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Short Communication

Infection Risks Faced by Public Health Laboratory Services Teams When Handling Specimens Associated With Coronavirus Disease 2019 (COVID-19)

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ABSTRACT

Infection risks of handling specimens associated with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) by public health laboratory services teams were assessed to scrutinize the potential hazards arising from the work procedures. Through risk assessments of all work sequences, laboratory equipment, and workplace environments, no aerosol-generating procedures could be identified except the procedures (mixing and transfer steps) inside biological safety cabinets. Appropriate personal protective equipment (PPE) such as surgical masks, protective gowns, face shields/safety goggles, and disposable gloves, together with pertinent safety training, was provided for laboratory work. Proper disinfection and good hand hygiene practices could minimize the probability of SARS-CoV-2 infection at work. All residual risk levels of the potential hazards identified were within the acceptable level. Contamination by gloved hands was considered as a major exposure route for SARS-CoV-2 when compared with eye protection equipment. Competence in proper donning and doffing of PPE accompanied by hand washing techniques was of utmost importance for infection control.

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1. Introduction

The novel pathogen identified in Wuhan, China, in December 2019 is associated with a novel coronavirus causing severe acute respiratory disease which was subsequently named as Coronavirus Disease 2019 (COVID-19) by the World Health Organization on February 11, 2020. Back to January, the first case of novel coronavirus infection was confirmed on January 23, 2020, in Hong Kong. Since then, Hong Kong was facing an increasing threat of imported and a number of local cluster cases of COVID-19. The medical services systems were expected to conform to the unavoidable burden of public health challenges as has befallen other medical systems all over the world. The Public Health Laboratory Services Branch of the Centre for Health Protection, Department of Health, was encountering an upsurge for requests of laboratory real-time reverse transcriptase polymerase chain reaction (RT-PCR) testing of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) for

inbound travelers, health quarantine persons, and affected individuals, as well as other required samples.

Facing the potential upsurge of specimens associated with COVID-19 for laboratory testing, in addition to deep throat saliva (DTS), clinical samples including upper and lower respiratory tract specimens, such as sputum, nasopharyngeal, environmental swabs, and even stool samples, would be anticipated. The manpower available for laboratory services should be swiftly deployed to handle the massive reception of clinical samples to cope with the provisional needs of SARS-CoV-2 detection service. Apart from focusing the risk of infection on frontline medical and healthcare professionals, public health supporting teams including laboratory courier crews for specimen transportation and public health laboratory testing services teams could not be excluded from the risk of contracting infection. To date, no laboratory-acquired SARS-CoV-2 infection has been reported in clinical diagnostic laboratories in England [1].

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		Hazard Severity			
		Low e.g. First aid needed	Medium e.g. Medical attention with several days off work	High e.g. Long term injury or illness	Catastrophic e.g. Fatality or permanent disability
Likelihood of Occurrence	Unlikely The event may occur, but probably never will	Low	Low	Medium	Medium
	Possible The event could occur, but only rarely	Low	Medium	Medium	High
	Likely The event could occur at some time	Medium	Medium	High	Extreme
	Almost Certain The event is expected to occur in most circumstances	Medium	High	Extreme	Extreme

Fig. 1. Risk assessment matrix for evaluation of residual risk level for activities/procedures performed in a laboratory. Risk assessment shall be updated when there is any significant change in laboratory activity/procedure or workplace. Residual risk level[^] = hazard severity × likelihood of occurrence. Keys: [^]Residual risk level = Low/Medium: laboratory activities/procedures can be performed. Annual review of the laboratory activities/procedures is required; Residual risk level = High: laboratory activities/procedures must be approved by laboratory director before implementation; Residual risk level = Extreme: laboratory activities/procedures must not be carried out in the laboratory.

To encounter this novel coronavirus never experienced before, some public health laboratory personnel in the Public Health Laboratory Services Branch at different occupational grades conveyed concerns about the possible risks of acquiring this viral infection from their occupational exposure. Laboratory personnel involved in (a) reception of clinical specimens (packed inside specimen carrier bags) associated with patients with suspected COVID-19 from outsourced courier teams at the Specimen Reception Area (SRA) of our laboratory services branch, (b) specimen transportation from the SRA to designated Biological Safety Level 2 (BSL-2) laboratories for further processing, (c) opening/unpacking and accessioning of COVID-19 specimens, and (d) disposal of items associated with COVID-19 specimens were considered as potentially susceptible groups to contract the disease from routine laboratory work. To protect the laboratory staff from getting COVID-19 infection when handling public health laboratory work, occupational health and safety risk assessments were conducted to review the overall implementation of laboratory safety guidelines and practices.

2. Methods

Recommendations and guidelines from the World Health Organization [2], US Centers for Disease Control and Prevention [3], the European Centre for Disease Prevention and Control [4], and Public Health England [1] on safe handling and processing of specimens associated with patients with suspected COVID-19 were referenced to scrutinize the potential hazards. Site- and task-specific risk assessments were conducted and reviewed by laboratory safety, medical, scientific, and technical professionals at the end of January and March 2020, respectively, to identify the potential hazards arising from the procedures performed at the point of (1) specimen reception, (2) specimen transportation to designated BSL-2 laboratories, (3) mixing the viral transport medium (TM)/phosphate buffer saline (PBS) with sputum/DTS in the specimen container and transferring the mixture to another specimen bottle before further processing for RT-PCR testing, (4) return of

empty outer containers to the SRA for reuse, and (5) disposal of specimen carrier bags and specimen primary containers potentially containing SARS-CoV-2 and other infectious disease agents. The residual risk levels for laboratory activities were assessed by using a risk assessment matrix (Fig. 1) as stipulated in the in-house safety manual. For the “low” or “medium” residual risk levels, laboratory activities/procedures can be performed. For the “high” residual risk, pertinent activities/procedures must be approved by the laboratory director before implementation. No activities/procedures can be carried out in the laboratory if “extreme” risk level is identified.

3. Results

3.1. Occupational health and safety risk assessment

3.1.1. Potential hazards

- (1) Reception of clinical specimens/samples of patients with suspected COVID-19 from outsourced courier staff at the SRA and transport of said specimens/samples by laboratory courier personnel to designated BSL-2 laboratories for processing.

The laboratory attendants/workmen and other users in the building were at risk of potential exposure to biohazardous materials due to handling and/or transportation of inappropriately packed or leaking specimens. In addition, environmental contamination of the SRA and other areas in the building could be possible after a biological spill or accident.

- (2) Opening/unpacking and accessioning of suspected COVID-19 specimens in BSL-2 laboratories

These activities involved laboratory technical staff and other users who worked in the BSL-2 laboratories. These staff members were at risk of being potentially exposed to biohazardous materials due to opening/unpacking of specimen carrier bags on the

Table 1

Sequences for proper donning and doffing of PPE and hand hygiene technique in laboratory

Sequence	Entering laboratory before work	Leaving laboratory after work	Key principle for disposal
	Donning (wearing) PPE [†]	Doffing (removing) PPE	
1	Perform hand hygiene	Remove laboratory gloves (perform hand hygiene)	(Folding inside out principle for disposal)
2	Put on surgical mask/respirator [†] (should perform seal check)	Remove protective gown (perform hand hygiene)	(Folding inside out principle for disposal/further processing for reuse)
3	Put on eye protection and disposable cap (optional)	Remove disposable cap and eye protection (disinfection for reuse, if practicable) (perform hand hygiene)	
4	Put on protective gown	Remove surgical mask/respirator (perform hand hygiene)	(Folding inside out principle for disposal of surgical mask)
5	Put on laboratory gloves		
Perform hand hygiene			
Seven steps of hand hygiene technique before and after laboratory work (soap): palms, back of hands, between fingers, back of fingers, thumbs, finger tips, wrist (use at least 20 seconds to rub all surfaces of hands and fingers)			

The discard action should be gentle. Selection of PPE for laboratory work should be based on risk assessment.

Disposable PPE should be properly discarded in autoclavable bags inside designated bins with lid for autoclave (121 °C, 30 min) before disposal.

Reusable protective clothes should be properly discarded in autoclavable bags inside a designated bin with lid for further processing (autoclave 121 °C, 20 min) for reuse. PPE, personal protective equipment.

* Competency assessment in wearing and removing PPE for laboratory staff should be performed. The assessment includes (1) perform hand hygiene; (2) wear surgical mask; (3) remove surgical mask; (4) wear eye protection; (5) remove eye protection; (6) wear laboratory gown; (7) remove laboratory gown; (8) wear laboratory gloves; (9) remove laboratory gloves.

[†] e.g. N95 respirator or equivalent (fit check required).

laboratory benches, handling the specimen primary containers, and sticking adhesive labels on the specimen containers for laboratory information system registration. Potential splash of specimens could occur due to the bag opening/unpacking procedures. Staff were also concerned about these specimen handling procedures because of the potential for aerosol generation.

- (3) Mixing the viral TM/PBS with sputum/DTS in the specimen primary container and transferring the mixture to another specimen bottle inside biological safety cabinets (BSCs) Class I/II, before further processing for COVID-19 RT-PCR testing

Laboratory technical staff who worked with BSCs Class I/II were at risk of being contaminated with biohazardous materials through the opening of specimen primary containers during mixing and transfer steps. Potential spillage and/or aerosol generation could occur, as well as contamination of areas inside the BSCs.

- (4) Return of empty outer containers to the SRA for reuse

The laboratory attendants/workmen and other users in the building were at risk of possibly being exposed to biohazardous materials due to handling or transportation of empty containers potentially contaminated with biohazardous or infectious substances from laboratories.

- (5) Disposal of specimen carrier bags and specimen primary containers potentially contaminated with SARS-CoV-2 and other infectious disease agents

The laboratory personnel involved in collecting the carrier bags and specimen primary containers for disposal were at risk of infection. In addition, these contaminated items could potentially contaminate other areas of the building.

3.1.2. Existing precautions

Importantly, proper procedures for donning and doffing personal protective equipment (PPE) were strictly followed before and after any laboratory work, respectively (Table 1). The promulgation of proper hand hygiene policy (Table 1, Seven steps of hand hygiene technique) to all staff after finishing the laboratory work, doffing PPE, or carrying out office work were well enacted. This consistent

practice is of utmost importance for maintaining a culture of good personal hygiene in workplaces. Follow-up actions subsequent to safety inspections and annual safety audits, relevant laboratory safety guidelines, training, and biological spill handling procedures (as stipulated in the in-house safety manuals) were strictly followed by laboratory staff. In addition, clean and dirty zones were well defined and demarcated in the laboratories.

At the SRA, the received specimens had been contained in intact plastic vials/containers (primary containers) which were packed inside one or two zip-lock specimen carrier bag(s). Some of the specimen carrier bags were collectively packed in transparent plastic bag(s) by officially appointed sender(s) for bulk handling. The relevant official guidelines issued by the authorities [5–7] were followed and reviewed for the collection and packing of primary and secondary containers associated with COVID-19. For samples with liquid content, at least one of the containers should be watertight. As a result, the clinical specimens/swab samples associated with COVID-19 were packed with sealed double packaging, as a minimum precaution. Coupled with the outer transport container, the triple packaging principle was adopted therefore for the duration of transport for all specimens. Appropriate PPE items were worn by, and readily accessible to, staff from each laboratory. Instructions and trainings were also given by individual laboratory supervisors to every member of supporting staff responsible for transportation, collection, and handling of specimen containers. Regular refresher trainings and updates were provided for routine operations. In addition, laboratory attendants were trained/briefed that bags of specimens should be gently placed inside the outer transport container, not to be congested or pressurized. The relevant courier team members for transport of the concerned specimens were instructed that any bags of specimens and the exterior surfaces of specimen carrier bags inside the transport containers should not be touched. Outer transport containers should be handled gently with care and throwing or dropping was prohibited. In addition, the outer transport containers for transportation of specimens were securely covered and disinfected to prevent contamination of exterior surfaces before transport. Hence, any potential spill or leakage of specimens from primary containers would be contained by the secondary container, as well as the outer transport container. Biological spill kits and appropriate disinfectants were available for designated staff teams to handle biological spills, should these occur in the laboratory or other building areas.

Disinfection of working benches and related equipment in the SRA, before and after work, was routinely performed. Laboratory technical staff were to be informed immediately, should any specimen leakage be found. Availability of feedback channels in the safety system was in place for staff to readily feedback their safety concerns to the management for immediate responses and review.

For the work involving opening/unpacking and accessioning of suspected COVID-19 specimens, after reviewing pertinent international guidelines, appropriate PPE (including surgical masks, laboratory gowns, face shields/safety goggles, and disposable gloves) was provided to, and readily accessible by, staff. Relevant staff training(s) and/or briefing(s) had been conducted by responsible laboratory staff for the task beforehand. In addition, specimen carrier bags associated with COVID-19 were carefully screened by laboratory technical professionals for any sign of leakage/spill and/or unclear information. Any specimen carrier bags that were found to be problematic were rejected, not to be unpacked and collectively kept in a rejection box separately for subsequent processing by responsible laboratory staff. The specimen carrier bags fulfilling the laboratory criteria were gently opened/unpacked. Appropriate tools (e.g. blunt end scissors) were available to facilitate the opening and unpacking procedures for certain specimen bags that were difficult to open. As large numbers of specimen carrier bags were required to be handled, cutters were not recommended for the sake of work safety. In addition, routine laboratory operational procedures were reviewed regularly by laboratory supervisors during the course of the laboratory testing programme. Safety assessments could also be conducted for any new procedures/activities to facilitate laboratory operational applications. Feedback channels were available for staff to readily relay their safety concerns to the management level for advanced improvement and review. To handle biological spillage, biological spill kits and appropriate disinfectants were available and readily accessible with regular safety trainings. Furthermore, bench top disinfectants were available to handle small-scale spills and perform disinfection on the working benches and equipment before and after work.

Regarding the steps about mixing the TM/PBS with sputum/DTS in the specimen primary container and transferring the mixture to another specimen bottle before further processing for SARS-CoV-2 RT-PCR testing, laboratory technical staff who worked with BSCs Class I/II were potentially exposed to the risk of contamination by biohazardous materials, from mixing and transfer procedures. As the working steps were considered as potential aerosol-generating procedures, contamination of the laboratory items and environment could be possible through contaminated gloved hands. The potential contamination, however, was expected to be restricted to the inside of the BSCs, as pertinent in-house guidelines for standard BSC operations were strictly followed. In addition, surgical masks, protective gowns, face shields/safety goggles, and disposable gloves were worn for handling microbiological and infectious samples inside BSCs; these items of PPE were readily accessible to staff before and during the work. Regular maintenance of BSCs was in place together with daily disinfection of all BSCs after the completion of work. Disinfection of working benches and equipment with appropriate disinfectants before and after laboratory work was regularly performed. Staff trainings/briefings on the work procedures, biological spills inside and outside BSCs, as well as BSC operation, were received from experienced laboratory staff before handling the assigned tasks.

Finally, all used outer transport containers for specimen transportation should be sent back to the SRA for reuse. These containers were disinfected with appropriate disinfectant(s) (e.g. 75% ethanol) before handling by staff responsible for the return. During disposal of empty specimen carrier bags and empty

primary containers for specimens, there could be possible contamination to building areas other than laboratories. As a result, specimen carrier bags and specimen primary containers were collectively put inside autoclavable bags to a suitable volume (~3/4 full), properly wrapped/sealed according to laboratory guidelines, and then autoclaved before disposal by trained laboratory staff. Staff training(s)/briefing(s) were provided to the staff responsible for handling the tasks, including operation of autoclave machines.

4. Discussion

Through mutual communication and understanding during the risk assessment activities and walking around the related workplaces, it was understood that the concerns of public health laboratory personnel originated from their perception of the potential risks of becoming infected with SARS-CoV-2 and developing COVID-19, during their laboratory work which involved possible aerosol-generating procedures, surface contaminations on the primary specimen containers, specimen carrier bags, and environmental contamination in the laboratories where they were working. In accordance with Anderson et al. [8], potential infection with SARS-CoV-2 mainly focused on the inhalation of aerosolized virus (droplet nuclei $<5\ \mu\text{m}$ in diameter, traveling $>1\ \text{m}$) or touching the virus-containing droplets from the affected patients. Blood-borne or other routes of transmission of the SARS-CoV-2 virus have not yet been confirmed clearly [4,9]. Cook [10] stated that generation of aerosol in the procedures may be possible provided that the situation of air accelerating across a wet surface has occurred. The faster airflow, theoretically, can create more aerosols. After reviewing the procedures of all work sequences, laboratory equipment items, and environments, it was concluded that no aerosol-generating procedures could be identified other than the procedures being carried out inside BSCs (mixing the viral TM/PBS with sputum/DTS in the specimen primary container and transferring the mixture to another specimen bottle). Furthermore, the assessment indicated that no other laboratory procedures had the potential to produce rapid airflows. As a result, unpacking and opening of specimen carrier bags in the laboratory under routine situations are unlikely to produce high airflows, leading to aerosol generation. Human coronaviruses (alpha and beta) including SARS-CoV-2 are enveloped (lipid bilayer) positive-strand RNA viruses. Understanding their stability on common inanimate surfaces and under different environmental conditions, together with their susceptibility to different biocidal agents, is beneficial for establishing control measures to reduce the chance of infection from the working environments. After reviewing recent studies [11–15], the susceptibility of SARS-CoV-2 to different temperatures, surfaces, and disinfectants is summarized in Table 2. These data could provide useful information for selecting the most effective disinfectant(s) for infection control in public health testing laboratories. According to experience of infection control in nosocomial environments [16,17], good disinfection and hand hygiene practices are known to greatly reduce the chance of SARS-CoV-2 infection, even in hospital isolation wards.

By reducing the major risks and sources of infection through the laboratory administrative, engineering, and PPE controls, the residual risk levels for various laboratory activities were assessed by using a risk assessment matrix (Fig. 1) as stipulated in our in-house safety manual. The residual risk levels obtained were the product of hazard severity and likelihood of occurrence. Notably, no centrifugation step was used in the procedures. All residual risk levels for the potential hazards were identified as “medium”, indicating that the residual risks of the tasks associated with the processing of

Table 2

Susceptibility of SARS-CoV-2 to different temperatures, surfaces and disinfectants and suggested virucidal disinfectants against SARS-CoV-2

Conditions	Detection of infectious virus (log unit per ml)*	Detection of infectious virus (log unit per ml)†
Temperature	4°C	Stable for 14 days
	22°C	Not detected on Day 14
	37°C	Not detected on Day 2
	56°C	Not detected at 30 min
	70°C	Not detected at 5 min
Printing/tissue paper	Not detected after 3 hr	
Cardboard	—	Not detected after 24 hr
Wood/cloth	Not detected on Day 2	
Glove/bank note	Not detected on Day 4	
Copper	—	Not detected after 4 hr
Stainless steel/plastic	Not detected on Day 7	Detected up to 72 hr
Surgical mask (inner)	Not detected on Day 7	
Surgical mask (outer)	Detected for 7 days	
Household bleach	(1:49), 0.1%, 1000 ppm	Not detected after 5 min
	(1:99), 0.05%, 500 ppm	Not detected after 5 min
Hand soap solution	(1:49)	Not detected after 15 min
Ethanol (70%)	Not detected after 5 min	
Povidone-iodine (7.5%)	Not detected after 5 min	
Chloroxyleneol (0.05%)	Not detected after 5 min	
Chlorhexidine (0.05%)	Not detected after 5 min	
Benzalkonium chloride (0.1%)	Not detected after 5 min	
Stable in pH 3–10 at room temperature*		
Kampf [13] and Kampf et al. [14] suggested that, in general, human coronavirus could be stable on inanimate surface for up to 9 days.		
Proven disinfectants suggested by the US CDC [3], Kampf [13], and Kampf et al. [14] against enveloped SARS-CoV-2: 62–71% ethanol (70–80% ethanol†), 0.5% hydrogen peroxide, quaternary ammonium compounds, phenolic compounds, 0.1% (1000 ppm, 1:49) sodium hypochlorite for general surface disinfection, 1% (10000 ppm, 1:4) sodium hypochlorite for disinfection of blood spills.		
Common disinfectants used for bench surface disinfection in our BSL-2 virology laboratories: 1% Virkon®, 70–75% ethanol. Sodium hypochlorite (0.1%) is available in laboratories. Sodium hypochlorite (1%) is used for treatment of spillage of infectious materials.		
Formalin fixation and paraffin embedding to 56°C would be effective to inactivate 2019-nCoV (SARS-CoV-2) [12].		

US CDC, US Centers for Disease Control and Prevention; BSL-2, Biological Safety Level 2.

* Source from: Chin et al. [11].

† Source from: van Doremalen et al. [15].

‡ European CDC [4].

COVID-19 specimens were within the acceptable level. Site- and/or task-specific risk assessment(s) shall also be reviewed if there is any significant change in laboratory activity/procedures or workplace(s).

Under the existing central safety system, standardized safety procedures and guidelines have already been implemented to govern the routine work practices, transport, and handling of clinical/environmental specimens. Those described here are existing precautions to be followed by staff performing the general laboratory work before RT-PCR testing procedures for the novel coronavirus/SARS-CoV-2. With reference to recommendations from international organizations, the surgical masks and eye protection (face shields/safety goggles) were considered as effective PPE to prevent the accidental splash of specimens to eyes or mucosal membranes during handling of the specimens. In recent studies, ocular transmission may be a potential route of occupationally acquired SARS-CoV-2 infection for healthcare workers in hospitals [18,19]. Nevertheless, Ye et al. [20] cited as evidence that SARS-CoV-2 contamination on eye protection equipment (1.7%) was lower than that on the contaminated gloves (15.4%). Therefore, this finding may reflect that contaminated gloved hands can be considered as a major route of transmission for infection when handling specimens associated with COVID-19 compared with eye protection equipment. Although the SARS-CoV-2 virus has been provisionally classified as Hazard Group 3 pathogen by the Advisory Committee on Dangerous Pathogens in early 2020 [1], some laboratory procedures with specimens associated with COVID-19 can still be performed in a BSC at BSL-2 laboratories (e.g. division, aliquoting, or diluting of respiratory tract specimens and

preparation of noninactivated specimens for molecular analysis). Existing precautions (both before and after risk assessment) can relieve the staff members' worries about the possible routes of occupational infection of SARS-CoV-2 and other infection exposures to specimens associated with COVID-19. From a laboratory safety perspective, proficiency and compliance in proper donning and doffing of PPE is a fundamental but crucial technique for infection control. Staff deployed for handling the COVID-19 specimens were also assessed for the competence in wearing and removing PPE, as well as hand hygiene technique (Table 1). The effective virucidal disinfectants (Table 2) were readily available and accessible in laboratories to perform regular disinfection and to control the possible spills of SARS-CoV-2 specimens during the required work procedures.

5. Conclusion

Bearing in mind that there is also a general but paramount guideline, there are valuable learnings from the safety manuals of any laboratory: proper hand hygiene is a must before touching face, eyes, mouth, nose, or mucosal membranes. Most importantly, proper hand hygiene is still a simple but the effective way for removing pathogens and terminating the possible route of SARS-CoV-2 transmission from this major contributor of contamination (i.e. hands). Given the limited supply of PPE around the world, appropriate use of existing PPE items in laboratories is also crucial to maintain the continuous supply of adequate stock for the unforeseeable circumstances of service requirement during the pandemic surge. On the other hand, ensuring the stable supply and

allocation of adequate PPE to frontline nosocomial and laboratory staff is a pivotal mission of management for confronting this battle against the COVID-19 pandemic.

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Conflicts of interest

The authors declare that they have no conflict of interest.

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References

- [1] Public Health England. COVID-19: safe handling and processing for samples in laboratories; 2020. Available from: <https://www.gov.uk/government/publications/wuhan-novel-coronavirus-guidance-for-clinical-diagnostic-laboratories/wuhan-novel-coronavirus-handling-and-processing-of-laboratory-specimens>. accessed April 06, 2020 and May 02, 2020.
- [2] World Health Organization. Laboratory biosafety guidance related to coronavirus disease (COVID-19). Interim guidance; 2020 March 19. Available from: <https://apps.who.int/iris/bitstream/handle/10665/331500/WHO-WPE-GIH-2020.2-eng.pdf?sequence=1&isAllowed=y>. [Accessed 12 February 2020] (accessed March 19, 2020) [previous version accessed].
- [3] US CDC. Interim laboratory biosafety guidelines for handling and processing specimens associated with coronavirus disease 2019 (COVID-19); 2020. Available from: <https://www.cdc.gov/coronavirus/2019-nCoV/lab/lab-biosafety-guidelines.html>. [Accessed 2 February 2020] (accessed March 15, 2020 and March 31, 2020) [previous version accessed].
- [4] European CDC. Disinfection of environments in healthcare and non-healthcare settings potentially contaminated with SARS-CoV-2. Stockholm: ECDC. 2020. Available from: https://www.ecdc.europa.eu/sites/default/files/documents/Environmental-persistence-of-SARS-CoV-2-virus-Options-for-cleaning2020-03-26_0.pdf. [Accessed 26 March 2020].
- [5] HA Committee on Infectious Diseases. Guideline on transport of clinical specimens and infectious substances. Hospital Authority, Hong Kong; 2006. Available from: <https://www.ha.org.hk/haho/hoc/conjoint/124711e.pdf>. [Accessed 30 January 2020].
- [6] Public Health Laboratory Services Branch. Safety guidelines on transport of clinical specimens and infectious substances for courier team. China: Centre for Health Protection, Department of Health of Hong Kong Special Administrative Region. 2006. Available from: https://www.chp.gov.hk/files/pdf/safety_guidelines_for_courier_team_2009nov.pdf. [Accessed 30 January 2020].
- [7] Public Health Laboratory Services Branch. Guidelines on biosafety in the clinical laboratory. Edition. China: Centre for Health Protection, Department of Health of Hong Kong Special Administrative Region. February 2008. 2008. Available from: http://www.chp.gov.hk/files/pdf/Guidelines_on_Biosafety_in_the_Clinical_Laboratory_2nd_Edn.pdf. [Accessed 30 January 2020].
- [8] Anderson EL, Turnham P, Griffin JR, Clarke CC. Consideration of the aerosol transmission for COVID-19 and public health. Risk Anal 2020;40(5):902–7. <https://doi.org/10.1111/risa.13500>.
- [9] Wang J, Feng H, Zhang S, Ni Z, Ni L, Chen Y, Zhuo L, Zhong Z, Qu T. SARS-CoV-2 RNA detection of hospital isolation wards hygiene monitoring during the Coronavirus Disease 2019 outbreak in a Chinese hospital. Int J Infect Dis 2020;94:103–6. <https://doi.org/10.1016/j.ijid.2020.04.024>.
- [10] Cook TM. Personal protective equipment during the COVID-19 pandemic—a narrative review. Anaesthesia 2020 April 04. <https://doi.org/10.1111/anae.15071>.
- [11] Chin AWH, Chu JTS, Perera MRA, Hui KPY, Yen H, Chan MCW, Peiris M, Poon LLM. Stability of SARS-CoV-2 in different environmental conditions. Lancet Microbe 2020 April 02. [https://doi.org/10.1016/S2666-5247\(20\)30003-3](https://doi.org/10.1016/S2666-5247(20)30003-3).
- [12] Henwood AF. Coronavirus disinfection in histopathology. J Histotechnol 2020 March 01. <https://doi.org/10.1080/01478885.2020.1734718>.
- [13] Kampf G. Potential role of inanimate surfaces for the spread of coronaviruses and their inactivation with disinfectant agents. Inf Prev Prac 2020;2:100044. <https://doi.org/10.1016/j.infpip.2020.100044>.
- [14] Kampf G, Todt D, Pfaender S, Steinmann E. Persistence of coronaviruses on inanimate surfaces and their inactivation with biocidal agents. J Hosp Infect 2020;104:246–51. <https://doi.org/10.1016/j.jhin.2020.01.022>.
- [15] van Doremalen N, Bushmaker T, Morris DH, Holbrook MG, Gamble A, Williamson BN, Tamin A, Harcourt JL, Thornburg NJ, Gerber SI, Lloyd-Smith JO, de Wit E, Munster VJ. Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1. N Engl J Med 2020;382(16):1564–7. <https://doi.org/10.1056/NEJMc2004973>.
- [16] Ong SWX, Tan YK, Chia PY, Lee TH, Ng OT, Wong MSY, Marimuthu K. Air, surface environmental, and personal protective equipment contamination by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) from a symptomatic patient. JAMA 2020;323(16):1610–2. <https://doi.org/10.1001/jama.2020.3227>.
- [17] Wang W, Xu Y, Gao R, Lu R, Han K, Wu G, Tan T. Detection of SARS-CoV-2 in different types of clinical specimens. JAMA 2020;323(18):1843–4. <https://doi.org/10.1001/jama.2020.3786>.
- [18] Lu C, Liu X, Jia Z. 2019-nCoV transmission through the ocular surface must not be ignored. Lancet 2020;395(10224):e39. [https://doi.org/10.1016/S0140-6736\(20\)30313-5](https://doi.org/10.1016/S0140-6736(20)30313-5).
- [19] Zhang X, Chen X, Chen L, Deng C, Zou X, Liu W, Yu H, Chen B, Sun X. The evidence of SARS-CoV-2 infection on ocular surface. Ocul Surf 2020;18:360–2. <https://doi.org/10.1016/j.jtos.2020.03.010>.
- [20] Ye G, Lin H, Chen L, Wang S, Zeng Z, Wang W, Zhang S, Rebmann T, Li Y, Pan Z, Yang Z, Wang Y, Wang F, Qian Z, Wang X. Environmental contamination of the SARS-CoV-2 in healthcare premises: an urgent call for protection for healthcare workers. medRxiv 2020. <https://doi.org/10.1101/2020.03.11.20034546>.