

THE ORTHOPAEDIC FORUM

Survey of COVID-19 Disease Among Orthopaedic Surgeons in Wuhan, People's Republic of China

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Background: Coronavirus disease 2019 (COVID-19) broke out in Wuhan, the People's Republic of China, in December 2019 and now is a pandemic all around the world. Some orthopaedic surgeons in Wuhan were infected with COVID-19.

Methods: We conducted a survey to identify the orthopaedic surgeons who were infected with COVID-19 in Wuhan. A self-administered questionnaire was distributed to collect information such as social demographic variables, clinical manifestations, exposure history, awareness of the outbreak, infection control training provided by hospitals, and individual protection practices. To further explore the possible risk factors at the individual level, a 1:2 matched case-control study was conducted.

Results: A total of 26 orthopaedic surgeons from 8 hospitals in Wuhan were identified as having COVID-19. The incidence in each hospital varied from 1.5% to 20.7%. The onset of symptoms was from January 13 to February 5, 2020, and peaked on January 23, 8 days prior to the peak of the public epidemic. The suspected sites of exposure were general wards (79.2%), public places at the hospital (20.8%), operating rooms (12.5%), the intensive care unit (4.2%), and the outpatient clinic (4.2%). There was transmission from these doctors to others in 25% of cases, including to family members (20.8%), to colleagues (4.2%), to patients (4.2%), and to friends (4.2%). Participation in real-time training on prevention measures was found to have a protective effect against COVID-19 (odds ratio [OR], 0.12). Not wearing an N95 respirator was found to be a risk factor (OR, 5.20 [95% confidence interval (CI), 1.09 to 25.00]). Wearing respirators or masks all of the time was found to be protective (OR, 0.15). Severe fatigue was found to be a risk factor (OR, 4 [95% CI, 1 to 16]) for infection with COVID-19.

Conclusions: Orthopaedic surgeons are at risk during the COVID-19 pandemic. Common places of work could be contaminated. Orthopaedic surgeons have to be more vigilant and take more precautions to avoid infection with COVID-19.

Level of Evidence: Diagnostic Level IV. See Instructions for Authors for a complete description of levels of evidence.

In December 2019, coronavirus disease 2019 (COVID-19) broke out in Wuhan, Hubei Province, the People's Republic of China. Now COVID-19 is spreading widely throughout the

world and is threatening the health of the public. COVID-19 is a highly contagious disease and is considered more dangerous than seasonal influenza, with a higher case fatality rate (1.4%)¹.

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TABLE I Information on the 8 Hospitals with COVID-19 Infection of Orthopaedic Surgeons

Variables	Hospital							
	H1	H2	H3	H4	H5	H6	H7	H8
No. of infected orthopaedic surgeons	7	1	1	6	8	1	1	1
Total no. of orthopaedic surgeons	127	65	33	29	108	36	36	24
Incidence (%)	5.5	1.5	3.0	20.7	7.4	2.8	2.8	4.2
Distance to Huanan Seafood Market (km)	5.6	8.8	11.2	1.1	3.6	5.1	4.7	1.5

In contrast to severe acute respiratory syndrome (SARS), COVID-19 is more transmissible, especially in the incubation or prodromal period^{2,4}, which could place populations at a higher risk of exposure, especially for health-care workers.

As of February 11, 2020, 1,716 health professionals were recorded as having confirmed COVID-19 in the People's Republic of China⁵, with a majority (1,080 [63%]) from Wuhan, the epicenter of this pandemic. At present, there is a great need to assess the COVID-19 infection status of health-care workers in Wuhan and to gain experience for future battles.

A report⁶ from Wuhan suggested that hospital-associated transmission might serve as the mechanism of COVID-19 infection for health-care workers. Among 138 patients, 40 (29.0%) were health-care workers who were presumed to have been infected in hospitals at the early stage of the outbreak. These infected health-care workers largely worked in general wards (31 [77.5%]), which are not generally regarded as the front lines of the pandemic as are fever clinics and designated isolation wards. So far, the situation of COVID-19 infections in health-care workers not working on the front lines of the pandemic in Wuhan has remained obscure.

To characterize this situation, we aimed to study orthopaedic surgeons, a particular group of the health-care workers not working on the front lines, as an indication to the overall infection situation of health-care workers. We investigated the situation of infection of orthopaedic surgeons and trainees working in general wards, outpatient clinics, intensive care units, or operating rooms in Wuhan hospitals, and we further explored the possible risk factors at the individual level using a matched case-control study.

Materials and Methods

Participants and Study Design

We identified orthopaedic surgeons and trainees (hereinafter referred to as orthopaedic surgeons) who were infected with COVID-19 from December 31, 2019, to February 24, 2020, in the urban area of Wuhan. Cases of COVID-19 were defined according to the guidance of the World Health Organization (WHO)⁷, based on the history of exposure to COVID-19, symptoms, pathogen test, chest computed tomographic (CT) scan, and hematological examination. The exclusion criteria ruled out orthopaedic surgeons who assisted in fever clinics and designated COVID-19 wards in hospitals. To explore the possible risk factors at the individual level, we

conducted a 1:2 ratio matched case-control study. The controls were selected from uninfected orthopaedic surgeons who worked in the same department as the case at each hospital. The age difference between case and control was limited to within 3 years.

We investigated 24 hospitals in the urban area of Wuhan. A total of 26 orthopaedic surgeons with COVID-19 were identified from 8 hospitals. Two of the 26 orthopaedic surgeons were excluded from further study because 1 orthopaedic surgeon had assisted in the fever clinics and designated COVID-19 wards, and the other orthopaedic surgeon was hospitalized in an isolation ward with severe COVID-19 and could not finish the questionnaire. Of 24 cases, 21 were confirmed cases with positive reverse transcription polymerase chain reaction (RT-PCR) tests or antibody tests, and 3 were clinically diagnosed cases with a history of exposure to COVID-19, fever and respiratory symptoms, a chest CT scan with ground-glass opacity and consolidation, leucopenia and/or lymphopenia, and negative influenza virus tests. The latter 3 cases were negative

TABLE II Demographic Characteristics of the Study Groups with and without COVID-19 in Wuhan, the People's Republic of China

	Case Group (N = 24)	Control Group (N = 48)
Age* (yr)	36.1 ± 6.3 (25 to 48)	36.9 ± 5.9 (26 to 51)
Sex†		
Male	23 (95.8%)	48 (100%)
Female	1 (4.2%)	0 (0%)
Job title†		
Surgeon	21 (87.5%)	46 (95.8%)
Fellow	1 (4.2%)	0 (0%)
Resident	2 (8.3%)	2 (4.2%)
Work experience†		
<3 yr	4 (16.7%)	5 (10.4%)
3 to 10 yr	10 (41.7%)	24 (50.0%)
11 to 20 yr	6 (25.0%)	14 (29.2%)
≥21 yr	4 (16.7%)	5 (10.4%)

*The values are given as the mean and the standard deviation.
†The values are given as the number of patients, with the percentage in parentheses.

TABLE III Clinical and Epidemiological Characteristics of 24 Orthopaedic Surgeons Infected with COVID-19 in Wuhan, the People's Republic of China

Variables	Cases* (N = 24)
Date of onset of symptoms	
Before January 15, 2020	1 (4.2%)
From January 15 to January 19, 2020	8 (33.3%)
From January 20 to January 24, 2020	12 (50.0%)
After January 24, 2020	3 (12.5%)
Symptoms	
Fever	20 (83.3%)
Cough	15 (62.5%)
Fatigue	17 (70.8%)
Diarrhea	9 (37.5%)
Headache	8 (33.3%)
Pharyngalgia	2 (8.3%)
Shortness of breath	1 (4.2%)
Muscle ache	1 (4.2%)
Chest congestion	1 (4.2%)
Chest pain	1 (4.2%)
Hematological examination	
Leucopenia	3 (12.5%)
Lymphopenia	14 (58.3%)
Increased C-reactive protein	6 (25.0%)
Normal	7 (29.2%)
CT findings	
Ground-glass opacity and consolidation	21 (87.5%)
Normal	3 (12.5%)
Etiological examination	
Positive viral nucleic acid test	15 (62.5%)
Negative viral nucleic acid test	7 (29.2%)
Positive viral antibody test	9 (37.5%)
Negative viral antibody test	0 (0%)
Treatment	
Hospitalization	15 (62.5%)
Self-isolation	9 (37.5%)
Outcome	
Cured	24 (100.0%)
Chronic medical illness	
None	23 (95.8%)
Diabetes mellitus	1 (4.2%)
Possible sites of exposure	
General wards	19 (79.2%)
Public places at hospital	5 (20.8%)
Intensive care unit	1 (4.2%)
Operating rooms	3 (12.5%)
Community	1 (4.2%)
Transmission to others	
Colleague	1 (4.2%)

*continued***TABLE III (continued)**

Variables	Cases* (N = 24)
Family member	5 (20.8%)
Patient	1 (4.2%)
Friend	1 (4.2%)
None	18 (75.0%)

*The values are given as the number of patients, with the percentage in parentheses.

on RT-PCR tests and had not taken any antibody tests at the last follow-up.

In total, 24 infected and 48 matched healthy orthopaedic surgeons were included for further analysis. There was no significant difference of demographic variables (age, sex, job title, and work years) between infected and matched orthopaedic surgeons.

Questionnaire

A self-administered questionnaire was developed and was distributed online for data collection (see Appendix). The questionnaire included the information about demographic characteristics, clinical manifestations, awareness to the outbreak at an early stage, COVID-19 exposure history, availability of and participation in the infection control training provided by the hospital, and individual protection practices (e.g., good hand-washing hygiene and wearing face masks). The study was approved by the Ethics Committee of Tongji Medical College, Huazhong University of Science and Technology. All of the participants signed the digital informed consent form.

Statistical Analysis

The database was established using Microsoft Excel, and all analyses were performed with SAS 9.3 software (SAS Institute). Significance was set at $p < 0.05$. Descriptive characteristics are presented as the mean and the standard deviation for normally distributed quantitative variables, and categorical variables are presented as numbers and percentages. The differences of means such as age were compared using the Student t test, and the chi-square test or the Fisher exact probability test was employed to compare the differences of categorical variables, such as health status and job title, between the case and control groups. Univariate conditional logistic regression models were used to assess the associations between the potential exposures and COVID-19 morbidity and to estimate the corresponding odds ratios (ORs).

Results

The number of cases in each hospital varied from 1 to 8 and the incidence of infection ranged from 1.5% to 20.7%; 5 of 8 hospitals had only 1 case. The distance from these hospitals to the Huanan Seafood Market (a live animal and seafood market), the presumptive ground zero of the COVID-19 pandemic,

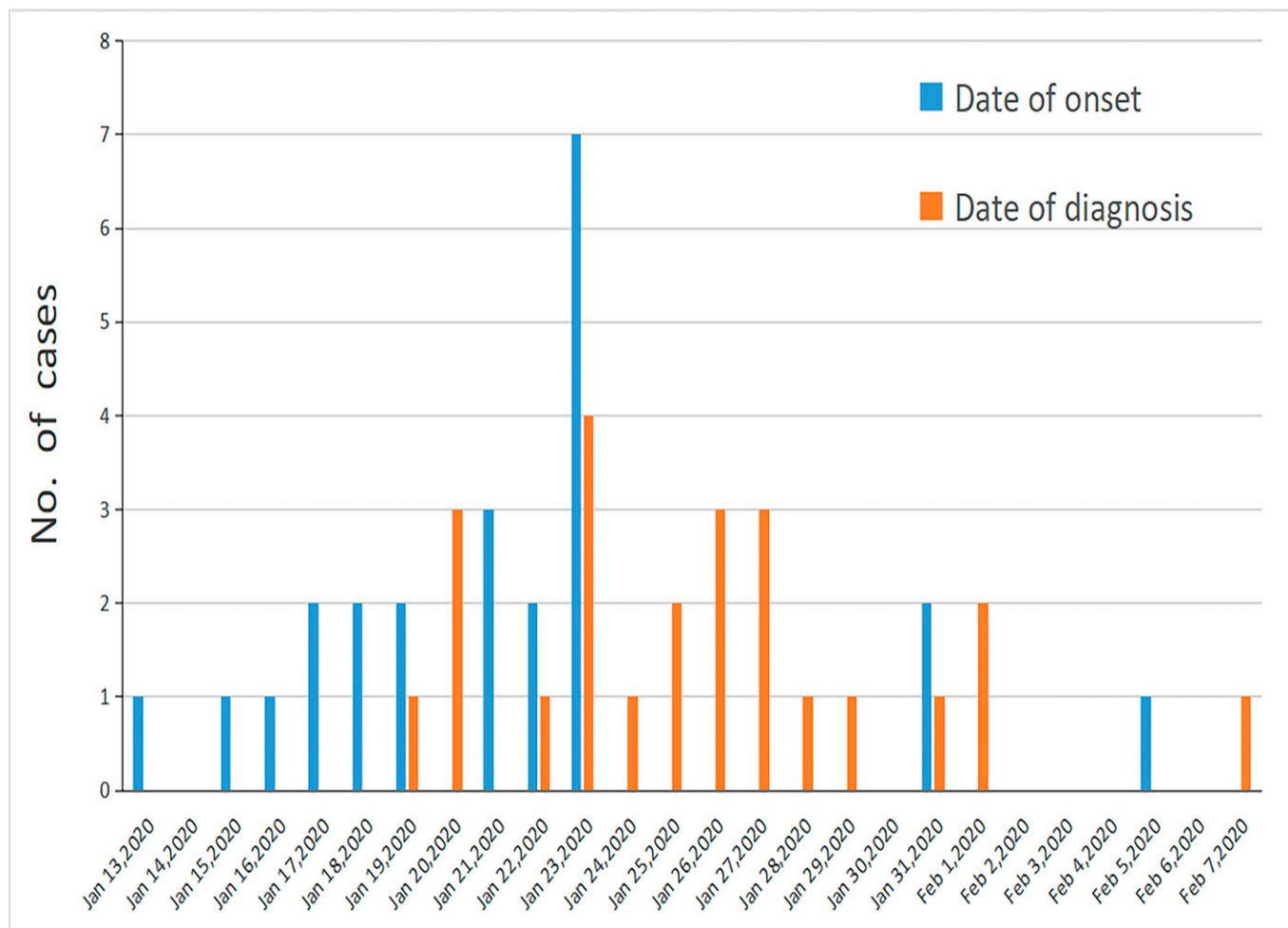


Fig. 1
Epidemic curve showing the date of onset of symptoms and of diagnosis of infected orthopaedic surgeons in Wuhan. The onset of symptoms was from January 13 to February 5, 2020, largely between January 15 and January 24, and peaked on January 23.

varies from 1.1 km to 11.2 km, and 6 of 8 hospitals are within 6 km of the market (Table I).

The mean age (and standard deviation) of 24 infected orthopaedic surgeons was 36.1 ± 6.3 years (range, 25 to 48 years) (Table II). They all reported having a good health condition before infection, except 1 orthopaedic surgeon (4.2%) who had diabetes mellitus (Table III).

The onset of symptoms among the cases was from January 13 to February 5, 2020, largely between January 15 and January 24, and peaked on January 23 (Table III, Fig. 1). The top 5 symptoms were fever (83.3%), cough (62.5%), fatigue (70.8%), diarrhea (37.5%), and headache (33.3%). The symptoms of these surgeons were mostly mild. Hematological examination showed lymphopenia (58.3%), increased C-reactive protein (25.0%), and leucopenia (12.5%). Fifteen surgeons were admitted to the hospital for treatment, and 9 surgeons were self-isolated at home or hotels with medicine for at least 2 weeks. All 24 surgeons recovered after treatment.

According to the questionnaire responses, suspected sites of exposure were general wards (79.2%), public places at the

hospital (20.8%), operating rooms (12.5%), intensive care units (4.2%), and outpatient clinics (4.2%).

There was confirmed transmission from these doctors to others in 25% of cases, including to family members (5 [20.8%]), colleagues (1 [4.2%]), patients (1 [4.2%]), and friends (1 [4.2%]).

Severe fatigue of orthopaedic surgeons during the 2 months before the outbreak of COVID-19 was found to be a risk factor for the infection (Table IV) (OR, 4 [95% confidence interval (CI), 1 to 16]). The case group had a higher proportion (79.2%) who slept <7 hours per night than the control group (60.4%), although significance was not reached ($p = 0.1246$).

We surveyed the awareness of human-to-human transmission of COVID-19 by the orthopaedic surgeons at the early stage of the outbreak. Before January 20, 2020, the date when the National Health Commission of the People's Republic of China confirmed and officially announced the human-to-human transmission and the outbreak of COVID-19⁸, 33.3% of infected orthopaedic surgeons were aware of human-to-

TABLE IV Univariate Conditional Logistic Regression for the Association Between the Exposures and the COVID-19 Morbidity

Variables	Case Group* (N = 24)	Control Group* (N = 48)	OR†	P Value
Fatigue before infection				
Mild or none	18 (75.0%)	45 (93.8%)	Reference	
Severe	6 (25.0%)	3 (6.3%)	4.00 (1.00 to 16.00)	0.0499
Sleep duration per night				
≥7 hours	5 (20.8%)	19 (39.6%)	Reference	
<7 hours	19 (79.2%)	29 (60.4%)	2.75 (0.76 to 9.96)	0.1246
Awareness of human-to-human transmission				
No	16 (66.7%)	25 (52.1%)	Reference	
Yes	8 (33.3%)	23 (47.9%)	0.35 (0.14 to 1.54)	0.4646
Knowledge of infection prevention and control measures				
Sufficient	5 (20.8%)	22 (45.8%)	Reference	
Insufficient	19 (79.2%)	26 (54.2%)	2.71 (0.94 to 7.81)	0.0650
Usage of N95 respirator				
Yes	4 (16.7%)	19 (39.6%)	Reference	
No	20 (83.3%)	29 (60.4%)	5.20 (1.09 to 25.00)	0.0392
Wearing respirators or masks all of the time				
No	17 (70.8%)	15 (31.3%)	Reference	
Yes	7 (29.2%)	33 (68.8%)	0.15 (0.04 to 0.55)	0.0038
Adherence to recommended hand-hygiene practice				
No	13 (54.2%)	24 (50.0%)	Reference	
Yes	11 (45.8%)	24 (50.0%)	0.85 (0.33 to 2.22)	0.7458
Participating in infection control training				
No	14 (58.3%)	11 (22.9%)	Reference	
Yes	10 (41.7%)	37 (77.1%)	0.12 (0.03 to 0.57)	0.0072
PPE supply				
Sufficient	3 (12.5%)	11 (22.9%)	Reference	
Insufficient	21 (87.5%)	37 (77.1%)	2.41 (0.49 to 11.76)	0.2768
Mask wearing by patients with suspected COVID-19				
Yes	5 (20.8%)	29 (60.4%)	Reference	
No	19 (79.2%)	19 (39.6%)	6.05 (1.70 to 21.51)	0.0054

*The values are given as the number of patients, with the percentage in parentheses. †The values are given as the OR, with the 95% CI in parentheses.

human transmission, whereas the rate of awareness of human-to-human transmission among the control group was 47.9%. However, the difference between the 2 groups was not significant.

The univariate analysis conditional logistic regression showed that lack of knowledge of infection prevention and control measures for highly contagious diseases among orthopaedic surgeons could be a risk, as it showed a trend toward significance ($p = 0.0650$). The participation in real-time training on infection prevention and control measures was found to have a protective effect against COVID-19 (OR, 0.12; $p = 0.0072$).

Not wearing N95 respirators was found to be a risk factor (OR, 5.20 [95% CI, 1.09 to 25.00]) for becoming infected with COVID-19. Before January 20, 2020, 83.3% of infected orthopaedic surgeons did not use N95 respira-

tors. Compliance with wearing N95 respirators or face masks was significantly different ($p = 0.0038$) between the case cohort (29.2%) and the control cohort (68.8%). Wearing respirators or masks all of the time was found to have a protective effect against becoming infected with COVID-19 (OR, 0.15; $p = 0.0038$).

There was no significant difference ($p = 0.7458$) between cases (45.8%) and controls (50.0%) in adherence to recommended hand-hygiene practice. The majority of orthopaedic surgeons in both the case group (87.5%) and the control group (77.1%) faced the situation of insufficiency of personal protective equipment (PPE) during the early stages of the outbreak.

We studied measures for infection source control in orthopaedic wards to prevent the transmission of COVID-19.

We found that, for orthopaedic patients with suspected COVID-19, not wearing masks was a risk factor to surgeons (OR, 6.05 [95% CI, 1.70 to 21.51]).

Discussion

Eight hospitals in Wuhan had orthopaedic surgeons infected with COVID-19, with an incidence range of 1.5% to 20.7% at the early stage of the outbreak. Hospitals without any infection cases among orthopaedic surgeons were not included in this current study. The incidence difference could be associated with the number of early admissions of patients with COVID-19, which was associated with the distance from the hospitals to the Huanan Seafood Market. For example, as the nearest hospital to the Huanan Seafood Market, the hospital designated as H4 in our study had the highest infection rate of 20.7% and was among the very first hospitals in Wuhan that admitted patients with COVID-19. The difference might also relate to the early awareness, alertness, and infection prevention and control measures taken by hospitals, but the answers regarding these hypotheses need more data at the hospital level.

According to analyses of the questionnaire, the main suspected site of infection was general wards. This is in line with another report about health-care workers infected with COVID-19⁹. In the orthopaedic wards at that time, there were several cases in which patients were admitted for elective or trauma surgical procedures during their incubation period of COVID-19. During the early stage of the outbreak in Wuhan, because of the serious shortage in virus test kits, testing for the pathogen could be performed only in suspected cases with symptoms that were severe or not self-limited. The real situation regarding how many patients in the orthopaedic wards had the comorbidity of COVID-19 was unknown. One surgeon consulted in the intensive care unit, where there was a patient with traumatic injury and fever of an unknown origin, which was later diagnosed as due to COVID-19. Three surgeons were exposed during operations on patients who were diagnosed as having COVID-19 several days after the surgical procedures. Thus, it is wise to minimize, postpone, or cancel elective operations during the pandemic. Family members of the patients and visitors also could be the source of virus in the wards. Public places at hospitals (e.g., elevators) could be contaminated and the virus could be transmitted from there by contact or droplet.

There are many asymptomatic patients with COVID-19 who are, nevertheless, shedding the virus and are unwittingly exposing other inpatients, outpatients, and health-care providers to the risk of contracting COVID-19⁹. Patients normally have compromised immunity, so, during the pandemic, inpatients should wear face masks, provided by the hospitals, to protect themselves, fellow patients, and health-care workers.

The onset of symptoms was largely from January 15 to January 24, and the largest number of patients (7) started to show symptoms on January 23 (Table III, Fig. 1). The reported median incubation period of COVID-19 is 4 days (interquartile range, 2 to 7 days)¹, so the possible exposure dates were before January 20, 2020, and the total number of confirmed cases in

Wuhan was only 258 on January 20, 2020¹⁰. By comparing the epidemic curve among the public⁵ with that of orthopaedic surgeons (Fig. 1), we found that the peak date of onset of orthopaedic surgeons' infection was 8 days earlier than that of the public, indicating that these orthopaedic surgeons more likely were exposed to COVID-19 in the hospitals, rather than in the community.

Transmission of COVID-19 from these infected orthopaedic surgeons to others happened in one-fourth of the cases. The transmission of COVID-19 to family members created great stress and depression for these surgeons. The high rate (20.8%) of transmission to family members raises the need for doctors to be cautious of household transmission. It is recommended that orthopaedic surgeons who still work in hospital settings during the COVID-19 pandemic period manage to avoid close contact with family members at home.

During the early stages of the outbreak of COVID-19 in Wuhan, knowledge of infection prevention and control measures was limited among orthopaedic surgeons in Wuhan. This limited knowledge may be due to little or no experience of these orthopaedic surgeons to cope with the highly contagious diseases in their routine practices, insufficient training in higher levels of infection prevention and control measures, and, in some cases, even a lack of awareness of the importance of such measures. The effect of real-time training could not be well defined in the current study because some of the surgeons were exposed before such training became available in the middle to late January.

Wearing N95 respirators was found to have a protective effect against COVID-19. Normally, orthopaedic surgeons do not need to use N95 respirators in the hospital, so the behavior of wearing N95 respirators is an indicator of their awareness and vigilance regarding transmission. The vigilance could help doctors to ensure compliance with infection prevention and control procedures, as shown in our results that a higher ratio of orthopaedic surgeons in the control group wore the respirators and/or masks all of the time than orthopaedic surgeons in the case group did.

The availability of PPE was insufficient for orthopaedic surgeons, which increased the risk for these doctors. There was a sudden, increased need for PPE, and the orthopaedic surgeons were not prioritized for the supply.

A status of severe fatigue was found to contribute to infection with COVID-19 (Table IV). Severe fatigue from overwork, less sleep, and mental stress are common issues for orthopaedic surgeons. Reducing workload could be a strategy for orthopaedic surgeons to defend against becoming infected with COVID-19.

There were several limitations to this study. One was the lack of data at the hospital level, the reasons for which have not yet been totally determined. The case-control study design was useful to test the possible link between the exposures and the outcome, but not to confirm the causal relationship, and recall bias could have occurred because of its nature. Nevertheless,

because the recall period in the study was less than about 1 month, we assumed that the recall bias, if any, would have been minor. The number of surgeons infected could have been higher than reported, as we could have missed the infected orthopaedic surgeons in some small hospitals, but we assume that the number will be very small.

The orthopaedic surgeons in Wuhan were infected by COVID-19 in the early stage of the epidemic. Understanding the related risk factors is of great importance, especially when many countries are currently facing a situation similar to what Wuhan faced in January 2020. A serious challenge in responding to COVID-19 is how to better protect health-care workers and prevent nosocomial infection¹¹.

We make some specific recommendations, based on our study, to prevent orthopaedic surgeons from becoming infected with COVID-19 in a territory reporting local transmission:

1. Orthopaedic surgeons should stay more vigilant, have a high level of clinical suspicion, and take more precautions to avoid COVID-19 infection.
2. Medical and orthopaedic associations should be prepared early, address the uncertainty of infection prevention and control procedures, provide real-time training as needed, and also address the shortage of PPE.
3. It is wise to minimize, postpone, or cancel elective operations. Have the patients tested for COVID-19 before the operation if resources allow. Place face masks on patients.
4. For the orthopaedic surgeons who still work in hospital settings, it is wise to adhere to the U.S. Centers for Disease Control and Prevention (CDC) recommendations for infection prevention and control and to wear N95 respirators all of the time when necessary during the pandemic.
5. After being exposed in environments contaminated by patients with confirmed or suspected COVID-19, orthopaedic surgeons should manage to avoid close contact with family members at home and maintain social distancing in other situations.
6. Orthopaedic surgeons should try to avoid long-term overwork and fatigue, which could compromise immunity against COVID-19.

It has been shown that health-care workers at risk require clear communication, emotional support, and effective leader-

ship. We believe that a united global orthopaedic community can contribute to the fight against COVID-19.

Appendix

 Supporting material provided by the authors is posted with the online version of this article as a data supplement at [jbj.org \(http://links.lww.com/JBJS/F828\)](http://links.lww.com/JBJS/F828). ■

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