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Original Article

Factors associated with the transmission of pandemic (H1N1) 2009 among hospital healthcare workers in Beijing, China

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Background With the increase in patient activity during the 2009 H1N1 pandemic, came an associated increase in occupational infections of healthcare workers (HCWs).

Objectives The aim of this study was to examine factors associated with the transmission of pandemic (H1N1) 2009 among HCWs.

Methods A 1:4 matched case–control study by hospital, ward, age, and gender was conducted in HCWs from hospitals in Beijing during February 2010. Cases were diagnosed with pandemic (H1N1) 2009, and controls had neither influenza-like illness nor diagnosis with pandemic (H1N1) 2009 during August 2009 to January 2010. Information during 7 days before symptom onset of case was collected, and controls were queried about the same period.

Results A total of 51 cases identified via National Notifiable Infectious Disease Surveillance System participated in this study. Controls were matched to cases for a total of 255 individuals. About 19·6% (10/51) of cases and 26·0% (53/204) of controls recalled they had conducted a high-risk procedure on a patient with pandemic (H1N1) 2009. 72·5% (37/51) of cases and 71·6% (146/204) of controls stated they wore medical masks in ≥80% of working time. Only 5·9% (3/51) and 36·3% (74/204) of cases and controls, respectively, reported receiving pandemic vaccination. Participants receiving pandemic vaccination had a significantly lower risk of infection during the pandemic (OR = 0·150, 95% CI: 0·047–0·479, P = 0·001). The estimated vaccine effectiveness was 85·0%.

Conclusions We showed a high vaccine effectiveness of the pandemic vaccine and that vaccination was the only factor significantly associated with risk of infection in HCWs.

Keywords Beijing, healthcare workers, hospitals, pandemic, vaccination.

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Introduction

On the May 16, 2009, the first case of pandemic (H1N1) 2009 was reported in Beijing, China. As predicted, hospitals were an important site for identifying cases. In Beijing, 56·3% of the imported confirmed cases were detected from influenza-like illness (ILI) screening in hospitals during the early phase,[1] and cases were routinely detected via sentinel hospital surveillance from August 2009.[2] After September 2009, a sharp increase in the number of ILI cases was observed with the commencement of the school term. During this period, hospitals were inundated with thousands of patients exhibiting ILI symptoms, presenting for rapid influenza A testing. The outpatient consultation rate of ILI case patients increased from 38% (August–September) to 48% (October–December).[3]

With the increase in patient activity during this period, not surprisingly, an associated increase in occupational infections has been documented. One study from the United States reported occupational infection rates of 28·8% and 25·0% in the adult emergency department and pediatric emergency department, respectively.[4] These figures are considerably higher than rates reported from Mexico (12%)[5] and Korea (9·1%).[6] Moreover, the infection rates of

7 and 12·8% were estimated in blood donors and HCW, respectively, after the first wave of pandemic (H1N1) 2009.[7] A simulation found the secondary attack rate among unprotected HCWs to be approximately 60% higher (54·3%) than that of all adults (34·1%).[8] HCWs were at increased risk of infection with pandemic (H1N1) 2009.

Measures to prevent influenza transmission to healthcare workers during a pandemic include all levels of infection controls. Vaccination along with the use of personal protective equipment (PPE) and antiviral medications are components of an overall infection prevention and control program that encompasses administrative, work practice and engineering controls. In China, technical guidelines on the use of PPE were published by the Ministry of Health of the People's Republic of China at the beginning of the pandemic (H1N1) 2009. As designated in the document, healthcare workers (HCWs) were encouraged to wear a N95 respirator, a gown, and a cap while in contact with a patient with suspected or confirmed pandemic H1N1. As highlighted by the US Institute of Medicine,[9] in their recent report on the use of PPE for healthcare professionals, there are ongoing challenges and controversies surrounding the use of PPE for HCWs.

To inform the infection control technical guidelines and prepare for future emerging disease outbreaks, a 1:4 matched case–control study was conducted in the post-epidemic period to examine behaviors and factors associated with pandemic (H1N1) 2009 infection.

Methods

Study participants

Cases were defined as any nurse, doctor, or ward clerk who (i) worked full time in a high-risk setting (i.e., wards such as intensive care, emergency, or respiratory wards); (ii) had contact with a patient with a respiratory illness in the public hospital within two meters; and (iii) was diagnosed as having pandemic (H1N1) 2009 during August 30, 2009, and January 31, 2010, which was confirmed by real-time reverse transcriptase-polymerase chain reaction (RT-PCR) for pandemic (H1N1) 2009. HCWs were excluded if they (i) were not contactable or (ii) had a household member with either (a) an acute respiratory illness (ARI) or (b) laboratory confirmed to have pandemic (H1N1) 2009 (with symptom onset 7 days before the HCWs onset of illness).

Control subjects were matched 4:1 with case patients by hospital, ward, age (±5 years), and gender. Controls were defined as any HCWs who (i) worked full time; (ii) were exposed to patients with respiratory infections; (iii) did not have an ILI nor had been laboratory diagnosed as having pandemic (H1N1) 2009 during August 2009 to January 2010. Control HCWs were excluded if they had a household member who was reported with ARI or was laboratory confirmed to have pandemic (H1N1) 2009 during August 2009 to January 2010.

Study design

In all hospitals of Beijing, China, clinicians were requested to report patients infected with pandemic (H1N1) 2009, confirmed by real-time reverse transcriptase-polymerase chain reaction (RT-PCR), in National Notifiable Infectious Disease Surveillance System (NNIDSS). All the patients reported as HCWs in NNIDSS between August 30, 2009, and January 31, 2010, were visited by us in February 2010, and those who met the above-mentioned definition of cases of this case–controls study were invited to participate in this study.

Simple randomization was used to select four control subjects for each case. For each case, HCWs who matched the control criteria were selected as potential controls. Control subjects' names were listed according to their initials. Four-digit identification numbers were created for each individual and randomly selected as controls.

Both cases and controls were informed about the purpose of study and verbally consented to participate. The study protocol was approved by the Institutional Review Board and Human Research Ethics Committee of the Beijing Centre for Disease Prevention and Control (CDC).

Data collection

A face-to-face survey was developed that assessed the following characteristics of cases during 7 days prior to symptom onset using a structured questionnaire: (i) demographic characteristics (age, gender, educational background, and living arrangement); (ii) job description; (iii) seasonal influenza and pandemic (H1N1) 2009 vaccination status; (iv) conduct of high-risk procedures (defined as procedure likely to generate respiratory aerosols, such as suctioning, intubation, nebulizer medications, chest physiotherapy, and other aerosol generating procedures); (v) hand washing practices and use of other personal protective equipment (masks, gowns, gloves, and hair/foot covers); and (vi) attitudes and perceived perceptions of risk toward pandemic H1N1. Tick boxes were provided for responses to questions, which were all closed. Controls were queried about a reference period corresponding to the same 7-day period as the matched case.

Statistical analysis

Data were analyzed using spss 16.0 statistical package (SPSS Inc., Chicago, IL, USA). Median and range values were calculated for continuous variables, and percentages were calculated for categorical variables. Univariate and multivariate conditional logistic regression analyses were conducted to determine risk factors associated with infection in hospital. The variables with $P < 0{\cdot}10$ in univariate

analysis were included in multivariate analysis. Backward logistic regression was conducted by removing variables with $P > 0{\cdot}10$, and statistical significance was defined as $P < 0{\cdot}05$. By multivariate analysis, odds ratio (OR) of pandemic (H1N1) 2009 vaccination among cases versus controls was calculated, and vaccine effectiveness was estimated as 100% × (1 − OR), as described previously.[10]

Results

Characteristics of case HCWs and control HCWs

There were 53 HCWs who were identified via National Notifiable Infectious Disease Surveillance System. Of these cases, two individuals refused to participate in the study. In all, 51 HCWs from 25 hospitals were included as cases, and 204 HCWs were selected as control participants. The sociodemographic characteristics of the surveyed participants were shown in Table 1. There were no significant differences between the two groups in terms of age, gender, educational background, ward type, occupational cohort, and technical titles.

Table 1. Demographic characteristics of participating healthcare workers

Demographic characteristic	Case *n* = 51 (%)	Control *n* = 204 (%)	Chi-square *P*-value
Age group (years)			
18∼29	36 (70·6)	124 (60·8)	0·330
30∼39	7 (13·7)	52 (25·5)	
40∼49	1 (2·0)	2 (1·0)	
50+	7 (13·7)	26 (12·7)	
Gender			
Female	42 (82·4)	167 (81·9)	0·935
Male	9 (17·6)	37 (18·1)	
Ward type			
Emergency & ICU	7 (13·7)	26 (12·7)	0·355
Respiratory department	5 (9·8)	24 (11·8)	
Other outpatient department	36 (70·6)	120 (58·8)	
Technical clinic department	1 (2·0)	14 (6·9)	
Management	2 (3·9)	20 (9·8)	
Highest level of education			
Secondary school	11 (21·6)	33 (16·2)	0·481
College or higher	40 (78·4)	171 (83·8)	
Occupational cohort			
Doctors	21 (41·2)	69 (33·3)	0·727
Nurses	24 (47·1)	107 (52·5)	
Technicians	4 (7·8)	20 (9·8)	
Manager	0 (0)	3 (1·5)	
Others	2 (3·9)	6 (2·9)	
Technical titles			
Intern	1 (2·0)	3 (1·5)	0·867
Resident	35 (68·6)	147 (72·1)	
Physician	9 (17·6)	34 (16·7)	
Chief Physician	4 (7·8)	9 (4·4)	
Other	2 (3·9)	11 (5·4)	

Factors associated with infection of 2009 H1N1 influenza

In regards to work practices during the pandemic, more control HCWs estimated that they saw more than 50 patients with ILI per day. No statistical differences were found between the groups (Table 2). Conducting a high-risk procedure on a patient with confirmed H1N1, during the pandemic, did not differ by groups; a slightly higher proportion of the control group reported conducting a high-risk procedure on a patient with ILI than the case group; however, the difference has no significance (Table 2).

The majority of the participants [72·5% (37/51) in case group and 71·6% (146/204) in control group] reported wearing a medical mask in more than 80% of the working time, while a further 17·3% (44/255) stated that they routinely used cloth masks, only 6·3% (16/255) reported using an N95 respirator. An additional 4·7% (12/255) of the participants stated that they never or seldom wear a facial mask in their clinical practice. There was no significant difference by cases and controls in the behavior of wearing mask. Of concern was the fact that 37·3% (95/255) of the participants reported drying their hands on their work clothes or on a reusable towel. No significant differences were found between the two groups for any of these variables (Table 2).

Participants (30·2%, 77/255) were more likely to report being vaccinated against pandemic (H1N1) 2009 than for seasonal influenza (13·7%, 35/255). We found that control HCWs were significantly more likely to indicate that they had received the pandemic vaccine ($P = 0{\cdot}002$; Table 2). After adjusting for confounding factors during the multivariate analysis, receiving the pandemic (H1N1) 2009 vaccine (OR = 0·150, 95% CI: 0·047–0·479, $P = 0{\cdot}001$) was the only significant factor. It was significantly associated with absence of infection of pandemic (H1N1) 2009. The estimated vaccine effectiveness was calculated at 85·0% (95% CI: 52·1–95·3).

A slightly higher proportion of the case group (96·1% versus 84·8%) felt that HCWs were at higher risk level than other occupational persons ($P = 0{\cdot}032$). The case group was also significantly more likely to report that they were more susceptible to acquiring respiratory infections ($P = 0{\cdot}002$).

Discussion

In our study, we found that participants in the control group were more likely to state that they have received the pandemic (H1N1) 2009 vaccine, which corroborates with

Table 2. Work practices and reported uptake of infection control behaviors in hospital healthcare workers during the pandemic

	Case HCWs *n* = 51 (%)	Control HCWs *n* = 204 (%)	*P*-value
Hours of contact with patients			
≤8 hours/day	46 (90·2)	177 (86·8)	0·555
>8 hours/day	5 (9·8)	27 (13·2)	
Number of contacted patients daily			
≥50/day	15 (29·4)	64 (31·3)	0·951
<50/day	36 (71·7)	140 (68·6)	
Number of contacted patients with ILI daily			
≥50	10 (19·6)	59 (28·9)	0·234
<50	41 (80·4)	145 (71·7)	
Conducting a HRP on a patient with confirmed pandemic influenza A/(H1N1)			
Yes	10 (19·6)	53 (26·0)	0·400
No	41 (80·4)	151 (74·0)	
Conducting a HRP on a patient with ILI			
Yes	14 (27·5)	86 (42·2)	0·161
No	37 (72·5)	118 (57·8)	
Frequency of mask-wearing			
Seldom or never	2 (3·9)	10 (4·9)	0·344
Often	11 (21·6)	59 (28·9)	
Always	33 (64·7)	119 (58·3)	
Only when doing a HRP	5 (9·8)	16 (7·8)	
Number of masks used daily			
<2/day	18 (35·3)	66 (33·3)	0·798
≥2/day	33 (64·7)	138 (67·7)	
Type of mask			
Never wore a mask	2 (3·9)	10 (4·9)	0·796
N95 mask	3 (5·9)	13 (6·4)	
Medical mask	37 (72·5)	146 (71·6)	
Cloth mask	9 (17·6)	35 (17·2)	
Wearing gloves			
Yes	25 (49·0)	115 (56·4)	0·400
No	26 (51·0)	89 (43·6)	
Hand washing after providing patient care			
Yes	49 (96·1)	204 (100)	n.a.
No	2 (3·9)	0 (0)	
Habit for hand drying			
Work clothes or reusable towel	24 (47·1)	71 (34·8)	0·065
Hand dryer	16 (31·4)	58 (28·4)	
Disposable paper towel	11 (21·6)	75 (36·8)	
Receipt of pandemic A (H1N1) 2009 vaccine			
Yes	3 (5·9)	74 (36·3)	0·002
No	48 (94·1)	130 (63·7)	
Receipt of seasonal influenza vaccine in 2009			
Yes	4 (7·8)	31 (14·2)	0·332
No	47 (92·2)	173 (84·8)	
Taking preventive medication (oseltamivir prophylaxis and Traditional Chinese herbal medicine)			
Yes	7 (13·7)	37 (16·9)	0·561
No	44 (86·3)	167 (81·9)	

HRP, high-risk procedure; n.a., not available (because data distribution was not suitable for conditional logistic regression model).

previous study.[11] The estimated vaccine effectiveness was calculated at 85·0% in this study. A study conducted by Wu *et al.*[12] showed that the vaccine effectiveness of pandemic (H1N1) 2009 vaccine was 87·3% (75·4–93·4%) in Beijing. Furthermore, a systematic review reported that the vaccine effectiveness of the pandemic (H1N1) 2009 vaccine for confirmed illness was 86% (73–93%) based on 11 case–control studies and 79% (22–94%) based on two cohort studies.[13]

The study regarding vaccination in Chinese HCWs was very limited. Only a few studies were undertaken to evaluate the willingness to accept the pandemic (H1N1) 2009

vaccine and the actual uptake among HCWs. Seale *et al.*[14] found that 65·8% of the HCWs in Beijing believed vaccinations provide a high to very high level of protection; however, the actual acceptance rate for pandemic (H1N1) 2009 vaccine was only 25%.[15] Aside from this, the seasonal flu vaccine uptake rate among Chinese HCWs was low too; a study showed only 13% of the invested HCWs in Beijing reported having undergone immunization for seasonal influenza vaccine 2009/10 and seasonal influenza vaccine 2008/09.[15] As demonstrated in a previous study, seasonal vaccination was associated with a willingness to accept the pandemic vaccine.[16] Therefore, efforts to improve seasonal vaccine acceptance among HCWs should be undertaken.

While there were relatively high levels of self-reported compliance with mask/respirator use in both groups, a small number of participants did report that they 'never' or 'seldom' wore a mask during their clinical practice. While this could be due to the patient activities undertaken, it may also be linked to the risk perceptions among the group of HCWs.[17,18] We also found that cloth masks were still being routinely used by some of the HCWs, even though the infection control guidelines issued for the pandemic indicated that surgical masks should be worn by HCWs working in any of the following wards/departments: outpatient, inpatient, emergency, and fever clinic. The guidelines also highlight that respirators should be used by staff in contact with confirmed pandemic patients in the observation and isolation ward. Cloth masks generally have not been recommended as effective respiratory protective devices or as devices that would prevent exposure to splashes, because there is uncertainty around whether they meet the standards set by regulatory bodies.[19] In a report by the National Institute of Health's (NIH) Committee on the development of reusable facemasks for use during an influenza pandemic, the members were hesitant to discourage the use of cloth masks but suggested caution around their use, as they were not likely to be as protective as medical masks or respirators.[19] The committee was also concerned that their use may give users a false sense of protection that would encourage risk-taking and/or decrease attention to other hygiene measures.[19]

The proper drying of hands is an integral part of routine hand washing, as wet hands can more readily acquire and spread microorganisms. While there is still some debate about the best method of hand drying, the underlying principle remains that care must be taken to avoid recontamination of washed and dried hands.[20] As promoted in the WHO guidelines on hand hygiene in health care,[21] hands should ideally be dried using either individual paper towels or hand driers that can dry hands effectively and as quickly as paper towels. Given that recommendations on proper hand drying have been around for many years, it is concerning that almost half of the case participants and 30% of the control HCWs reported that they dried their hands on their work suit or on a reusable towel. This may be attributable to a lack of promotion about correct hand hygiene procedures or may be that there are no alternatives available. We were unable to demonstrate any impact of masks or hand washing in HCWs against pandemic influenza.

There are a number of limitations in this study. The first and main limitation is recall bias. As designed, the controls were not recruited whenever a case was identified, but recruited when the study was conducted during February 2010, and the data for both cases and controls, especially the exposure information, were collected retrospectively. Therefore, other than non-differential imperfect recall, controls might be more likely to have forgotten about their high-risk behaviors than cases. Second, the sample size was relatively small, which may have limited the ability to detect factors associated with H1N1 infection. In addition, serological tests were not performed on control HCWs, so laboratory-positive HCWs could be included in the control group leading to an underestimated OR value. The matching procedure utilized in the study also prevents analysis by type of occupational duties or type of ward. Lastly, as our study only concentrated on the factors in the hospital, we omitted factors outside of the hospital, which may be associated with pandemic (H1N1) 2009 transmission.

During the inter-pandemic period, lessons from the pandemic can be used to identify and rectify issues around health system preparedness. The role of vaccination should be emphasized, given it was the only factor that protected against infection, and influenza vaccination of staff should continue to be encouraged. A review of the standards around the type and use of PPE should be undertaken. Addressing these issues will support the healthcare workforce and improve health system response.

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Conflict of interest

No conflict of interest to declare.

Ethical approval

This study was approved by the Institutional Review Board and Human Research Ethics Committee of Beijing Center for Disease Prevention and Control.

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