First Reported Nosocomial Outbreak of Severe Acute Respiratory Syndrome Coronavirus 2 in a Pediatric Dialysis Unit

Vera Schwierzeck,1,a Jens Christian König,2,3,a Joachim Kühn,4 Alexander Mellmann,1 Carlos Luis Correa-Martínez,1 Heymut Omran,2 Martin Konrad,2,3 Thomas Kaiser,2,b and Stefanie Kampmeier1,b

1Institute of Hygiene, University Hospital Münster, Münster, Germany, 2Department of General Pediatrics, University Children’s Hospital Münster, Münster, Germany, 3KfH Kidney Center for Children and Adolescents, Münster, Germany, and 4Institute of Virology, University Hospital Münster, Münster, Germany

Background. Coronavirus disease 2019 (COVID-19) is a life-threatening respiratory condition caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and was initially detected in China in December 2019. Currently, in Germany >140 000 cases of COVID-19 are confirmed. Here we report a nosocomial outbreak of SARS-CoV-2 infections in the pediatric dialysis unit of the University Hospital Münster (UHM).

Methods. Single-step real-time reverse-transcription polymerase chain reaction (rRT-PCR) from nasopharyngeal swabs was used to diagnose the index patient and identify infected contacts. Epidemiological links were analyzed by patient interviews and medical record reviews. In addition, each contact was assessed for exposure to the index case and monitored for clinical symptoms. Cycle threshold (Ct) values of all positive test results were compared between symptomatic and asymptomatic cases.

Results. Forty-eight cases were involved in this nosocomial outbreak. Nine contact cases developed laboratory-confirmed COVID-19 infections. Two SARS-CoV-2–positive cases remained clinically asymptomatic. Eleven cases reported flulike symptoms without positive results. Ct values were significantly lower in cases presenting typical COVID-19 symptoms, suggesting high viral shedding (P = .007).

Conclusions. Person-to-person transmission was at the heart of a hospital outbreak of SARS-CoV-2 between healthcare workers (HCWs) and patients in the pediatric dialysis unit at UHM. Semiquantitative rRT-PCR results suggest that individuals with high viral load pose a risk to spread SARS-CoV-2 in the hospital setting. Our epidemiological observation highlights the need to develop strategies to trace and monitor SARS-CoV-2–infected HCWs to prevent COVID-19 outbreaks in the hospital setting.

Keywords. nosocomial SARS-CoV-2 outbreak; COVID-19; super-spreader; exposure-based risk classification; infection control measures.

In December 2019, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), a novel B lineage betacoronavirus, was discovered in Wuhan City, Hubei Province, China [1, 2]. SARS-CoV-2 causes coronavirus disease 2019 (COVID-19), a severe respiratory syndrome that is associated with fever, cough, dyspnea, myalgia, and fatigue [3]. On 11 March 2020, the World Health Organization declared COVID-19 a pandemic, and SARS-CoV-2 infections currently pose a serious threat to healthcare systems worldwide [4]. SARS-CoV-2 is the third member of the Coronaviridae family, along with the severe acute respiratory syndrome coronavirus (SARS-CoV) and the Middle East respiratory syndrome virus (MERS-CoV), to cause major epidemic outbreaks in the last 20 years [2, 5, 6]. Recent studies demonstrate that SARS-CoV-2 is more contagious than SARS-CoV and MERS-CoV [7]. While persistence of SARS-CoV-2 has been described on inert surfaces, person-to-person transmission via droplets is believed to be the main mode of transmission followed by an incubation period of 5 days on average before onset of illness [2, 7, 8].

Several publications have described nosocomial transmission for the current COVID-19 pandemic [9, 10]. It has been estimated that >3300 healthcare workers (HCWs) in China have been infected with SARS-CoV-2 during the outbreak and in Italy, an estimated 20% of those infected were HCWs [11]. However, detailed epidemiological characterization of transmission chains in the hospital setting remains scarce. Consequently, there is concern that infection control measures are not adequate to prevent SARS-CoV-2 transmissions between individuals in healthcare settings.

The first COVID-19 case in Germany was diagnosed on 27 January 2020 and the first case of SARS-CoV-2 infection at the University Hospital Münster (UHM) was detected on 29
February 2020 [12]. The UHM is a 1500-bed university hospital in the federal state of North-Rhine-Westphalia, Germany, with a catchment area of 310,000 inhabitants. By the beginning of April, >140,000 cases of COVID-19 have been detected in Germany and >29,000 cases of COVID-19 in the region of North-Rhine-Westphalia [13].

Here we describe an outbreak of SARS-CoV-2 among 28 HCWs, 13 patients, and 7 accompanying persons (ACPs) at the pediatric dialysis unit of UHM. Recently the European Dialysis Working Group of the European Renal Association–European Dialysis Transplant Association has classified uremic patients on hemodialysis as a risk group for COVID-19 infection due to an impaired immune system, high burden of comorbidities, and frequent hospitalization [7].

As the pandemic continues to spread, it will be important to establish effective infection control strategies to protect frontline HCWs and patients from nosocomial SARS-CoV-2 infections. Here we provide a detailed contact investigation including clinical and laboratory findings of all individuals associated with the outbreak. Our observation emphasizes that nosocomial SARS-CoV-2 outbreaks require effective infection control strategies to prevent transmission within the hospital setting.

METHODS

Epidemiological Data Collection

Individuals with laboratory-confirmed SARS-CoV-2 infection were recorded as COVID-19 cases. Contacts were identified based on potential exposure to the index case on the day of the index case’s symptom onset. For the purposes of this outbreak investigation, day 0 was considered as 2 days prior to the day of first symptoms for the index case. Cases were classified as hospital acquired, if SARS-CoV-2 real-time reverse-transcription polymerase chain reaction (rRT-PCR) was positive after contact to the index case without any alternative source of transmission (eg, SARS-CoV-2-positive household contacts).

Patients, ACPs, and HCW were interviewed to identify COVID-19 typical symptoms (n = 11) each day for 10 days and to trace additional individuals who had contact with the index case while symptomatic.

Exposure Risk Classification, Monitoring of Contacts, and Hygienic Measures

Persons with contact to SARS-CoV-2–infected individuals were assessed for their type of exposure with the help of a risk-based questionnaire, adopted from the guidelines issued by the Robert Koch Institute, Germany’s national public health institute. The criteria considered for the different types of exposure were duration of exposure, personal protective equipment used during exposure, distance to the infective source, and potential infectivity of body fluids (Table 1). In case of suspected or confirmed SARS-CoV-2 infection, personnel were instructed to wear filtering facepiece-2 masks, and sterile gloves and gowns for personal protective equipment. For aerosol-generating procedures, goggles were additionally recommended.

The outbreak was defined as 2 or more COVID-19 infections resulting from a common exposure that was either suspected or laboratory-confirmed as SARS-CoV-2. After identification, the outbreak was reported to the local public health department. In addition, following the recommendations of the Robert Koch Institute for hygienic measures (Table 1), patients were preemptively isolated. Alternatively, if an outpatient treatment was necessary due to their underlying diseases (eg, hemodialysis), patients were cohorted together with their ACP.

Swab Sampling and Laboratory Testing

Following internal standard operating procedures for specimen collection, nasopharyngeal swabs of all persons with contact to the index case were collected from day 5 onward (after the index case was confirmed on day 4). If first test showed a negative result but contact cases presented new or worsened symptoms, testing was repeated. SARS-CoV-2 was detected by specific assays targeting 2 separate genes via rRT-PCR as described previously [14]. Detection of the envelope (E) gene was used as a screening test, and detection of the RNA-dependent RNA polymerase (RdRp) gene was used for confirmation. The cycle threshold (Ct) value, which is inversely proportional to the viral load, was documented for every SARS-CoV-2–positive sample.

Statistical Analysis

Statistical analysis was performed using the Student t test. Statistical significance was declared at P < .05.

RESULTS

Involved Outbreak Cases and Outbreak Dynamics

Forty-eight cases (28 HCWs, 13 patients, and 7 ACPs) were involved in the outbreak, including index case and contact cases. The average age of HCWs was 46 years, of patients was 10 years, and of ACPs was 32 years. In total 15 cases were male and 33 were female. All patients suffer from chronic kidney disease, with the majority being on regular hemodialysis.

After contact to the index case, 9 contact cases (7 HCWs, 1 patient, and 1 ACP) developed laboratory-confirmed COVID-19 infections. All of these were categorized as type I or Ib exposure, according to mentioned criteria (Table 1). No contact was categorized as Ia. In total, 4 of 8 type I and 7 of 7 type Ib contacts became infected. No type II contact tested positive for SARS-CoV-2. Additionally, 2 patients were tested positively for SARS-CoV-2 but did not present with apparent COVID-19 symptoms. Another 11 HCWs affirmed common cold symptoms without being tested positively. No case reported dyspnea (Figure 1; Table 2).
In total, during the outbreak 12 cases were confirmed SARS-CoV-2 positive by rRT-PCR. Of these, 6 individuals presented with symptoms at the time they were tested. Ct values of symptomatic cases were significantly lower compared to asymptomatic cases (22.55 [range, 16.03–23.50] vs 29.94 [range, 21.89–37.49]; \( P = .007 \)), indicating an approximately 200-fold higher viral load (Table 2).

After establishing adequate hygienic measures (Table 1) for all HCWs, patients, and ACPs from day 4 on, no further laboratory-confirmed COVID-19 infection was discovered.

**DISCUSSION**

COVID-19 is currently a public health–relevant pandemic that will increase hospital admissions for severe acute respiratory disorders. In addition, hospital-acquired COVID-19 infections are a potential route of transmission and pose a threat to vulnerable inpatients and HCWs.

We characterized a nosocomial outbreak of SARS-CoV-2 on a pediatric dialysis unit that involved 48 cases including patients, ACPs, and HCWs. Detailed contact investigation and initial laboratory testing identified an index case and infected contact cases, confirming previous findings that person-to-person transmission is also the most likely mode of transmission in the hospital setting [15].

Part of our outbreak investigation was a detailed assessment of clinical symptoms associated with COVID-19 infection. Interestingly, 2 infected children with chronic kidney disease either presented a very mild phenotype or even remained asymptomatic, despite being considered to be at particular risk for respiratory infections because of hemodialysis [16, 17]. This might confirm reports that children suffering from COVID-19 often present with relatively mild symptoms [18]. However, the majority of confirmed cases became symptomatic, with body aches accompanied by flank and loin

---

**Table 1. Risk Classification and Infection Control Measures of Healthcare Workers and Patients After Contact With Coronavirus Disease 2019 Confirmed Cases**

| Risk Type of Exposure | Measures |
|----------------------|----------|
|                      | HCWs     | No Shortage of Personnel | Patients |
| I                    | Shortage of Personnel | Home quarantine (14 d<sup>a</sup>) | Symptom monitoring (14 d<sup>a</sup>) In case of typical COVID-19 symptoms: further diagnostics after contact to local health authorities |
|                      | No Shortage of Personnel | Home quarantine (14 d<sup>a</sup>) | Symptom monitoring (14 d<sup>a</sup>) In case of typical COVID-19 symptoms: further diagnostics after contact to local health authorities |
| I<sub>a</sub> HCWs with direct exposure to respiratory secretions, body fluids, or aerosols of confirmed COVID-19 cases, without usage of PPE | Home quarantine for 7 d; if no symptoms, continue work while wearing a surgical face mask | Home quarantine (14 d<sup>a</sup>) | Symptom monitoring (14 d<sup>a</sup>) In case of typical COVID-19 symptoms: further diagnostics after contact to local health authorities |
| I<sub>b</sub> HCWs exposed during treatment or nursing in a distance of ≤ 2 m, without PPE | Continue work while wearing surgical face mask In case of typical symptoms, SARS-CoV-2 test when possible and home quarantine until infection excluded or confirmed Excluded infection: continue work Confirmed infection: home quarantine 14 d | Home quarantine (14 d<sup>a</sup>) | Symptom monitoring (14 d<sup>a</sup>) In case of typical COVID-19 symptoms: further diagnostics after contact to local health authorities |
| II Shared indoor environment without cumulative 15 min of face-to-face contact; HCWs exposed during treatment or nursing in a distance of > 2 m, without PPE | Symptom monitoring (14 d<sup>a</sup>) If contact to respiratory secretions, body fluids, or aerosols of confirmed COVID-19 cases, see I<sub>b</sub> If no contact to respiratory secretions, body fluids, or aerosols of confirmed COVID-19 cases, see III | Symptom monitoring (14 d<sup>a</sup>) | |
| III HCWs exposed during treatment or nursing in a distance of > 2 m HCWs exposed during treatment or nursing using in a distance ≤ 2 m, using PPE | Symptom monitoring for 14 d Continue work, if possible while wearing surgical face mask | |

**Abbreviations:** COVID-19, coronavirus disease 2019; HCW, healthcare worker; PPE, personal protective equipment; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

<sup>a</sup>Adopted according to the Robert Koch Institute, Germany; 21 April 2020; [https://www.rki.de/DE/Content/InfAZ/N/Neuartiges_Coronavirus/HCW.html](https://www.rki.de/DE/Content/InfAZ/N/Neuartiges_Coronavirus/HCW.html).

<sup>b</sup>PPE is defined as surgical masks; unsterile gloves and gowns; and, for aerosol-generating procedures, filtering facepiece-2 masks and additional goggles.

<sup>c</sup>After last exposure.
pain, fatigue, and headache. Similar to influenza, infected individuals described loss of taste and smell several days after onset of illness. This is consistent with statements of the British Association of Otorhinolaryngology and the American Academy of Otolaryngology–Head and Neck Surgery reporting dysgeusia and anosmia in COVID-19 patients [19, 20]. These particular symptoms should be investigated in larger epidemiological cohorts [21].
Previous studies suggest better positive predictive values if tests are performed in symptomatic individuals [22]. Our findings in HCW25 seem to corroborate these findings: Whereas the initial test was negative after contact to the index case without any symptoms, the HCW was positively tested 3 days later after development of clinical signs of a SARS-CoV-2 infection. Since lower Ct values and therefore higher viral load were detected in symptomatic patients and HCWs, our observations give a first hint to support this testing strategy for the hospital setting. For example, HCW1 (index case) experienced

### Table 2. Type of Exposure and Symptoms at Time of Testing

| Person | Type of Exposure | SARS-CoV-2 rRT-PCR Test Result | New Symptoms at Time of Testing | Ct Value |
|--------|-----------------|-------------------------------|--------------------------------|----------|
| HCW1   | Index case      | +                             | Yes                            | 17.96    |
| P1     | I               | +                             | Yes                            | 20.62    |
| HCW2   | lb              | +                             | No                             | 21.89    |
| HCW3   | lb              | +                             | No                             | 25.25    |
| HCW4   | lb              | +                             | No                             | 23.85    |
| HCW5   | lb              | +                             | No                             | 32.98    |
| HCW6   | lb              | +                             | No                             | 31.50    |
| HCW7   | II              | No                            | No                             | ...      |
| HCW8   | II              | Yes                           | No                             | ...      |
| HCW9   | II              | No                            | No                             | ...      |
| HCW10  | II              | No                            | No                             | ...      |
| HCW11  | II              | No                            | No                             | ...      |
| HCW12  | II              | Yes                           | No                             | ...      |
| HCW13  | II              | No                            | No                             | ...      |
| HCW14  | II              | No                            | No                             | ...      |
| HCW15  | II              | No                            | No                             | ...      |
| HCW16  | II              | No                            | No                             | ...      |
| HCW17  | II              | No                            | No                             | ...      |
| HCW18  | II              | No                            | No                             | ...      |
| HCW19  | II              | No                            | No                             | ...      |
| HCW20  | II              | No                            | No                             | ...      |
| HCW21  | II              | No                            | No                             | ...      |
| HCW22  | II              | No                            | No                             | ...      |
| HCW23  | II              | No                            | No                             | ...      |
| HCW24  | II              | No                            | No                             | ...      |
| HCW25  | lb              | +; -                          | No; yes                         | 21.35    |
| P2     | I               | +                             | No                             | 37.49    |
| ACP1   | I               | +                             | Yes                            | 16.03    |
| HCW26  | lb              | +                             | Yes                            | 23.50    |
| HCW27  | II              | No                            | No                             | ...      |
| HCW28  | II              | No                            | No                             | ...      |
| P3     | I               | No                            | No                             | 30.58    |
| P4     | I               | No                            | No                             | ...      |
| P5     | I               | No                            | No                             | ...      |
| P6     | I               | No                            | No                             | ...      |
| P7     | II              | No                            | No                             | ...      |
| P8     | II              | No                            | No                             | ...      |
| P9     | II              | No                            | No                             | ...      |
| P10    | I               | No                            | No                             | ...      |
| ACP2   | II              | No                            | No                             | ...      |
| ACP3   | II              | No                            | No                             | ...      |
| ACP4   | II              | No                            | No                             | ...      |
| ACP5   | II              | No                            | No                             | ...      |
| P11    | II              | No                            | No                             | ...      |
| ACP6   | II              | No                            | No                             | ...      |
| ACP7   | II              | No                            | No                             | ...      |
| P12    | II              | No                            | No                             | ...      |
| P13    | II              | No                            | No                             | ...      |

Abbreviations: -, negative; +, positive; ACP, accompanying person; Ct, cycle threshold; HCW, healthcare worker; P, patient; rRT-PCR, real-time reverse-transcription polymerase chain reaction; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.
fever on day 2, resulting in a low Ct value when she was tested 2 days later. As many healthcare systems are facing the problem of reduced laboratory testing capacity, based on our results we are cautious to recommend testing asymptomatic contacts but would preferably monitor clinical key symptoms. On the other hand, individuals with high viral load could potentially serve as a source of transmission, supporting the theory of so-called super-spreaders [23].

During the outbreak management, we classified contacts according to duration and severity of exposure (Table 1). While only cases with type I/Ib exposure became symptomatic, several other cases with type I/IIb exposure did not develop symptoms. This result suggests that an exposure-based classification is not specific enough to discriminate high-risk from no-risk contacts. However, this recommendation in combination with infection control measures allows key personnel to continue work while self-monitoring symptoms. This strategy can be used to maintain an adequate healthcare service while facing staff shortages during the current SARS-CoV-2 pandemic.

In summary, our investigation suggests that application of appropriate infection control measures, including contact tracing, assessment of exposure, and optimal symptom-based testing strategies, is essential to prevent outbreaks of SARS-CoV-2 within hospital settings.

Notes
Author contributions. V. S., J. C. K., A. M., C. L. C.-M., H. O., M. K., T. K., and S. K. provided contact investigation and collected epidemiological data. J. C. K., T. K., H. O., and M. K. provided clinical care to the patients and provided clinical case histories. J. K. evaluated and provided laboratory test results. V. S. and S. K. performed data analysis and interpretation, and drafted and revised the manuscript. All authors reviewed, revised, and approved the final manuscript. The corresponding author had full access to all data in the study and final responsibility for the decision to submit for publication.

Acknowledgments. The authors thank the patients and staff at the Pediatric Nephrology unit for their collaboration during this investigation, and the team of the Institute of Virology for excellent laboratory work.

Disclaimer. The funding institution had no role in the study design; data collection, analysis, or interpretation; writing of the manuscript; or decision to publish.

Financial support. This work was supported by the German Research Foundation (DFG) Clinical Research Unit 342.

Potential conflicts of interest. The authors: No reported conflicts of interest. All authors have submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest.

References
1. Chan JF-W, Yuan S, Kok K-H, et al. A familial cluster of pneumonia associated with the 2019 novel coronavirus indicating person-to-person transmission: a study of a family cluster. Lancet 2020; 395:514–23.
2. Zhou P, Yang XL, Wang XG, et al. A pneumonia outbreak associated with a new coronavirus of probable bat origin. Nature 2020; 579:270–3.
3. Huang C, Wang Y, Li X, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. Lancet 2020; 395:497–506.
4. World Health Organization. Coronavirus disease 2019 (COVID-19) situation report–51. Available at: https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200311-sitrep-51-covid-19.pdf?sfvrsn=1ba6e57_10. Accessed 20 April 2020.
5. Liu J, Zheng X, Tong Q, et al. Overlapping and discrete aspects of the pathology and pathogenesis of the emerging human pathogenic coronaviruses SARS-CoV, MERS-CoV, and 2019-nCoV. J Med Virol 2020; 92:491–4.
6. Lu R, Zhao X, Li J, et al. Genomic characterisation and epidemiology of 2019 novel coronavirus: implications for virus origins and receptor binding. Lancet 2020; 395:565–74.
7. Basile C, Combe C, Pizzarelle F, et al. Recommendations for the prevention, mitigation and containment of the emerging SARS-CoV-2 (COVID-19) pandemic in haemodialysis centres [manuscript published online ahead of print 20 March 2020]. Nephrol Dial Transplant 2020; doi:10.1093/ndt/gfaa069.
8. Kampf G, Todis D, Pfaender S, Steinhann E. Persistence of coronaviruses on inanimate surfaces and their inactivation with biocidal agents. J Hosp Infect 2020; 104:246–51.
9. Wang D, Hu B, Hu C, et al. Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus-infected pneumonia in Wuhan, China [manuscript published online ahead of print 7 February 2020]. JAMA 2020; doi: 10.1001/jama.2020.1585.
10. Eurosurveillance Editorial Team. Updated rapid risk assessment from ECDC on the novel coronavirus disease 2019 (COVID-19) pandemic: increased transmission in the EU/EEA and the UK. Euro Surveill 2020; 25. doi:10.2807/1560-7917. ES.2020.25.10.2003121.
11. The Lancet. COVID-19: protecting health-care workers. Lancet 2020; 395:922.
12. Rothe C, Schunk M, Sothmann P, et al. Transmission of 2019-nCoV infection from an asymptomatic contact in Germany. N Engl J Med 2020; 382:970–1.
13. Robert Koch Institute. Coronavirus disease 2019 (COVID-19) daily situation report of the Robert Koch Institute. Available at: https://www.rki.de/DE/Content/InfAZ/N/Neuartiges_Coronavirus/Situationsberichte/2020-03-26_en.pdf?__blob=publicationFile. Accessed 20 April 2020.
14. Corman VM, Landt O, Kaiser M, et al. Detection of 2019 novel coronavirus (2019-nCoV) by real-time RT-PCR. Euro Surveill 2020; 25. doi:10.2807/1560-7917. ES.2020.25.13.200045.
15. Ghinai I, McPherson TD, Hunter JC, et al; Illinois COVID-19 Investigation Team. First known person-to-person transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in the USA. Lancet 2020; 395:1137–44.
16. Eickhoff TC, Sherman IL, Serfling RE. Observations on excess mortality associated with epidemic influenza. JAMA 1961; 176:776–82.
17. Kwan BC, Leung CB, Szeto CC, et al. Severe acute respiratory syndrome in dialysis patients. J Am Soc Nephrol 2004; 15:1883–8.
18. Qu H, Wu J, Hong L, Luo Y, Song Q, Chen D. Clinical and epidemiological features of 36 children with coronavirus disease 2019 (COVID-19) in Zhejiang, China: an observational cohort study [manuscript published online ahead of print 25 March 2020]. Lancet Infect Dis 2020; doi:10.1016/S1473-3099(20)30198-5.
19. ENT UK. Loss of sense of smell as marker of COVID-19 infection. Available at: https://www.entuk.org/sites/default/files/files/Loss%20of%20sense%20of%20smell%20as%20marker%of%20COVID.pdf. Accessed 20 April 2020.
20. American Academy of Otolaryngology–Head and Neck Surgery. AAO-HNS: anosmia, hyposmia, and dysgeusia symptoms of coronavirus disease. Available at: https://www.entnet.org/content/aoa-hns-anosmia-hyposmia-and-dysgeusia-symptoms-coronavirus-disease. Accessed 20 April 2020.
21. Flanagan CE, Wise SK, DelGaudio JM, Patel ZM. Association of decreased rate of influenza vaccination with increased subjective olfactory dysfunction. JAMA Otolaryngol Head Neck Surg 2015; 141:225–8.
22. To KK-W, Tsang OT-Y, Leung W-S, et al. Temporal profiles of viral load in posterior oropharyngeal saliva samples and serum antibody responses during infection by SARS-CoV-2: an observational cohort study [manuscript published online ahead of print 23 March 2020]. Lancet Infect Dis 2020; doi: 0.1016/S1473-3099(20)30196-1.
23. Chowell G, Abdirizak F, Lee S, et al. Transmission characteristics of MERS and SARS in the healthcare setting: a comparative study. BMC Med 2015; 13:210.