Journal of Vocational Health Studies

www.e-journal.unair.ac.id/index.php/JVHS

MODES OF SARS-COV-2 TRANSMISSION

CARA TRANSMISI SARS-COV-2

Nilesh D. Patel, Kairavi J. Desai *, Shirishkumar M. Patel

Department of Microbiology, Government Medical College, Bhavnagar - 364001, Gujarat-India

Literature Review
Studi Literatur

ABSTRACT

Background: *On 12th December 2019, pneumonia of unknown etiology was reported in number of human cases from Wuhan, central China. On 11th February 2020, the WHO named the disease COVID-19, short for "COronaVIrus Disease 2019". This COVID-19 out-break has grown substantially to that of pandemic nature currently. Close personal contact and respiratory droplets from sneezes and coughs of patient can disseminate SARS-CoV-2. The WHO continues to stress the usefulness of environmental cleaning and disinfection, frequent hand hygiene, respiratory etiquette. The WHO also suggests avoidance of close, unprotected contact and maintenance of physical distance with people having fever or respiratory symptoms.* ***Purpose:*** *To develop strategies for lowering transmission of COVID-19, development of ways for distinguishing the various modes of transmission such as urine and fecal samples is need of the hour.* ***Review:*** *In a clinical scenario where possibility of vertical transmission of Covid-19 is increasingly being reported and transplacental transmission of the SARS-COV-2 cannot be ruled out, medical fraternity requires more evidence on vertical transmission for better mother and newborn care.* ***Conclusion:*** *In order to study the vertical dissemination of SARS-CoV-2, the heath authorities should include additional examinations of maternal and newborn samples in standard treatment guideline for pregnant women.*

ABSTRAK

Latar Belakang: Pada 12 Desember 2019, pneumonia dengan etiologi yang tidak diketahui dilaporkan dalam jumlah kasus manusia dari Wuhan, Cina tengah. Pada 11 Februari 2020, WHO menamai penyakit ini COVID-19, kependekan dari "COronaVIrus Disease 2019". Wabah COVID-19 ini telah berkembang secara substansial dengan sifat pandemi saat ini. Kontak pribadi yang dekat dan tetesan pernapasan dari bersin dan batuk pasien dapat menyebarkan SARS-CoV-2. WHO terus menekankan kegunaan pembersihan dan desinfeksi lingkungan, kebersihan tangan yang sering, etiket pernapasan. WHO juga menyarankan untuk menghindari kontak dekat tanpa pelindung dan menjaga jarak fisik dengan orang yang mengalami demam atau gejala pernapasan. **Tujuan:** Untuk mengembangkan strategi penurunan penularan COVID-19, diperlukan pengembangan cara untuk membedakan berbagai cara penularan seperti sampel urin dan feses. **Tinjauan Pustaka:** Dalam skenario klinis di mana kemungkinan penularan vertikal Covid-19 semakin dilaporkan dan penularan transplasenta dari SARS-COV-2 tidak dapat dikesampingkan, persaudaraan medis memerlukan lebih banyak bukti tentang penularan vertikal untuk perawatan ibu dan bayi baru lahir yang lebih baik. **Kesimpulan:** Untuk mempelajari penyebaran vertikal SARS-CoV-2, otoritas kesehatan harus memasukkan pemeriksaan tambahan sampel ibu dan bayi baru lahir dalam pedoman pengobatan standar untuk wanita hamil.

ARTICLE INFO

Received 02 October 2020
Revised 19 April 2021
Accepted 09 June 2021
Online 31 July 2021

Correspondence:
Kairavi J. Desai

E-mail :
drkairavi@yahoo.in

Keywords:
COVID-19, Modes of transmission, SARS-COV-2

Kata kunci:
COVID-19, Cara transmisi, SARS-COV-2

Journal of Vocational Health Studies p-ISSN: 2580–7161; e-ISSN: 2580–717x
DOI: 10.20473/jvhs.V5.I1.2021.47-52

INTRODUCTION

A human case series caused by unknown pneumonia were reported from Wuhan, Hubei, central China, on 12th December 2019. The clinicians diagnosed this illness as viral pneumonia, which was based on clinical findings like pyrexia, lymphopenia, lung infiltrates on X-ray chest and no clinical improvement after antibiotic treatment of three days. It was noticed that the majority of the early cases gave contact history with the seafood market of Wuhan. Clinical samples from seven patients having severe pneumonia, who was under treatment at the intensive care unit of Wuhan Jin Yin-Tan Hospital at the start of the outbreak, were sent to the Wuhan Institute of Virology (WIV) for the diagnosis of the etiological pathogen. Five samples were found to be PCR-positive for Coronaviruses. (Zhou et al., 2020). Based on these data, the World Health Organization (WHO) declared a pneumonia outbreak of unknown etiology in Wuhan on 31st December 2019. (WHO, 2020a).

On 30th January 2020, the WHO declared the Chinese outbreak of pneumonia to be a Public Health Emergency of International Concern, posing a high risk to countries with weaker health systems. (WHO, 2020b). At first, the virus had been designated as 2019-novel CoV (2019-nCoV). On 5th February 2020, It was renamed Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) by the International Committee on Taxonomy of Viruses (ICTV), due to the genetic relatedness with human SARS-CoV. (Gorbalenya et al., 2020). On 11th February 2020, the WHO named the disease COVID-19, an acronym for "COronaVIrus Disease 2019". (WHO, 2020c). SARS-CoV-2 is a member of the giant coronavirus family, which causes illnesses starting from the common cold infection to serious infections in humans. (WHO, 2020d). This COVID-19 out-break has grown substantially to that of pandemic nature currently. A complete of 7941791 Laboratory confirmed cases, 434796 confirmed deaths have been reported from 216 Countries, areas or territories with COVID-19 cases, as of 17 June 2020. (World Health Organization, n.d.).

The clinical spectrum of COVID-19 patients varies from gentle non-specific symptoms to severe pneumonia with end-organ damage. The common symptoms are fever, dyspnea, cough, sputum production, myalgia, fatigue and headache. Less commonly, symptoms like rhinorrhea, sore throat, chest pain, hemoptysis, nausea, vomiting, diarrhea, and conjunctival congestion are also observed. The COVID-19's incubation period range is calculated as 2-14 days, median incubation period starting from clinical exposure to illness onset is 3-5 days. Conjointly, the incubation period as long as 24 days have been reported. (Ge et al., 2020; Lauer et al., 2020). We summarize the latest scientific data on SARS-COV-2 transmission and emphasize specific interventions to break the COVID-19 transmission cycle. This review article intends to enhance our understanding of COVID-19 transmission so that we can intensify our interventions against it.

LITERATURE REVIEW

Time-line in COVID-19 pandemic

1. 12th December 2019: A human case series caused by unknown pneumonia were reported from Wuhan, Hubei, central China
2. 31st December 2019: WHO had been informed of pneumonia outbreak of unknown etiology, Wuhan
3. 30th January 2020: WHO declared the Chinese outbreak of pneumonia to be a Public Health Emergency of International Concern
4. 5th February 2020: International Committee on Taxonomy of Viruses renamed the virus as SARS-CoV-2
5. 11th February 2020: WHO named the disease COVID-19, short for "COronaVIrus Disease 2019"

DISCUSSION

• Respiratory droplets and close contact transmission

COVID-19 is a respiratory disease which is caused by a recently discovered coronavirus SARS-CoV-2. Many patients among initial COVID-19 cases had been connected to the Huanan Seafood Wholesale Market, Wuhan, China, suggesting that SARS-CoV-2 was possibly transmitted from animals to humans. Person-to-person transmission has been confirmed by the presence of COVID-19 in a group of infected family members and health workers. (Harapan et al., 2020). Human-to-human transmission of the COVID-19 virus takes place primarily through salivary droplets or nasal discharge when an infected person coughs or sneezes. (WHO, 2020e). According to the Center for Disease Control and Prevention (CDC), coronavirus is most likely to spread through close contact from person to person. Coronavirus also spreads through respiratory droplets, from coughs and sneezes of the patient, that can land on a nearby person's mouth or nose. (Centers for Disease Control and Prevention, 2020).

Respiratory infections may spread by way of droplets of various sizes. Respiratory droplets are referred to as droplet particles when having more than 5-10 μm in diameter, and when they have less than 5μm diameter, they are referred to as droplet nuclei. Based on current-day evidence, SARS-CoV-2 is essentially disseminated in the population via respiratory droplets

and contact routes. Direct contact transmission can occur by droplet transmission, which occurs when a person is within the one-meter distance of coughing or sneezing a patient. Such a person is at risk of having his oral mucosa, nasal mucosa or conjunctiva exposed to potentially infective respiratory droplets. Indirect contact transmission may additionally occur through fomites like stethoscopes or thermometers, within the nearby environment of the infected people.

Airborne transmission occurs by microbes present in droplet nuclei. Droplet nuclei are small particles less than 5μm in diameter. They can stay suspended in the air for long periods and be transmitted to others over distances of more than one meter. As far as COVID-19 is concerned, airborne transmission may be possible where procedures or aerosol-generating treatments are performed. They may include administration of nebulized treatment, bronchoscopy, cardiopulmonary resuscitation, disconnecting the ventilated patient, tracheostomy, endotracheal intubation, manual ventilation before intubation, open suctioning, non-invasive positive-pressure ventilation and turning the patient to the prone position. (WHO, 2020f). In stark contrast, the airborne transmission was not reported in a study from China, involving 75,465 COVID-19 patients. (Ong et al., 2020). Hong Kong hospital research suggested that SARS-CoV-2 is not spread by the airborne route. It is also recommended that nosocomial transmissions can be prevented through environmental cleaning, hand hygiene and the wearing of surgical masks. (Wong et al., 2020).

Contact transmission plays a role in the spread of COVID-19. Virus particles discharged from the respiratory tract of an infected person contaminate a surface. When another individual comes into contact with that contaminated surface and then touches his mouth, eyes or nose, the virus can enter into the body through the mucosa, infecting the second person. (Ghose, 2020). A group of coronavirus patients was detected, having a history associated with a shopping mall in Wenzhou, China. The investigation was conducted upon them to determine possible modes of virus transmission. The data suggested indirect coronavirus transmission, maybe arising from virus aerosolization in a closed space, virus contamination of common objects or transmission from asymptomatic infected persons. (Cai et al., 2020). Coronavirus survival time under different circumstances had been studied and the analysis of 22 studies reveals that human coronaviruses have capability to survive on inanimate surfaces like glass, metal or plastic for up to nine days. Coronaviruses can be expeditiously rendered inactive by surface disinfection procedures with 0.5% hydrogen peroxide, 62-71% ethanol or 0.1% sodium hypochlorite within one minute. However, tidal agents like 0.02% chlorhexidine digluconate or 0.05-0.2% benzalkonium chloride are less effective. An identical result is expected against the SARS-CoV-2. In absence of specific therapies for SARS-CoV-2, containment at an early stage and prevention of further spread will be decisive to stop the ongoing outbreak and to control this new infectious threat. (Kampf et al., 2020). Such transmission variables may have varied clinical implications, as documented in a research study. SARS-CoV-2 infection was highly contagious during the incubation period, along with fast transmission in a specific group of youngsters outside Wuhan. COVID-19 infection developed rapidly in these youngsters along with various nonspecific atypical clinical manifestations. Infection in these youngsters was much milder than in older patients as previously reported. (Huanga et al., 2020). Scientific evidence demonstrates that asymptomatic carriers, during the incubation period can transmit COVID-19. (Yea et al., 2020).

Based on the available evidence, WHO goes on to advocate contact, droplet and airborne precautions for those people caring for COVID-19 patients. The WHO recommends rational and appropriate use of all personal protective equipment. The WHO continues to stress the usefulness of environmental cleaning and disinfection, frequent hand hygiene, respiratory etiquette, along with avoidance of close unprotected contact, maintaining physical distances with people having fever or respiratory symptoms. (WHO, 2020f).

• Nosocomial transmission

Nosocomial spread of COVID-19 infection has been reported worldwide, and all Health Care Workers (HCWs) are at a high risk of getting this infection. (Wang et al., 2020; Wong et al., 2020; Wei et al., 2021) Human-to-human transmission via close contact and respiratory droplets remains the core risk factor for hospital outbreak of SARS-CoV-2 between HCWs and patients. Hospitals should develop their plans to trace and supervise COVID-19 infected HCWs to prevent COVID-19 outbreaks in their settings. All HCWs should be protected from COVID-19 infection by strict surveillance and infection-control practices. At the same time, the HCWs should remain vigilant during this pandemic, and make self-quarantine at their home if self-suspected.

• Super-spreader transmission

"S"Super-spreader" or "super-spreading event" terms are not scientifically defined. The WHO refers to a super-spreader as a patient (or an event) in which a significant number of individuals become infected from one event that is more than usual. There are many reasons for the manifestation of super-spreading events, which include asymptomatic individuals, increased disease severity and viral load, immune suppression, and large-scale social communication. Immuno-suppressed individuals may have an atypical clinical presentation of COVID. They may shed SARS-COV-2 for a longer period and at a higher level. Asymptomatic persons or mild symptomatic may go unrecognized, and no infection

control measures can be exercised, which may result in a super-spreading event. Variability in viral shedding by the patient is also a possible contributing factor. Few other super-spreading contributing factors include taking care at many hospitals, numerous inter-hospital transfers, big numbers of personal contacts and an extended duration of viral exposure. Super-spreading may be the result of the heightened association between the index case and other people. Hence, a person having a wide-ranging and diverse social life is more likely to infect people than a person who has finite social relations. Thus, to flatten the curve during an epidemic, it is essential to practice social distancing. (Al-Tawfiq and Rodriguez-Morales, 2020).

• Vertical transmission

There is very little data on the clinical picture of COVID-19 in pregnant women and children. Mother to fetus vertical transmission is certainly an area of great medical significance, as mothers may be at higher risk for severe respiratory complications, and the fetuses may be at risk of congenital COVID-19.

On 26th March 2020, Renmin Hospital, Wuhan, China raised a probability of vertical transmission of SARS-COV-2 from a laboratory-confirmed infected mother to her newborn. The mother was Reverse Transcriptase Polymerase Chain Reaction (RT-PCR) confirmed COVID-19 positive for 23 days at the time of delivery. The mother's vaginal secretions were tested by RT-PCR and found negative for SARS-CoV-2. Neither amniotic fluid nor placenta RT-PCR testing was performed. The mother delivered a girl child by cesarean section in a negative-pressure isolation room. The mother wore an N95 mask during delivery and didn't hold her newborn after delivery. This infant showed abnormal cytokine test results and elevated IgM antibody levels two hours after birth. The raised IgM levels are indicative of in-utero neonatal infection. Since the mother was confirmed COVID-19 positive for 23 days at the time of delivery, the infant potentially might have been exposed in-utero during this period. The infant was repeatedly RT-PCR negative on nasopharyngeal swabs. (Dong et al., 2020). Recent research from New York (8th May 2020), directed towards the identification of SARS-CoV-2 in fetal membrane and placental samples, finds placental or membrane swabs positivity in a few clinical samples from COVID-19 positive women. Although there were no clinical signs of vertical transmission, these findings bring up the likelihood of intrapartum viral exposure. Several factors might play out during childbirth, like the merging of fetal and maternal fluid and tissue at the time of delivery, COVID-19 infection of the amniotic sac and membranes, or contamination from amniotic fluid, maternal blood. Presently, a newborn is PCR tested by nasopharyngeal swab, immediately after birth. This approach may not be ideal to assess vertical transmission. Even if neonatal exposure occurs at the time of delivery, a virus may require a longer incubation period before these swabs convert to PCR positive. (Christina A. et al., 2020). Accordingly, nasopharyngeal swab testing of the newborn should be done 4-5 days after delivery.

Of late, the vertical transmission has been studied in one mother and confirmed by comprehensive virological and pathological findings from Paris Saclay University Hospitals in a case report published on 15th May 2020. In our literature search, this is the only study where (RT-PCR) was performed on five maternal clinical samples- amniotic fluid, blood, nasopharyngeal swab, placenta, and vaginal swab, and on three neonatal clinical samples- Blood, Nasopharyngeal swab, and Rectal swab. Clinically, SARS-CoV-2 transmission resulted in placental inflammation neonatal and viremia. This neonate showed neurological presentation, clinically uniform with those expressed in adult patients. (Vivanti et al., 2020). The WHO shows concerns on coronavirus transmission to an infant by contact with infectious respiratory secretions. The WHO advises all mothers with suspected, probable, or confirmed COVID-19 to feed their infants according to standard infant feeding guidelines, and to carry out necessary precautions for infection prevention and control. All symptomatic mothers who are breastfeeding or practicing direct skin contact or kangaroo mother care should wear a medical mask, wash hands before and after contact with the child, and regularly clean and disinfect surfaces with which the symptomatic mother has been in contact. (WHO, 2020g)

In a clinical scenario where the possibility of vertical transmission of Covid-19 is increasingly being reported and transplacental transmission of the SARS-CoV-2 cannot be ruled out, the medical fraternity requires more evidence on vertical transmission for better mother and newborn care.

• Transfusion transmission

As of 25th March 2020, blood transfusion-transmission cases for the SARS-CoV and MERS-CoV were not reported. Viremia has been detected in symptomatic COVID-19 patients only. There is no data or percentage indicating risk of transmission for COVID-19 with blood transfusion. Hence, the American Association of Blood Banks, CDC and US Food and Drug Administration (US-FDA) have not suggested any extra action by blood collection units at this time. There are no suspected or reported cases of transfusion-transmitted COVID-19 as per US-FDA. (Council, 2020). Ever since asymptomatic infections among COVID-19 cases are being found more frequently, a review of blood safety from a coronavirus perspective has become apparent especially in endemic areas. WHO and US-FDA had hypothesized the risk of SARS transmission through transfusion of blood products in their draft recommendations on blood safety. They recommended blood donation deferral for some time period by donors from regions having local transmission. In addition, blood donors have been urged to report to blood collection units, if they had been labeled as confirmed or suspected SARS patients within

one month of their donation. On such occasions, either blood recipients would be traced or non transfused blood products would be recalled. (Chang et al., 2020).

• Feco–oral transmission

Recent studies have unearthed the SARS-CoV-2 hiding in the gastrointestinal tract to be transmitted via the fecal-oral route. In the USA, this virus had been detected in the feces of a patient, who presented with diarrhea before fever. Similar findings have been noted earlier in the SARS pandemic, in which 10%–15% of patients had gastrointestinal symptoms. Owing to the similarity of receptors for both these viruses, SARS-CoV-2 is also expected to replicate in the gastrointestinal tract, hence the name is given as pneumoenteric viruses. (Gupta et al., 2019; Ge et al., 2020) Recently, SARS-CoV-2 was successfully isolated on Vero E6 cell culture lines from the urine sample of a patient. (Team, n.d.). Based on this clinical evidence, we need to develop analytic strategies for identifying different routes of transmission such as, via feces and urine. So that we can devise action plans to reduce transmission of COVID-19. (Hamid et al., 2020).

Research conducted on SARS-CoV and MERS-CoV indicated that transmission of these viruses did not occur through food consumption. As of 21st February 2020, there are no reports of SARS-CoV-2 transmission through food. Yet, issues were raised regarding the capacity of these viruses to survive on raw meat. In general, coronaviruses have been stable in a frozen state. Research studies have shown that they can survive for up to two years at -20°C. MERS-CoV can remain viable for up to 72 hours at 4°C. Current evidence on various coronavirus strains shows that sound food hygiene and food safety practices can stop their transmission through food. In particular, coronaviruses are labile to a normal cooking temperature at 70°C. In general, it would be prudent to avoid the consumption of raw or undercooked animal products. Similarly, raw milk, raw animal organs or raw meat should be tackled with care to circumvent cross-contamination with uncooked foods. (WHO, 2020h).

CONCLUSION

The role of aerosol transmission in hospital settings need be clearly defined for patient and HCW protection from COVID-19. Further research is required in this mode of transmission for better control. In order to study the vertical transmission of SARS-CoV-2, the heath authorities should include additional examinations of maternal and newborn samples in standard treatment guideline for pregnant women. Additional examinations like, virus culture and RT-PCR, can be performed on maternal clinical samples like amniotic fluid, blood, nasopharyngeal swab, placenta, and vaginal swab, and on neonatal clinical samples like blood, nasopharyngeal swab, and rectal swab. Further research is required in this mode of transmission for better intervention.

ACKNOWLEDGMENTS

Researchers would like to thank all corona warriors for their super-human fight against COVID-19. The authors state that there is no conflict of interest in this study.

REFERENCES

Al-Tawfiq, J.A., Rodriguez-Morales, A.J., 2020. Super-Spreading Events and Contribution to Transmission of MERS, SARS and SARS-CoV-2 (COVID-19). J. Hosp. Infect. 105, 111–112.

Cai, J., Sun, W., Huang, J., Gamber, M., Wu, J., He, G., 2020. Indirect Virus Transmission in Cluster of COVID-19 Cases, Wenzhou, China, 2020. Emerg. Infect. Dis. 26, 1343–1345.

Centers for Diseace Control and Prevention, 2020. Coronavirus Disease 2019 (COVID-19) [WWW Document]. URL https://www.cdc.gov/coronavirus/2019-ncov/faq.html#How-COVID-19-Spreads (accessed 5.21.20).

Chang, L., Yan, Y., Wang, L., 2020. Coronavirus Disease 2019: Coronaviruses and Blood Safety. Transfus. Med. Rev. 34, 75–80.

Christina A. Penfield, Sara G. Brubaker, Jennifer Lighter, Adam J. Ratner, Kristen M. Thomas, J.A.M., 2020. Detection of severe acute respiratory syndrome coronavirus 2 in placental and fetal membrane samples. Am. J. Obstet. Gynecol. MFM Ahead of P.

Council, N.B.T., 2020. National Guidance to Blood Transfusion Services in India in Light of COVID-19 Pandemic. New Delhi.

Dong, L., Tian, J., He, S., Zhu, C., Wang, J., Liu, C., Yang, J., 2020. Possible Vertical Transmission of SARS-CoV-2 From an Infected Mother to Her Newborn. JAMA 323.

Ge, H., Wang, X., Yuan, X., Xiao, G., Wang, C., Deng, T., Yuan, Q., Xiao, X., 2020. The Epidemiology and Clinical Information about COVID-19. Eur. J. Clin. Microbiol. Infect. Dis. 39, 1011–1019.

Ghose, T., 2020. How are People being Infected with COVID-19? [WWW Document]. Live Sci. URL https://www.livescience.com/how-covid-19-spreads-transmission-routes.html (accessed 5.21.20).

Gorbalenya, A.E., Baker, S.C., Baric, R.S., de Groot, R.J., Drosten, C., Gulyaeva, A.A., Haagmans, B.L., Lauber, C., Leontovich, A.M., Neuman, B.W., Penzar, D., Perlman, S., Poon, L.L.M., Samborskiy, D. V., Sidorov, I.A., Sola, I., Ziebuhr, J., 2020. The Species Severe Acute Respiratory Syndrome-Related Coronavirus: Classifying 2019-nCoV and naming it SARS-CoV-2. Natur Microbiol. 5, 536–544.

Gupta, P., Goyal, K., Kanta, P., Ghosh, A., Singh, M., 2019. Novel 2019-coronavirus on new year's Eve. Indian J. Med. Microbiol. 37, 459.

Hamid, S., Mir, M.Y., Rohela, G.K., 2020. Novel Coronavirus Disease (COVID-19): A Pandemic (Epidemiology, Pathogenesis and Potential Rherapeutics). New Microbe New Infect 35.

Harapan, H., Itoh, N., Yufika, A., Winardi, W., Keam, S., Te, H., Megawati, D., Hayati, Z., Wagner, A.L., Mudatsir, M., 2020. Coronavirus Disease 2019 (COVID-19): A Literature Review. J. Infect. Public Health 13, 667–673.

Huanga, L., Zhang, Xiuwen, Zhang, Xinyue, Wei, Z., Zhang, L., Xub, J., Liangf, P., Xug, Y., Zhang, C., Xue, A., 2020. Rapid Asymptomatic Transmission of COVID-19 during The Incubation Period Demonstrating Strong Infectivity in A Cluster of Youngsters Aged 16-23 years Outside Wuhan and Characteristics of Young Patients with COVID-19: A Prospective Contact-Tracing Study. J. Infect. 80, e1–e13.

Kampf, G., Todt, D., Pfaender, S., Steinmann, E., 2020. Persistence of Coronaviruses on Inanimate Surfaces and their Inactivation with Biocidal Agents. J. Hosp. Infect. 104, 246–251.

Lauer, S.A., Grantz, K.H., Bi, Q., Jones, F.K., Zheng, Q., Meredith, H.R., Azman, A.S., Reich, N.G., Lessler, J., 2020. The Incubation Period of Coronavirus Disease 2019 (COVID-19) from Publicly Reported Confirmed Cases: Estimation and Application. Am. Coll. Physicians Public Heal. Emerg. Collect. 172, 577–582.

Ong, S.W.X., Tan, Y.K., Chia, P.Y., Lee, T.H., Ng, O.T., Wong, M.S.Y., Marimuthu, K., 2020. Air, Surface Environmental and Personal Protective Equipment Contamination by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) From a Symptomatic Patient. JAMA 323, 1610–1612.

Team, H. co. Z.N., n.d. Isolating virus from urine of the patient with novel coronavirus pneumonia (2020) [WWW Document].

Vivanti, A., Vauloup-Fellous, C., Prevot, S., Zupan, V., Suffee, C., Cao, J. Do, Benachi, A., Luca, D. De, 2020. Transplacental Transmission of SARS-CoV-2 Infection. Nat. Commun. 11, 1–7.

Wang, X., Zhou, Q., He, Y., Liu, L., Ma, X., Wei, X., Jiang, Nanchuan, Liang, L., Zheng, Y., Ma, L., Xu, Y., Yang, D., Zhang, J., Yang, B., Jiang, Ning, Deng, T., Zhai, B., Gao, Y., Liu, W., Bai, X., Pan, T., Wang, G., Chang, Y., Zhang, Z., Shi, H., Ma, W.-L., Gao, Z., 2020. Nosocomial outbreak of COVID-19 pneumonia in Wuhan, China. Eur. Respir. J. 55, 2000544.

Wei, X.-S., Wang, X.-R., Zhang, J.-C., Yang, W.-B., Ma, W.-L., Yang, B.-H., Jiang, N.-C., Gao, Z.-C., Shi, H.-Z., Zhou, Q., 2021. A Cluster of Health Care Workers with COVID-19 Pneumonia caused by SARS-CoV-2. J. Microbiol. Immunol. Infect. 54, 54–60.

Wong, S.C.Y., Kwong, R..-S., Wu, T.C., Chan, J.W.M., Chu, M.Y., Lee, S.Y., Wong, H.Y., Lung, D.C., 2020. Risk of Nosocomial Transmission of Coronavirus Disease 2019: An Experience in A General Ward Setting in Hong Kong. J. Hosp. Infect. 105, 119–127.

World Health Organization, n.d. Coronavirus Disease (COVID-19) pandemic [WWW Document]. URL https://www.who.int/emergencies/diseases/novel-coronavirus-2019 (accessed 6.17.20).

World Health Organization (WHO), 2020a. (2019-nCoV) SITUATION REPORT - 1.

World Health Organization (WHO), 2020b. WHO Director-General's statement on IHR Emergency Committee on Novel Coronavirus (2019-nCoV) [WWW Document].URL https://www.who.int/director-general/speeches/detail/who-director-general-s-statement-on-ihr-emergency-committee-on-novel-coronavirus-(2019-ncov) (accessed 6.17.20).

World Health Organization (WHO), 2020c. Novel coronavirus - China 11-fev 2020. Nov. Coronavirus(2019-nCoV) Situat. Rep. – 22.

World Health Organization (WHO), 2020d. Novel Coronavirus (2019-nCoV) Situation Report - 12 1 February 2020. Nov. Coronavirus(2019-nCoV) Situat. Rep. - 12 1–7.

World Health Organization (WHO), 2020e. Corona Virus [WWW Document]. URL https://www.who.int/health-topics/coronavirus#tab=tab_1 (accessed 6.17.20).

World Health Organization (WHO), 2020f. Modes of transmission of virus causing COVID-19 : implications for IPC precaution recommendations. Sci. Br. 1–3.

World Health Organization (WHO), 2020g. HIV, antiretrovirals and COVID-19 [WWW Document]. URL https://www.who.int/emergencies/diseases/novel-coronavirus-2019/question-and-answers-hub/q-a-detail/q-a-on-covid-19-hiv-and-antiretrovirals (accessed 5.23.20).

World Health Organization (WHO), 2020h. World Health Organization. Coronavirus disease 2019 (COVID-19). Situat. Report, 32.

Yea, F., Xub, S., Rong, Z., Xu, R., Liu, X., Deng, P., Liu, H., Xu, X., 2020. Delivery of Infection from Asymptomatic Carriers of COVID-19 in A Familial Cluster. Int. J. Infect. Dis. 94, 133–138.

Zhou, P., Yang, X. Lou, Wang, X.G., Hu, B., Zhang, L., Zhang, W., Si, H.R., Zhu, Y., Li, B., Huang, C.L., Chen, H.D., Chen, J., Luo, Y., Guo, H., Jiang, R. Di, Liu, M.Q., Chen, Y., Shen, X.R., Wang, X., Zheng, X.S., Zhao, K., Chen, Q.J., Deng, F., Liu, L.L., Yan, B., Zhan, F.X., Wang, Y.Y., Xiao, G.F., Shi, Z.L., 2020. A pneumonia outbreak associated with a new coronavirus of probable bat origin. Nature 579, 270–273.