal pathogens among health care workers during the 2015 Hajj season



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## Key Words:

Respiratory  
Gastrointestinal  
Carriage

**Background:** Data on the risk of transmission of infection to health care workers (HCWs) serving ill pilgrims during the Hajj is scarce.

**Methods:** Two cohorts of HCWs, the first serving Hajj pilgrims in Mecca and the second serving patients in Al-Ahsa, were investigated for respiratory and gastrointestinal symptoms and pathogen carriage using multiplex polymerase chain reaction before and after the 2015 Hajj.

**Results:** A total of 211 HCWs were enrolled of whom 92 were exposed to pilgrims (Mecca cohort), whereas 119 were not exposed (Al-Ahsa cohort). Symptoms were observed only in HCWs from the Mecca cohort, with 29.3% experiencing respiratory symptoms during the Hajj period or in the subsequent days and 3.3% having gastrointestinal symptoms. Acquisition rates of at least 1 respiratory virus were 14.7% in the Mecca cohort and 3.4% in the Al-Ahsa cohort ( $P = .003$ ). Acquisition rates of at least 1 respiratory bacterium were 11.8% and 18.6% in the Mecca and Al-Ahsa cohorts, respectively ( $P = .09$ ). Gastrointestinal pathogens were rarely isolated in both cohorts of HCWs and acquisition of pathogens after the Hajj was documented in only a few individuals.

**Conclusions:** HCWs providing care for pilgrims both acquire pathogens and present symptoms (especially respiratory symptoms) more frequently than those not working during Hajj.

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Every year, approximately 2–3 million Muslims congregate in Mecca, Kingdom of Saudi Arabia (KSA), to perform the Hajj.<sup>1</sup> The crowded conditions within a confined area and the close contact with others, particularly during rituals, may lead to an increased risk of pilgrims acquiring and spreading infectious diseases.<sup>2</sup> Respiratory tract infections (RTIs) are the most common infections transmitted among pilgrims, and the majority of whom will develop RTI symptoms

during their few weeks in Saudi Arabia, mostly due to viral infection and notably rhinovirus and influenza viruses.<sup>3,4</sup> Cough attack rates over 90% have been recorded among pilgrims from various nationalities.<sup>4</sup> Gastrointestinal infections, although less frequent than RTIs, may also affect Hajj pilgrims. For instance, a diarrhea attack rate of 23% was observed in a cohort of French pilgrims.<sup>5</sup>

Each Hajj season, thousands of health care workers (HCWs) are drafted from across the Kingdom to oversee and provide health care during Hajj. This workforce may be at increased risk of acquiring infection during the event. Although many studies regarding communicable disease during Hajj have been conducted in pilgrims, not much has been conducted among HCWs. One study investigated respiratory viruses among HCWs treating pilgrims during the 2009

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Funding/support: This work was sponsored by the Saudi Ministry of Health.

Conflicts of interest: None to report.

Hajj and detected rhinovirus and coronavirus 229E in 12.6% and 0.6% of the participants, respectively.<sup>6</sup> Rhinovirus was detected in 21% of those who had respiratory symptoms during Hajj.

Transmission of respiratory infections in controlled medical settings is well known.<sup>7</sup> However, the risk of acquisition and transmission of infections in such settings during the Hajj is even more significant first, infected pilgrims returning from the Hajj may assist in a wider spread outside the borders of the Kingdom, and second, Hajj HCWs may serve as a vehicle to transmit infections to other hospitals within the Kingdom on return to work post-Hajj. Today, this is an even bigger concern in the context of the ongoing detection of Middle East Respiratory Syndrome (MERS) coronavirus infections in the Arabian Peninsula as a potential pandemic virus.<sup>8</sup>

This study was conducted with the aim to estimate the prevalence of respiratory and gastrointestinal symptoms, as well as to determine the acquisition of potential respiratory and gastrointestinal pathogens among HCWs attending pilgrims during the 2015 Hajj season and comparing them with HCWs not serving in Hajj.

## METHODS

### *Participants and study design*

Two cohorts of HCWs were investigated. The Mecca cohort attended to the 2015 Hajj pilgrim patients at various hospitals at the holy site of Mina, Mecca province, in Western KSA. These were: Mina New Street Hospital, Mina Emergency Hospital, Mina Al-Jisr Hospital, and Mina Al-Wadi Hospital. The Al-Ahsa cohort attended non-pilgrim patients at various hospitals in Al-Ahsa in Eastern KSA approximately 1200 km from Mina. These were: King Fahad Hospital, Prince Sultan Cardiac Center, and Prince Saud Ben Jalawi Hospital. HCWs were asked to answer a standardized questionnaire that collected information on demographics, vaccination status, and chronic conditions. Information on symptoms during the Hajj and during the following 2 weeks were also collected.

Participants were asked to fill in the questionnaire and to provide pre-Hajj (September 15, 2015 to September 20, 2015) and post-Hajj (September 26, 2015 to October 4, 2015) samples. During the period September 15, 2015 to October 4, 2015, HCWs were followed for the development of respiratory or gastrointestinal symptoms. HCWs were then followed-up by telephone (October 4, 2015 to November 4, 2015) to collect information regarding development of symptoms in the 2 weeks after Hajj.

### *Respiratory and rectal specimens*

Nasopharyngeal (NP) and rectal swabs were collected from each participant before (September 15, 2015 to September 20, 2015) and after the Hajj (September 26, 2015 to October 4, 2015) using commercial rigid cotton-tipped swab applicators (Remel, Lenexa, KS), placed in universal transport medium (Remel) at the time of collection and stored in a  $-80^{\circ}\text{C}$  freezer within 48 hours of collection. Respiratory samples (NP swabs and sputum) and/or rectal swabs were also collected from HCWs experiencing symptoms during Hajj, as appropriate. The specimens were transported in dry ice to Aix-Marseille University, France for analysis after the end of the sampling period.

### *Extraction of total nucleic acids*

A 200- $\mu\text{L}$  volume of sample was transferred to a 96 wells S-Bloc (Qiagen, Venlo, Netherlands) for purification using the Cador Pathogen 96 QIacube HT kit run on a QIacube HT biorobot, according to the manufacturer's recommendations. Total nucleic acids were eluted in 90  $\mu\text{L}$  and stored at  $-80^{\circ}\text{C}$  until processing.

### *Detection of pathogens*

All respiratory pathogens were tested using the FTD Respiratory pathogens 33 and the FTD hCoV-EMC kits following manufacturer's recommendations (Launch Diagnostics Ltd, Kent, England) except for *Coxiella burnetii* DNA, which detection was performed according to previously described protocols.<sup>9</sup>

All enteric pathogens were tested using the FTD Viral gastroenteritis, the FTD Bacterial gastroenteritis, the FTD Stool parasites, and the FTD EPA kits following manufacturer's recommendations (Launch Diagnostics Ltd), except for *Tropheryma whipplei* DNA and human cytomegalovirus DNA, in which detection was performed according to previously described protocols.<sup>10,11</sup>

Polymerase chain reaction (PCR) and reverse transcription-PCR reactions were performed using CFX96 Biorad thermal cyclers (Bio-Rad Laboratories, Inc., Hercules, CA).

## STATISTICAL ANALYSIS

Characteristics of the study population were summarized as frequencies and percentages for qualitative variables and as means, range, and SDs for quantitative variables. Univariate analyses were performed using the t test, the Pearson  $\chi^2$  test or the Fisher exact test, as appropriate, to compare carriage and acquisition rates between the 2 cohorts and to investigate the associations between clinical symptoms and NP, and rectal pathogen carriage. All tests for significance were 2-sided and *P* values  $<.05$  were considered statistically significant. All analyses were done using SPSS Version 21.0 (IBM Corp, Armonk, NY) software program.

## ETHICS

The study was approved by the King Fahad Medical City ethics committee and the institutional review board. All participants were informed about the study and consented to participate. The study was conducted in accordance with the ethics committee guidelines and good clinical practices recommended by the Declaration of Helsinki and its amendments.

## RESULTS

### *Demographics, vaccination status, and chronic medical conditions*

A total of 211 HCWs were enrolled of whom 92 (43.6%) were exposed to pilgrims (Mecca cohort), whereas 119 (56.4%) were not exposed (Al-Ahsa cohort). Most HCWs were in the 20–40 year age range (85.4%), were women (73.1%), non-Saudi (68.2%), and nurses (77.8%) (Table 1). Over 60% of HCWs were immunized against meningitis, but only 11.6% were vaccinated against invasive pneumococcal disease. Immunization rate against influenza was 47% in 2015. Only 9.0% were current smokers and the prevalence of chronic conditions was low (Table 1). Significant differences were observed between the 2 cohorts with those in Mecca being older, with a higher proportion of men, Saudi nationals, and physicians compared with HCWs in the Al-Ahsa cohort. Mecca HCWs were also more likely to be immunized against meningitis and influenza and to be smokers (Table 1). No differences in underlying health conditions were observed between the two cohorts (Table 1).

### *Clinical symptoms*

Clinical symptoms were reported only in HCWs from the Mecca cohort, whereas HCWs from Al-Ahsa were all asymptomatic during the study period. Clinical symptoms were reported in 31.5% (29 of 92) of the Mecca cohort, most of which (82.8%, 24 of 29) were

**Table 1**  
Demographic and baseline characteristics of health care workers

Characteristic	Mecca cohort (n = 92)	Al-Ahsa cohort (n = 119)	P value
Mean age, y (SD; age range)	35.3 (8.1; 24–64)	31.5 (7.3; 25–62)	.001 <sup>†</sup>
<b>Age groups, Number (%)</b>			
20–40 years	68 (84.0)	96 (86.5)	
41–60 years	11 (13.6)	14 (12.6)	
>60 years	2 (2.5)	1 (0.9)	
<b>Sex, Number (%)</b>			<10 <sup>−3†</sup>
Male	46 (50.0)	10 (8.6)	
Female	46 (50.0)	106 (91.4)	
<b>Nationality, Number (%)</b>			<10 <sup>−3†</sup>
Saudi	51 (60.7)	13 (11.1)	
Non-Saudi	33 (39.3)	104 (88.9)	
<b>Occupation*, Number (%)</b>			.001 <sup>†</sup>
Medical doctor	24 (27.3)	10 (8.7)	
Nurse	56 (63.6)	102 (88.7)	
Other	8 (9.1)	3 (2.6)	
<b>Vaccination status, Number (%)</b>			
Meningitis	81 (88.0)	47 (39.8)	<10 <sup>−3†</sup>
Invasive pneumococcal disease	8 (15.1)	10 (9.8)	.11
Influenza (2015)	59 (75.6)	20 (22.2)	<10 <sup>−3†</sup>
<b>Risk factors and chronic conditions, Number (%)</b>			
Smoking habit	17 (18.5)	2 (1.7)	<10 <sup>−3†</sup>
Chronic respiratory disease	3 (3.3)	2 (1.7)	.59
Chronic cardiac disease	2 (2.2)	0	2.64
Hypertension	4 (4.3)	2 (1.7)	1.34
Chronic kidney disease	1 (1.1)	0	1.34
Chronic gastrointestinal disease	2 (2.2)	0	2.64
Diabetes mellitus	3 (3.3)	3 (2.5)	.11
Cancer	0	0	-
Immune deficiency	1 (1.1)	0	1.33

\*Medical doctor versus other.

<sup>†</sup>Statistically significant difference.

reported only post-Hajj. Four HCWs experienced symptoms only during the Hajj and 1 during and after the Hajj. HCWs experienced symptoms lasting between 2 and 15 days. Nearly 30% (27 of 92) of HCWs from the Mecca cohort experienced respiratory symptoms during the Hajj period and up to 2 weeks after the event, and 3 (3.3%) reported gastrointestinal symptoms (Table 2). Fever, cough, and sore throat were the most common symptoms reported in respectively 15.2%, 18.5%, and 14.1% of the Mecca cohort HCWs during the study period.

**Table 2**  
Clinical symptoms of health care workers during the study period

Characteristic	Mecca cohort* (n = 92)	Al-Ahsa cohort (n = 119)
Fever	12 (13.0)	0
Headache	2 (2.2)	0
<b>Respiratory symptoms</b>		
Cough	14 (15.2)	0
Sore throat	12 (13.0)	0
Runny nose	5 (5.4)	0
Voice failure	0	0
Dyspnea	1 (1.1)	0
Chest pain	0	0
Sputum	4 (4.3)	0
At least 1 respiratory symptom	27 (29.3)	0
<b>Gastrointestinal symptoms</b>		
Nausea	1 (1.1)	0
Vomiting	0	0
Diarrhea	3 (3.3)	0
Abdominal pain	2 (2.2)	0
At least 1 gastrointestinal symptom	3 (3.3)	0

\*Five health care workers reported symptoms during the Hajj (1 had dyspnea, nausea, diarrhea, and abdominal pain; 1 had rhinitis, diarrhea, and abdominal pain; 1 had cough, sore throat, and headaches; 1 had rhinitis, sore throat, and sputum; 1 had cough, sputum, rhinitis, sore throat, and headaches).

### Detection of pathogens in respiratory and rectal samples

The median time between pre- and post-Hajj sampling was 11 days (range 8–18 days). At least 1 respiratory virus was isolated in 13.5% of pre-Hajj samples in the Mecca cohort, compared to 4.2% in the Al-Ahsa cohort (Table 3). The overall prevalence of respiratory virus carriage increased to 21.1% in post-Hajj samples in the Mecca cohort, whereas it did not change in the Al-Ahsa cohort (4.2%). Post-Hajj respiratory carriage was significantly higher in the Mecca cohort compared to the Al-Ahsa cohort ( $P < 10^{-3}$ ). Acquisition rates of at least 1 respiratory virus were respectively 14.7% in the Mecca cohort and 3.4% in the Al-Ahsa cohort ( $P = .003$ ).

Rhinovirus accounted for the majority of positive samples, and its prevalence was significantly higher in post-Hajj samples (19.7%) compared with pre-Hajj samples (6.7%) in the Mecca group ( $P = .014$ ), whereas no significant differences were observed in the Al-Ahsa group (3.4% vs 2.5%;  $P = .72$ ). Rhinovirus acquisition rate in the Mecca cohort (16.2%) was significantly higher than in the Al-Ahsa cohort (2.5%) with  $P = .001$ .

At least 1 respiratory bacterium was isolated in 32.6% of pre-Hajj samples in the Mecca cohort, compared to 37.0% in the Al-Ahsa cohort (Table 3). Compared with pre-Hajj samples, no significant differences were observed in the overall prevalence of respiratory bacterial carriage in post-Hajj samples in both cohorts (28.2% and 36.4%, respectively). Acquisition rates of at least 1 respiratory bacterium were respectively 11.8% in the Mecca cohort and 18.6% in the Al-Ahsa cohort ( $P = .09$ ).

*Staphylococcus aureus* and *Klebsiella pneumoniae* accounted for the majority of positive cases either in pre- or post-Hajj samples. In the Al-Ahsa cohort, the prevalence of *Staphylococcus aureus* significantly increased from 12.6% before the Hajj to 33.9% after the Hajj ( $P < 10^{-3}$ ), whereas the prevalence of *K pneumoniae* significantly

**Table 3**  
Prevalence of respiratory pathogens among health care workers before and after the 2016 Hajj

Respiratory Pathogens	Mecca cohort			Al-Ahsa cohort		
	Before Hajj (n = 89) Number (%)	After Hajj (n = 71) Number (%)	P value	Before Hajj (n = 119) Number (%)	After Hajj (n = 118) Number (%)	P value
<b>Viruses</b>						
Influenza virus C	1 (1.1)	0 (0.0)	1	0 (0.0)	0 (0.0)	-
Human coronavirus 229E	1 (1.1)	0 (0.0)	1	1 (0.8)	0 (0.0)	1
Human coronavirus NL63	2 (2.2)	0 (0.0)	.50	0 (0.0)	1 (0.8)	.50
Human coronaviruses	3 (3.4)	0 (0.0)	.25	1 (0.8)	1 (0.8)	1
Human enterovirus	0 (0.0)	1 (1.4)	.44	0 (0.0)	0 (0.0)	-
Human metapneumovirus	2 (2.2)	0 (0.0)	.50	0 (0.0)	0 (0.0)	-
Human parainfluenza virus 4	0 (0.0)	0 (0.0)	-	1 (0.8)	1 (0.8)	1
Human parainfluenza viruses	0 (0.0)	0 (0.0)	-	1 (0.8)	1 (0.8)	1
Human respiratory syncytial virus	0 (0.0)	1 (1.4)	.44	0 (0.0)	0 (0.0)	-
Human rhinovirus	6 (6.7)	14 (19.7)	.014 <sup>†</sup>	3 (2.5)	4 (3.4)	.72
Other viruses*	0 (0.0)	0 (0.0)	-	0 (0.0)	0 (0.0)	-
At least 1 virus	12 (13.5)	15 (21.1)	.20	5 (4.2)	5 (4.2)	1
<b>Bacteria and fungi</b>						
<i>Haemophilus influenzae</i>	2 (2.2)	3 (4.2)	.66	5 (4.2)	2 (1.7)	.45
<i>Klebsiella pneumoniae</i>	8 (9.0)	10 (14.1)	.31	21 (17.6)	4 (3.4)	<10 <sup>-3†</sup>
<i>Moraxella catarrhalis</i>	1 (1.1)	2 (2.8)	.58	1 (0.8)	1 (0.8)	1
<i>Staphylococcus aureus</i>	17 (19.1)	10 (14.1)	.40	15 (12.6)	40 (33.9)	<10 <sup>-3†</sup>
<i>Streptococcus pneumoniae</i>	2 (2.2)	1 (1.4)	1	7 (5.9)	1 (0.8)	.066
Other bacteria and fungi <sup>‡</sup>	0 (0.0)	0 (0.0)	-	0 (0.0)	0 (0.0)	-
At least 1 bacteria or fungi	29 (32.6)	20 (28.2)	.55	44 (37.0)	43 (36.4)	.53

\*Influenza virus A/H3N2, influenza virus B, influenza virus 2009 A (H1N1), human adenovirus, human bocavirus, human coronavirus HKU1, human coronavirus OC43, Middle East Respiratory Syndrome coronavirus, human cytomegalovirus, human parainfluenza virus 1, human parainfluenza virus 2, human parainfluenza virus 3, human parechovirus.

<sup>†</sup>Statistically significant difference.

<sup>‡</sup>*Bordetella pertussis*, *Chlamydia pneumoniae*, *Coxiella burnetii*, *Legionella* spp, *Mycoplasma pneumoniae*, *Pneumocystis jirovecii*, *Salmonella* spp.

decreased from 17.6% pre-Hajj to 3.4% post-Hajj ( $P < 10^{-3}$ ). *Staphylococcus aureus* acquisition rate was 5.9% in the Mecca cohort compared to 26.3% in the Al-Ahsa cohort ( $P = .002$ ). *K pneumoniae* acquisition rate was 10.3% in the Mecca cohort compared to 1.7% in the Al-Ahsa cohort ( $P = .018$ ). No significant effect of tobacco smoking, chronic medical conditions, and vaccination status was observed on the acquisition rates of respiratory viruses in the Mecca cohort. No statistically significant association was observed between respiratory pathogen carriage and clinical symptoms in the Mecca cohort.

Enteric pathogens were rarely isolated in both cohorts of HCWs, and acquisition of pathogens after the Hajj was documented in only a few individuals (Table 4). Of note, *Clostridium difficile* was acquired by

1 HCW in the Mecca cohort, and *Tropheryma whipplei* by 2 HCWs in the Al-Ahsa cohort. No statistically significant association was observed between rectal pathogen carriage and clinical symptoms in both cohorts.

#### Pathogens detected during the Hajj episodes among HCWs with symptoms

Five HCWs in the Mecca cohort were sampled at the onset of symptoms during the Hajj. One was positive for *Haemophilus influenzae*, 1 had a dual infection with rhinovirus/*H influenzae*, 1 with rhinovirus/*K pneumoniae*, and 2 were negative.

**Table 4**  
Prevalence of rectal pathogens among health care workers before and after the 2016 Hajj

Rectal Pathogen	Mecca cohort			Al-Ahsa cohort		
	Before Hajj (n = 53) Number (%)	After Hajj (n = 37) Number (%)	P value	Before Hajj (n = 110) Number (%)	After Hajj (n = 117) Number (%)	P value
<b>Viruses</b>						
Adenovirus	0 (0.0)	0 (0.0)	-	1 (0.9)	0 (0.0)	.48
Norovirus G1	0 (0.0)	0 (0.0)	-	0 (0.0)	1 (0.9)	1
Other viruses*	0 (0.0)	0 (0.0)	-	0 (0.0)	0 (0.0)	-
<b>Bacteria</b>						
<i>Clostridium difficile</i>	0 (0.0)	1 (2.7)	.41	0 (0.0)	0 (0.0)	-
Verocytotoxin-producing <i>Escherichia coli</i>	0 (0.0)	1 (2.7)	.41	3 (2.7)	0 (0.0)	.112
<i>Salmonella</i> spp	0 (0.0)	0 (0.0)	-	1 (0.9)	0 (0.0)	.48
<i>Tropheryma whipplei</i>	1 (1.9)	0 (0.0)	1	1 (0.9)	3 (2.6)	.62
Other bacteria <sup>‡</sup>	0 (0.0)	0 (0.0)	-	0 (0.0)	0 (0.0)	-
<b>Protozoa</b>						
<i>Giardia lamblia</i>	1 (1.9)	0 (0.0)	1	0 (0.0)	0 (0.0)	-
Other protozoa <sup>‡</sup>	0 (0.0)	0 (0.0)	-	0 (0.0)	0 (0.0)	-
At least 1 pathogen	2 (3.8)	2 (5.4)	1	6 (5.5)	4 (3.4)	.53

\*Astrovirus, Enterovirus, Norovirus G2, Parechovirus, Rotavirus, Sapovirus.

<sup>‡</sup>*Campylobacter coli*, *Campylobacter jejuni*, *Campylobacter lari*, *Enteroinvasive Escherichia coli*, *Shigella* spp, *Yersinia enterocolitica*.

<sup>‡</sup>*Cryptosporidium* spp, *Entamoeba histolytica*.

## DISCUSSION

Previous studies addressing the prevalence of respiratory infection in Hajj HCWs are scant. In a study conducted among 250 personnel (25.6% of whom were physicians or nurses) serving at 2 Hajj mission hospitals during the 2004 season, a 22.6% attack rate of acute respiratory infections during and after the Hajj was observed with acute respiratory infections defined by the association of at least 1 constitutional symptom (fever, headaches, and myalgia) and at least 1 respiratory symptom.<sup>12</sup> In a study conducted among 120 HCWs from the Saudi Ministry of Health (MOH) and other Hajj medical missions during the 2009 season, 10.6% reported respiratory symptoms during the Hajj, and 12.5% were found infected by at least 1 virus post-Hajj comparing to 7.5% pre-Hajj using a PCR assay.<sup>6</sup> All positive cases were due to rhinovirus, but 1 post-Hajj case was due to coronavirus 229E.<sup>6</sup>

We confirm in the current work that HCWs attending ill Hajj pilgrims present frequently with respiratory symptoms (29%) during and soon after the Hajj period. Additionally, we show that diarrhea is rare (3%). Such symptoms were not observed in another cohort of HCWs attending non-pilgrim patients in another region of Saudi Arabia during the same period of time. HCWs attending pilgrims reported symptoms that lasted up to 2 weeks. No symptomatic HCWs reported loss of workdays during the Hajj in our study, and the number of sick days because of illness post-Hajj was not recorded. Nevertheless, illness during or post-Hajj among HCWs does not only affect the wellbeing of the HCWs involved, but may also have an impact on work productivity, delivery of health care services, as well as potentially an economic cost. This is especially relevant during Hajj when the health care system is under a significant amount of stress and operating at near surge capacity in many Hajj areas. Numerous studies reported that employee absence is related to decreased job productivity and important economic costs including in the health care sector.<sup>13–15</sup> Further studies are needed for a better understanding of the impact of Hajj-related illness among HCWs.

Although no correlation was observed between clinical symptoms and detection of respiratory pathogens, we report that HCWs exposed to ill pilgrims carried and acquired a number of respiratory pathogens including acquisition of rhinovirus, enterovirus, respiratory syncytial virus, *H influenzae*, *K pneumoniae*, *Moraxella catarrhalis*, *Staphylococcus aureus*, and *Streptococcus pneumoniae*. These organisms have been shown to also be commonly carried by and transmitted among Hajj pilgrims.<sup>16–18</sup> Significant acquisition of rhinovirus in superior airways of Mecca HCWs was recorded at a rate of 16.2%, whereas the acquisition rates of the 2 most frequently detected bacterial pathogens (*K pneumoniae* and *Staphylococcus aureus*) among this cohort were 10.3% and 5.9%, respectively. In a carriage study among pilgrims from 13 countries in 2013 Hajj, acquisition rates of rhinovirus, *K pneumoniae*, and *Staphylococcus aureus* were 34.1%, 3.9%, and 7.5%, respectively.<sup>19</sup> Influenza A and B viruses were not isolated, which may be owing to the relatively high rate of influenza vaccination, notably in the Mecca cohort (76%). Lower rates of influenza vaccination were recorded among Hajj HCWs in 2003 (6%) and 2009 (35%).<sup>19,20</sup> *Streptococcus pneumoniae* carriage was documented in a few HCWs, notably in the Al-Ahsa cohort, in which the vaccination rate against invasive pneumococcal disease was low (10%).

No MERS coronavirus was identified in HCWs either before or after Hajj. This is in accordance with previous reports showing lack of MERS coronavirus carriage and infection among Hajj pilgrims.<sup>21–26</sup>

Acquisition and carriage of potentially pathogenic organisms by HCWs do not only constitute a risk for development of disease by the HCWs carriers themselves, but also a risk of transmission and infection of the vulnerable patients they care for. The role of HCWs as a vector for nosocomial infections is well established,<sup>27,28</sup> especially in relation to RTIs.<sup>27</sup> Therefore, effective infection prevention and control (IPC)

strategies in health care settings to reduce the likelihood of infection among HCWs and patients are crucial in the Hajj context. As such, the Saudi MOH has a strict IPC training and educational program for HCWs deployed for Hajj, beyond the standard training programs these HCWs undertake throughout the year in their own health care facilities across the Kingdom. This is because HCWs deployed during Hajj come from a wide range of health institutions in KSA with diverse backgrounds on IPC measures. Some may be stationed at seasonal hospitals in the Mecca holy sites that are only operational during Hajj and will be providing care to pilgrims originating from all over the world. Therefore, since 2016, the Saudi MOH requires all HCWs deployed during Hajj to complete training to acquire a basic infection control skills license (BICSL). The latter involves 5 basic components: proper hand hygiene, proper use of personal protective equipment, application of the N95 fit test, principles of safe injection practice, as well as compulsory influenza and meningococcal vaccination. For the 2017 Hajj, 14,029 HCWs were trained for the BICSL representing 100% of the targeted number to be trained.<sup>29</sup>

The Kingdom also ensures that health care centers and hospitals providing services for pilgrims are equipped with the necessary facilities for infection prevention. During the 2017 Hajj, 403 isolation rooms, 168 negative pressure rooms, and 461 high efficiency particulate air filters were available at the Hajj health care facilities.<sup>29</sup> The Saudi MOH also has developed and published various IPC policies, including those specifically for Hajj, to help HCWs develop their knowledge and skills in the area and adhere to best practices. In addition, various trainings and drills are conducted pre-Hajj for HCWs as per their function and in relation to a number of possible infectious risks such as MERS. Awareness campaigns are also part of the IPC program for HCWs during Hajj, especially in relation to the importance of immunization, food and safety hygiene standards, and general IPC practices that go hand-in-hand with those awareness campaigns aimed at pilgrims, holy cities residents, and non-HCWs.

Our results indicate that there is a need for better adherence to immunization policies, especially in relation to influenza vaccination for all HCWs and meningococcal vaccination for those deployed to Hajj. Due to various initiatives by the Saudi MOH, rates of influenza vaccination among HCWs in KSA are high in recent years.<sup>30,31</sup> Nevertheless, we found low influenza vaccination rates among HCWs not deployed to Hajj in 2015. One possible contributor to this finding is that the influenza vaccination season in KSA for HCWs not deployed to Hajj runs from September to March. Given that our data collection was conducted mid-September, it is possible that a number of HCWs from the Al-Ahsa cohort did not yet receive their influenza vaccination at the time of the study. For HCWs deployed in Hajj, the rates of immunization in our study were similar to those reported in a study conducted in the 2015–2017 Hajj seasons.<sup>32</sup> However, our data indicates that the rate of immunization of influenza vaccination among the Hajj cohort was higher than that reported pre-2015.<sup>19,20</sup> In general, since the introduction of the compulsory BICSL license that includes the compulsory influenza and meningococcal immunization section, data from the MOH indicate that in 2017, all HCWs deployed to Hajj were vaccinated with both vaccines.

Our study has some limitations. Although we enrolled an adequate number of HCWs in both cohorts and had a good follow-up rate, the number represents a small fraction of the thousands of HCWs deployed for Hajj. Therefore, our results may not be generalizable to all HCWs working during Hajj and in all specialties. Also, data on the number of days off work due to sickness among HCWs post-Hajj was not collected, and that would have given a better picture of the burden of illness associated with Hajj deployment for HCWs and the health system at large. Finally, although we aimed to match the Al-Ahsa cohort with our Mecca cohort in terms of health care facilities size, type of patients, and other factors, given the specific nature of the Hajj, it was impossible to completely match the two cohorts.

## CONCLUSIONS

We conducted the first study to investigate illness and carriage of respiratory and gastrointestinal pathogens among HCWs during Hajj. We found that HCWs providing care for pilgrims both acquire pathogens and present symptoms (especially respiratory symptoms) more frequently than those not working during Hajj. The Kingdom has a strict IPC awareness, training, and education program for HCWs deployed for Hajj each year, in conjunction with compulsory influenza and meningococcal vaccination and provision of IPC facilities, and equipment to reduce the risk of transmission and illness among both HCWs and patients during the event. The Kingdom has also the capacity to deploy extra HCWs for Hajj in times of need. Nevertheless, strict adherence to IPC policies and guidelines among HCWs, especially in relation to preventing respiratory infections, and continuous monitoring, feedback, and improvement of IPC strategies for Hajj are needed. This to preserve the health and wellbeing of HCWs working during Hajj, to protect the patients they care for and to prevent potential workdays and economic loss resulting from HCWs illness either during or post-Hajj.

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