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Coronavirus Pandemic

Restraining SARS-CoV-2 in histopathology laboratory amid COVID-19 pandemic

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Abstract

Medical laboratory personnel encounter diverse health and workplace-related hazards leading to severe health challenges including the ravaging SARS-CoV-2 infection, which is the causal agent of COVID-19. It was first announced in Wuhan, China in December 2019 but started to spread globally by late January 2020. COVID-19 pandemic and subsequent global spreading poses additional danger to healthcare personnel particularly the laboratorians. Other health practitioners may engage patients by observing social / physical distancing, but how laboratory staff observe or apply same rule to infectious samples remain a notable question. Activities of laboratorians result in repeated exposure at close interactions to patient's samples including SARS-CoV-2 infected specimens, which make them susceptible to COVID-19. Therefore, it is imperative to review mitigating measures in restraining possible exposure and spreading of SARS-CoV-2 in the best interest of laboratory staff and pathologists. It is against this backdrop that this paper intends to update readers on measures to restrain SARS-CoV-2 invasion in histopathology laboratory and deduce precautionary measures for observation by healthcare providers in COVID-19 era. Also discussed, is health hazards associated with histopathology laboratory with the objective of encouraging safety consciousness and safe laboratory practices in the face of COVID-19 pandemic.

Key words: Coronavirus disease 2019; COVID-19 pandemic; laboratory disinfection; laboratorians; pathologists; SARS-CoV-2 infection.

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Introduction

In the last 7 decades many coronaviruses (CoV) have been discovered both in wild and domesticated animals plus humans. This family is called "Coronavirus" derived from Latin corona, meaning "crown", which refers to the characteristic appearance of the virion that is observable with an electron microscope [1,2]. In humans, coronavirus infection is commonly associated with respiratory tract causing common cold while, in its severe conditions, it results to pneumonia-like disease like the Middle East Respiratory Syndrome (MERS-CoV) and Severe Acute Respiratory Syndrome (SARS) [1-4]. Seven separate strains within the family of coronaviruses have been identified to infect humans, of which four of them: OC43, HKU1, 229E, NL63 e.t.c cause mild respiratory tract infections mimicking common cold [1-2,5-6]. As of 28th January, 2022; around 364,191,494 people are infected worldwide with mortality rate of about 5,631,457 while, recovery rate is about two-third of the

total number of reported cases [7,8]. COVID-19 has currently spread to virtually all continents of the world [8,9], with increased number of health care providers being infected in the course of service deliveries [8]. In a concise review by Malizgani *et al*. [9], the report has it that exposure to SARS-CoV-2 can occur in health care settings when health workers attend to COVID-19 patients or SARS-CoV-2 infected samples. Varying samples are sent to the medical laboratory for diagnosis, which include unsuspecting samples from SARS-CoV-2 infected individuals. Histopathology laboratory in particular receives samples in form of tissues, blood and body fluid, secretion and smeared slides amongst others, which pose potential threats to medical laboratory scientists particularly in the COVID-19 era. The need to increase SARS-CoV-2 testing amongst the populace has been underscored as a key to curtail spreading of the virus [10,11]. This will in turn increase the number of samples received, processed and analyzed by clinical laboratories for diagnosis of COVID-19, including increased risk of acquiring SARS-CoV-2 infection by medical laboratory staff from infectious specimens.

Although, procedure differ from one clinical diagnostic laboratory specialty to the other, as risk of acquiring infections in histopathology laboratory is limited compared to other clinical laboratories: hematology, medical microbiology, clinical chemistry e.t.c, due to the use of formalin and alcohol-based fixatives. In histopathology, fixatives often accompany most samples to the laboratory excluding fresh frozen sections, and as such optimum precautionary measures must be observed. From the ongoing, there is a need to deduce measures to curtailing infections from unsuspecting life-threatening specimens sent to histopathology laboratory. It is against this information that this paper reviewed measures to arrest SARS-CoV-2 infection in histopathology laboratory and deduce precautionary measures needed by laboratorians and pathologists amid COVID-19 pandemic. Also discussed, is health hazards associated with the histopathology laboratory with the objective of encouraging safety consciousness and safe laboratory practices.

Restraining SARS-CoV-2 in histopathology laboratory

Exposure to SARS-CoV-2 is almost inevitable in the face of COVID-19 Pandemic in medical laboratories including histopathology laboratory [2]. However, with strict adherence to infection prevention and control (IPC) measures, the risk of exposure will be less including SARS-CoV-2 [12, 14-16]. This measure is a fundamental part of public health programs throughout the world. Key among its component includes: disinfection and fumigation [13-17]. Exposure to contaminated surfaces is a major factor of aerial transmission of the coronaviruses like SARS-CoV-2 [18]. Therefore, disinfection and fumigation of histopathology laboratory and its environs should be considered as the first precautionary measure to restraining SARS-CoV-2 infection [19]. Disinfection process has been found to reduce transmission scale of diseases globally and has been adopted as a safety measure in the general populace [20]. This process creates an aseptic working environment in the laboratory using suitable and effective disinfectant [19-22]. Efficient disinfectant removes infectious agent from both biotic surfaces e.g skin and abiotic surfaces e.g equipment and laboratory wares [19,20].

Essential and effective disinfectants that can be employed for disinfecting processes include: formaldehyde, glutaraldehyde and ortho-phthalaldehyde [19,20]. Alcohols, per-acetic acid, hydrogen peroxide, quaternary ammonium compounds, chlorine and chlorine compounds are commonly used disinfectants [20-24,26,31,32]. Asides chemical disinfectants, physical methods are also employed for surface disinfection. Materials like microbicide metals, ultraviolet radiation (UV) and pasteurizations are highly effective [20,25,26]. Advancement in technology has led to the introduction of automatic disinfection system for prompt and continuous surface disinfection [27]. It is fondly referred to as “no-touch” automatic decontamination technology. It makes use of aerosolised and vaporized hydrogen peroxide, and movable devices that continuously emit light of high-intensity narrow-spectrum. Any of these disinfecting measures can be embraced in an effort to restrain SARS-CoV-2 infection. For it to be more effective, disinfection processes should be appropriately carried out on all surfaces across each unit of the laboratory and at least before and after daily routine procedures [28].

On the other hand, SARS-CoV-2 viability studies conducted by Kampf *et al*. [26] showed that just like other members of the *coronavirdae*, it has characteristics of being infective on different surfaces up to nine days [19,25,26]. Restraining SARS-CoV-2 thus requires prompt fumigation of laboratory surroundings for an effective containment of the virus. Fumigation process is an essential procedure to quickly and thoroughly eradicate and inactivate any viable infectious agent in the environment. It is carried out using chemicals in the correct ratio to the active

fumigant, mostly in a gaseous state at a given temperature and pressure as well as spraying over the intending surroundings. This method is excellent and widely employed for decontamination of large spaces including laboratory equipment. In addition, formaldehyde, a famous chemical in histopathology laboratory can be employed in its gaseous form as a suitable decontaminating agent [19,20,25,26]. Other surface decontamination agents include vaporized hydrogen peroxide and chlorine dioxide gas [19,20,25,26,29]. Meanwhile, for an effective and adequate contact time, fumigation processes should be carried out overnight in a given laboratory setting.

Autopsy specimens handling amid SARS-CoV-2 invasion

Autopsy examination procedures amidst suspected COVID-19 corpse should be discouraged, and an alternative to the conventional autopsy practice called virtopsy (virtual autopsy) may be adopted as measures for restraint of SARS-CoV-2. In virtual autopsy techniques, bodies are examined using imaging methods like the computed tomography and magnetic resonance imaging for determining causes and manners of death [30]. This procedure leaves a zero to minimal invasiveness on examined corpses, and thus reduces manipulation of body organs including transmission risk of infectious agents like SARS-CoV-2 that may be active in the corpses [30]. However, where it becomes a must for conventional autopsy to be conducted in cases of forensic examination or research findings, containment measures to start with in histopathology laboratory identifies the hazard associated with the procedures and handling of sampled materials for post mortem examination. Also, strict compliance with the CDC and W.H.O regulations for autopsy in the face of COVID-19 will enhance the containment of SARS-CoV-2 transmission amid autopsy procedures [31,32]. According to CDC and W.H.O pro-sections on suspected or confirmed COVID-19 bodies for autopsy investigations recommend that autopsy may be conducted in an airborne infection isolation rooms with a negative pressure in relation to the surrounding areas, and preferably with air changes system of at least 12 cycles per hour [32-34]. As a restraint measure, the air from isolation rooms must be removed to an outside space and filtered using a high efficiency particulate air (HEPA) filter before re-circulation [32].

Aerosol generating procedures should be avoided during the pro-sections. Otherwise, appropriate control measures both logistically and mechanically must however be put in place where aerosol generation becomes inevitable. SARS-CoV-2 alongside with MERS-CoV and SARS-CoV have been classified as a HG3 (hazard group 3) pathogen [31]. Therefore, all personnel in this unit, from the forensic pathologists to laboratory scientists, assistants and attendants that come in contact with tissue specimens should be acquitted with safety technicalities relating to HG3 pathogen [32]. Also, optimal personal hygiene of the personnel involved in the procedures and disinfection processes of contaminated surfaces and equipment should be promptly and strictly adhered to. Tissues from an autopsy procedure should be fixed using appropriate fixatives. This will not only preserve and maintain the viability of the tissue sample, but will also inactivate several micro-organism including coronaviruses [1,35]. Furthermore, Xu *et al*. [36], reported an autopsy finding of a COVID-19 patient with many inactivated SARS-CoV-2 shown in the photomicrograph of the tissue fixed in formalin. Thus, the choice of a good fixative and fixation process assists some containment measures against transmission of SARS-CoV-2 and should be properly performed. Transmission risks associated with autopsy procedures may increase while manipulating e.g grossing and sampling of some organs, as studies showed that almost all organs rich in ACEs cells have high titer of SARS-CoV- 2 [37,38], and have been linked to roles played by enzymes stationed at entrances of SARS-CoV-2 into host cells [34]. As a result, much caution should be observed during such organ manipulation and adequate personal protective equipment fully acquired while autopsy outfits should be thoroughly disinfected after each procedure [32,34].

Histopathology specimens in the face of SARS-CoV-2 invasion

Restraint measures in COVID-19 era encompasses samples sent to the three units of histopathology laboratory e.g routine histological, frozen sections preparation and diagnostic cytology unit must be accompanied with detailed filled request forms [39,40]. In addition, request forms should be boldly marked as regard the SAR-CoV-2 or COVID-19 status of the patient [39], which should be disinfected with a dry spray disinfectant. Measures like this will increase the chances of curbing SAR-CoV-2 infections among laboratory staff and pathologists. Owing to the differences in the nature of samples received in histopathology laboratory, the preparation and processing methods differ and play a crucial role in the analysis and reporting of samples. While, some histological preparations influence the risk of SAR-

CoV-2 transmission, others may allow some level of containment of infections. The routine histological preparations begin with fixation of tissue samples. Fixation of histological specimen is an indispensable stage in histological preparations and processing. It preserves the tissue thereby maintaining the integrity, macro and microarchitectures of the specimen. Fixatives forestall decompositions of the tissue and prevent growth of micro-organism including viral agents [25,26].

Xu *et al*. [36] attributed the inactivated SARS-CoV-2 seen in backgrounds of photomicrograph from tissue sections of a COVID-19 patient in their study to actions of formalin fixatives. In this regard, fixation process could serve as containment measure against infections with SAR-CoV-2 if properly carried out. Notable and common fixatives used are aldehyde compound e.g formaldehyde and gultarldehyde. The effectiveness of aldehyde compounds as SARS-CoV-2 inactivating agent was studied in relation to time and temperature. Darnell *et al*. [35] reported a complete inactivation of SARS-CoV-2 in 1-2 days when treated in glutaraldehyde, while infectivity of the virus was reduced drastically with a formalin fixative in one day, and at room temperature. In another study by Henwood [19], a collaborative inactivation of coronaviruses by fixing in formalin and processing the tissue at 56^{o}C were reported. Other fixatives include: alcohol (ethyl alcohol), acetone, mercuric chloride, picric acid, acetic acid, osmium tetroxide and potassium dichromate. These fixatives are either used singly as a simple fixative or combined as a compound fixative in order to complement the fixing potentials.

Contrarily, cytology unit of the laboratory may receive and process unfix fresh samples for diagnosis, and nearly all cytology samples are fluid in nature ranging from gastric wash or larvage, alveolar wash or larvage and body fluids and secretions. Thus, the risk of exposure to infectious biological agents including SARS-CoV-2, in a fresh unfixed sample is enormous. Hence, the need for measures to restrain infection transmission while handling samples for clinical diagnosis in COVID-19 era. In view of the above, all specimens must be regarded as infectious agent particularly SARS-CoV-2, and as such, adherence to standard precautionary measures must be observed when handling these specimens. Disinfection of specimen containers by spraying it with hypochlorite and wearing of personal protective equipment are critical at specimen reception benches [39,40].

The preparation of cytological investigations e.g concentration, smearing, and air drying of samples heightens the transmission of infectious agents in specimens, and influences the health hazard of laboratorians. To curb pathogenic transmission in the course of specimen preparations, a minimum of stage II biosafety cabinet should be put into use for all cytological preparations particularly openings of specimen containers, centrifugation, slide smearing and drying including any potential aerosol generating processes [2,39,40]. Though fixation of specimens is carried out after preparatory procedures, it effectiveness as a containment measure makes it a shield in histopathology laboratory [39,42,43]. Therefore, the choice of a fixative should be made with its effect as a containment measure put into consideration.

Prepared cytology specimens should be treated in a fixative with proven properties of viral inactivation [2,39,42]. Preferably, laboratory constituted fixative from alcohol or formalin solution often gives the best results. The use of fixatives like PreservCyt and CytoLyt, which may contain weaker alcohol solutions should be avoided [2,39]. Additional measures in cytology unit may include subdividing personnel into a team that works in alternate weeks; and enforcing strict restrictions of personnel in and out of the laboratory thereby reducing contacts with personnel from other units. This will reduce the chances of transmission of SARS-CoV-2 infection.

Frozen section procedure amid SARS-CoV-2 infection

Frozen section unit in histopathology is where much mind bugging is ensued because specimens for this procedure are received devoid of fixatives as obtained from surgical procedures and manipulated for diagnosis without any chemical pretreatment compared to routine histological or some cytology preparations. As a result, the health hazard to laboratorians handling the procedure is heightened. With regards to the level of risk, frozen section should not be carried out on a confirmed or suspected SARS-CoV-2 infected patient as a measure to reduce infection transmission of the virus. If it becomes necessary for the procedure to be conducted probably for a research purpose or forensic testing; it should only be undertaken in an aerosol controlled cryostat with the medical laboratory scientist properly dressed in personal protective equipment (PPE) [39]. In addition, standard precautionary measures on handling fresh tissues from suspected or confirmed COVID-19 cases must be maintained as prescribed by WHO, CDC and other health related institutions. Contrary to grossing procedures during routine histological techniques that are closely related

to manipulations in frozen section procedures; grossed tissues are fixed with nearly all infectious agents inactivated by the fixative used, and as such, the risk level is reduced to almost zero.

Vaccination as a lasting solution to SARS-CoV-2 invasion

The cheapest precautionary measure employed against a known viral infection in some countries is the prevention measure via vaccination [45,46]. Administration of vaccines is an effective and efficient preventive measure against infectious diseases in a community [46]. The health care workers particularly laboratory personnel who are prone to infectious viral agents employ this measure [47]. Unfortunately, as at the time of this review, there is no known vaccine developed against SARS-COV-2, MERS and SARS coronaviruses. Studies on Bacillus Calmette-Guérin (BCG) vaccination by Aeron *et al.* [48] hypothesis suggest that BCG vaccine against *Mycobacterium* spp. infections may mitigate transmission of COVID-19 [48]. The BCG potency is linked to its broad spectrum protection against infections geared towards the respiratory tract. The study also compared the volume of cases of COVID-19 among countries practicing universal BCG vaccination and reported a low volume of cases in countries that implemented the universal BCG vaccination, while a larger volume of cases are recorded in countries not following vaccination policies.

In another study, vaccines like the BCG produce positive humoral "heterologous" types of immune responses that resulted in the conferment of a better immunity against pathogens other than mycobacterium spp., while the phenomenon is referred to as "immunity training" [49]. Though, vaccination stands out as the tool in proffering an effective and efficient prevention measure in limiting SARS-CoV-2. However, researchers are working to come up with an ideal vaccination plan with the world health organization. "Access to COVID-19 tools accelerator" (ACT-A) with about 200 vaccines for COVID-19 are in the pipeline while about 24 are at different clinical trial phases [50]. The safety and efficacy will not be available before 2022 in which access will be addressed at that point. Therefore, there is the need for vaccines while the numbers of dosages depend on the target population.

Measures for health workers amidst COVID-19 pandemic

There are many frontline soldiers in the fight against COVID-19 pandemic but the healthcare workers stand out amongst all. This group of workers is exposed to hazards that not only increase the chances of being infected with SARS-CoV-2 but include arrays of trauma and anxiety; like physical and psychological distress, stigma and violence [51-53]. This has led to about 35,000 healthcare personnel being infected with COVID-19 within three months of the pandemic and many deaths recorded from different parts of the world [54,55]. These and many stories of despair faced by healthcare workers in the COVID-19 pandemic are alarming, devastating and intolerable to already weakened healthcare services across the globe. Thus, robust and substantive measures are needed to curtail SARS-CoV-2 invasion in the laboratory. To date, the most perfect preventive measure against SARS-COV-2 infection is to avoid exposures to the virus [56]. However, this is near impossible for healthcare workers whose primary objective is to provide diagnosis, treatment and care for the ailing COVID-19 patients. In this regard, series of mitigating measures are required to reduce the risk of exposures to nosocomial infections.

Furthermore, the nature of services rendered by different cadre of healthcare workers determines the level of exposure including associated risks encountered in the line of duty [57]. Obtaining risk assessment of all cadres of healthcare practitioners based on the services rendered is the first step in proffering appropriate measures towards protection of individual healthcare workers [39-41]. Hazard evaluations should be conducted with the aim of using the outcome as a guide for adopting appropriate prevention and control measures to mitigate against SARS-CoV-2 infection by relevant authorities [40,41]. Items for consideration include: structural facility, administrative control and strict supervision of the use of PPE [2,39,58]. Measures like readjustment of routine duties to the shift pattern, and a firm restriction of personnel among key hospital facilities like: wards, laboratories, and intensive care units as part of efforts that will reduce contact between hospital staff. Measures to identify early infections among healthcare personnel like body temperature checks for staff at the units level must be enforced [2,58]. Those with typical symptoms of COVID-19 should remain at home and seek medical interventions [2,40,54].

Conclusions and recommendations

Emergence of SARS-CoV-2 increases health hazards faced by laboratory personnel particularly in histopathology laboratory, and medical laboratory scientists that toil with infectious viral components

while testing patient's samples. New measures to protect staff on duty are urgently needed to curb occupational transmission of SARS-CoV-2 infection. Considering the pathogenesis of COVID-19, this paper recommends that all medical laboratories should urgently review and re-evaluate the modus of operandi including staff capacity in terms of competency and workforce. This will bring about appropriate biohazard risk assessments prior to investigations on routine specimens from suspected or confirmed COVID-19 patients. It is strongly advisable to adopt standard operational procedures including safety protocols recommended by the W.H.O and other sister agencies. Policy makers should prioritize public health policies that bring about sustainable measures to protect healthcare providers in the COVID-19 era.

References

1. Su S, Wong G, Shi W, Liu J, Lai ACK, Zhou J, Liu W, Bi Y, Gao GF (2016) Epidemiology, genetic recombination, and pathogenesis of corona viruses. Trend Microbiol 24: 490-502.
2. Pambuccian SE (2020) The COVID-19 pandemic: implications for the cytology laboratory. J Am Soc Cytopathol 9: 202-211.
3. Li Q, Guan X, Wu P, Wang X, Zhou L, Tong Y, Ren R, Leung KSM, Lau EHY, Wong JY, Xing X, Xiang N, Wu Y, Li C, Chen Q, Li D, Liu T, Zhao J, Liu M, Tu W, Chen C, Jin L, Yang R, Wang Q, Zhou S, Wang R, Liu H, Luo Y, Liu Y, Shao G, Li H, Tao Z, Yang Y, Deng Z, Liu B, Ma Z, Zhang Y, Shi G, Lam TTY, Wu JT, Gao GF, Cowling BJ, Yang B, Leung GM, Feng Z (2020) Early transmission dynamics in wuhan, china, of novel corona virus–infected pneumonia. N Engl J Med 382: 1199-1207.
4. Li JY, You Z, Wang Q, Zhou ZJ, Qiu Y, Luo R, Xing-Yi Ge XY (2020) The epidemic of 2019-novel-coronavirus (2019-nCoV) pneumonia and insights for emerging infectious diseases in the future. Microb Infect 22: 80-85.
5. Lu R, Zhao X, Li J, Niu P, Yang B, Wu H, Wang W, Song H, Huang B, Zhu N, Bi Y, Ma X, Zhan F, Wang L, Hu T, Zhou H, Hu Z, Zhou W, Zhao L, Chen J, Meng Y, Wang J, Lin Y, Yuan J, Xie Z, Ma J, Liu WJ, Wang D, Xu W, Holmes EC, Gao GF, Wu G, Chen W, Shi W, Tan W (2020) Genomic characterization and epidemiology of 2019 novel corona virus: implications for virus origins and receptor binding. Lancet 395: 565-574.
6. Adhikari S, Meng S, Wu Y, Mao Y, Ye R, Wang Q, Chang S, Sean S, Scott R, Hein R, Zhou H (2020) Epidemiology, causes, clinical manifestation and diagnosis, prevention and control of Coronavirus disease (COVID-19) during the early outbreak period: a scoping review. Infect Dis Poverty 9: 29.
7. Worldometer (2020) Current world population. Available: https://www.worldometers.info/world-population/ Accessed 11 July 2020.
8. World Health Organization (WHO) (2021) Coronavirus disease (COVID-19) outbreak situation. Available: https://covid19.who.int/. Accessed 9 September 2020.
9. Malizgani M, Mathias D, Itai C Tafadzwa D (2020) COVID-19 Risk factors among health workers: a rapid review. Saf Health Work 11: 262-265.
10. Li R, Pei S, Chen B, Song Y, Zhang T, Yang W, Shaman J (2020) Substantial undocumented infection facilitates the rapid dissemination of novel corona virus (SARS-CoV-2). Science 368: 489-493.
11. Sironi M., Hasnain SE, Rosenthal B, Phan T, Luciani F, Shaw M, Sallum MA, Mirhashemi ME, Morand S, González-Candelas F (2020) SARS-CoV-2 and COVID-19: a genetic, epidemiological, and evolutionary perspective. Infect Genet Evol 84: 104384.
12. World Health Organization (WHO) (2020) Infection prevention and control during health care when novel coronavirus (nCoV) infection is suspected. Available: https://www.who.int/publications-detail/infection-prevention-and-control-during-health-care-when-novel-coronavirus-(ncov)-infection-is-suspected-20200125. Accessed 10 February 2020.
13. Akhter MS (2020) Preparedness and responses for prevention and control of COVID-19: a review. Preprints 202004.0495.v1.
14. European Centre for Disease Prevention and Control (2020) Infection prevention and control for the care of patients with 2019-nCoV in healthcare settings. Available: https://www.ecdc.europa.eu/sites/default/files/documents/nove-coronavirus-infection-prevention-control-patients-healthcare-settings.pdf. Accessed 10 February 2020.
15. Public Health England (2020) COVID-19: Infection prevention and control guidance. London: PHE Available: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/910885/COVID-19_Infection_prevention_and_control_guidance_FINAL_PDF_20082020.pdf. Accessed 1 April 2020.
16. Bureau of Disease Prevention and Control of the National Health Commission of the People's Republic of China (2020) Novel Coronavirus pneumonia and prevention control program, 5th edition. Beijing: Bureau of Disease Prevention and Control of the National Health Commission of the People's Republic of China. Available: http://en.nhc.gov.cn/. Accessed 1 April 2020. [Available in Chinese]
17. World Health Organization (WHO) (2016) Guidelines on core components of infection prevention and control programmes at the national and acute health care facility. Geneva: WHO. Available: https://www.who.int/gpsc/ipc-components/en/. Accessed 11 May 2020.
18. Guo ZD, Wang ZY., Zhang SF, Li X., Li L, Li C, Cui Y, Fu RB, Dong YZ, Chi XY, Zhang MY, Liu K, Cao C, Liu B, Zhang K, Gao YW, Lu B, Chen W, Liu B (2020) Aerosol and surface distribution of severe acute respiratory syndrome corona virus 2 in hospital wards, Wuhan, China. Emerg Infect Dis 26: 1583-1591.
19. Henwood AF (2020) Corona virus disinfection in histopathology. J Histotech 43: 102-104.
20. Kırmusaoğlu S (2018) Introductory chapter: overview of disinfection. In Kırmusaoğlu S (editor) Disinfection. London: IntechOpen. Available: https://www.intechopen.com/chapters/64076. Accessed 10 June 2020.
21. Zhang S, Wang C, Lin M, Deng Q, Ye Y, Li Z, Qiu L, Wang Z (2020) Analysis of the virus contamination and disinfection effect in isolation ward of patients with COVID-19. Front. Public Health 8: 486.

22. National Pesticide Information Center (2020) Disinfectants and COVID-19. Available: http://npic.orst.edu/ingred/ptype/amicrob/covid19.html. Accessed 27 August 2020.
23. United States Environmental Protection Agency (2017) Emerging viral pathogen guidance and status for antimicrobial pesticides. Available: https://www.epa.gov/pesticide-registration/guidance-registrants-process-making-claims-against-emerging-viral-pathogens. Accessed 6 August 2020.
24. United States Environmental Protection Agency (2020) About list N: disinfectants for Coronavirus (COVID-19). Available: https://www.epa.gov/coronavirus/about-list-n-disinfectants-coronavirus-covid-19-0. Accessed 2 August 2020.
25. Duan SM, Zhao XS, Wen RF, Wen FU, Huang JJ, Pi GH, Zhang SX, Han J, Bi SL, Ruan L, Dong XP; SARS Research Team (2003) Stability of SARS coronavirus in human specimens and environment and its sensitivity to heating and UV irradiation. Biomed Environ Sci 16: 246-255.
26. 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.
27. Otter JA, Yezli S, Perl TM, Barburt F, French GL (2014) A guide to no-touch automated room disinfection (NTD) systems. In Walker JT (editor) Decontamination in hospitals and healthcare, 2nd edition. Netherlands: Elsevier. 413-460.
28. Center for Disease and Prevention Control (CDC) (2008) Recommendations for disinfection and sterilization in healthcare facilities. Guideline for disinfection and sterilization in healthcare facilities. Available: https://www.cdc.gov/infectioncontrol/guidelines/disinfection/recommendations.html#r5. Accessed 15 June 2020.
29. Pottage T, Walker JT (2014) Use of gaseous decontamination technologies for wards and isolation rooms in hospitals and healthcare settings. In Walker JT (editor) Decontamination in Hospitals and Healthcare, 2nd edition. Netherlands: Elsevier. 299-324.
30. Tejaswi KB Periya HEA (2013) Virtopsy (virtual autopsy): a new phase in forensic investigation. Forensic Dent Sci 5: 146-148.
31. World Health Organization (WHO) (2020) Infection prevention and control for the safe management of a dead body in the context of COVID-19. Interim guidance. Available: https://apps.who.int/iris/bitstream/handle/10665/331538/WHO-COVID-19-lPC_DBMgmt-2020.1-eng.pdf. Accessed 7 March 2020.
32. Centers for Disease Control and Prevention (CDC) (2020) Collection and submission of postmortem specimens from deceased persons with known or suspected COVID-19. Available: https://www.cdc.gov/coronavirus/2019-ncov/hcp/guidance-postmortem-specimens.html. Accessed 25 June 2020.
33. Sapino A, Facchetti F, Bonoldi E, Gianatti A, Barbareschi M, Società Italiana di Anatomia Patologica e Citologia - SIAPEC (2020) The autopsy debate during the COVID-19 emergency: the Italian experience. Virchows Arch 476: 821-823.
34. Calabrese F, Pezzuto, F, Fortarezza F, Hofman P, Kern I, Panizon A, Jan von der T, Timoveef S, Gorkiewicz G, Lunardi F (2020) Pulmonary pathology and COVID-19: lessons from autopsy. The experience of European pulmonary pathologists. Virchows Arch 477: 359-372.
35. Darnell ME, Subbarao K, Feinstone SM, Taylor DR (2004) Inactivation of the coronavirus that induces severe acute respiratory syndrome, SARS-CoV. J Virol Methods 121: 85-91.
36. Xu Z, Shi L, Wang Y, Zhang J, Huang L, Zhang C, Liu S, Zhao P, Liu H, Zhu L, Tai Y, Bai C, Gao T, Song J, Xia P, Dong J, Zhao J, Wang FS (2020) Pathological findings of COVID-19 associated with acute respiratory distress syndrome. Lancet Respir Med 8: 420-422.
37. Hoffmann M, Kleine-Weber H, Schroeder S (2020) SARS-CoV-2 cell entry depends on ACE2 and TMPRSS2 and is blocked by a clinically proven protease inhibitor. Cell 181: 271-280.
38. Puelles VG, Lütgehetmann M, Lindenmeyer MT, Sperhake JP, Wong MN, Allweiss L, Chilla S, Heinemann A, Wanner N, Liu S, Braun F, Lu S, Pfefferle S, Schröder AS, Edler C, Gross O, Glatzel M, Wichmann D, Wiech T, Kluge S, Pueschel K, Aepfelbacher M, Huber TB (2020) Multiorgan and renal tropism of SARS-CoV-2. N Engl J Med 383: 590-592.
39. Lamas NJ, Esteves S, Alves JR, Costa FE, Tente D, Fonseca P, Vizcaíno JR (2020) The anatomic pathology laboratory adjustments in the era of COVID-19 pandemic: the experience of a laboratory in a Portuguese central hospital. Ann Diagn Pathol 48: 151560.
40. World Health Organization (WHO) (2020) Laboratory biosafety guidance related to coronavirus disease (COVID-19): interim guidance, 19 March 2020. Available: https://apps.who.int/iris/handle/10665/331500. Accessed 1 June 2020.
41. Centre for disease and prevention control (CDC) (2020) Interim laboratory biosafety guidelines for handling and processing specimens associated with coronavirus disease 2019 (COVID-19). Available: https://www.cdc.gov/coronavirus/2019-ncov/lab/lab-biosafety-guidelines.html. Accessed 19 August 2020.
42. Odega K, Iyamah E, Ibadin E, Idomeh F, Odega D (2020) Safe laboratory practices in the light of Covid-19 pandemic: way forward in a resource limited setting. Preprints 2020040103.
43. Iwen PC, Stiles KL, Pentella MA (2020) Safety considerations in the laboratory testing of specimens suspected or known to contain the severe acute respiratory syndrome corona virus 2 (SARS-CoV-2). Am J Clin Path 153: 567-570.
44. Chen CC, Chi CY (2020) Biosafety in the preparation and processing of cytology specimens with potential coronavirus (COVID-19) infection: perspectives from Taiwan. Cancer Cytopathol 128: 309-316.
45. Elliott AY (2011) Vaccines. Comprehensive Biotechnology, 2nd edition. Netherland: Elsevier Press. 355p.
46. World Health Organization (WHO) (2020) Global vaccine action plan 2011-2020. Available: https://www.who.int/publications-detail-redirect/global-vaccine-action-plan-2011-2020. Accessed 24 June 2020.
47. Field RI (2009) Mandatory vaccination of health care workers: whose rights should come first? P T 34: 615-618.
48. Aaron M, Mac Josh R, Kimberly F, Violeta R, Yan L Gonzalo HO (2020) Correlation between universal BCG vaccination policy and reduced morbidity and mortality for COVID-19: an epidemiological study. MedRxiv preprints. 20042937
49. O'Neill LAJ, Netea MG (2020) BCG-induced trained immunity: can it offer protection against COVID-19? Nat Rev Immunol 20: 335-337.
50. World Health Organization (WHO) (2020) Colombia secures COVID-19 vaccines through WHO/PAHO. Available: https://www.who.int/news-room/feature-

stories/detail/colombia-secures-covid-19-vaccines-through-who-paho Accessed 24 July 2020.
51. Samuel AF, Samuel CN, Loveth OF, Ahmed OA, Ibukun AO, Tolulope SO, Godwin OO, Dayo EA, Kingsley KA (2020) COVID-19: the role of welfare and safety of health workers in combating the outbreak. Afr J Bio Med Res 3: 60-65.
52. New York Times (2020) Doctors fear bringing Coronavirus home: 'I am sort of a pariah in my family'. Available: https://www.nytimes.com/2020/03/16/us/coronavirus-doctors-nurses.html Accessed 16 April 2020.
53. Islam MS, Rahman KM, Sun Y, Qureshi MO, Abdi I, Chughtai AA, Seale H (2020) Current knowledge of COVID-19 and infection prevention and control strategies in healthcare settings: a global analysis. Infect Control Hosp Epidemiol 41: 1196-1206.
54. Nagesh S, Chakraborty S (2020) Saving the frontline health workforce amidst the COVID-19 crisis: challenges and recommendations. J Glob Health 10: 010345.
55. Burrer SL, de Perio MA, Hughes MM, Kuhar DT, Luckhaupt SE, McDaniel CJ, Porter RM, Silk B, Stuckey MJ, Walters M, CDC COVID-19 Response Team (2020) Characteristics of health care personnel with Covid-19 - United States, February 12-April 9, 2020. MMWR Morb Mortal Wkly Rep 69: 477-481.
56. Ailing L, Dexiang J, Tong Z, Yonghui W (2021) Investigation on psychological state of occupational exposure of medical staff in operation room under novel coronavirus. Saudi J Bio Sci 28: 2726-2732.
57. Martí-Amengual G, Sanz-Gallen P, Arimany-Manso J (2020) Medico-legal assessment of the COVID-19 infection in workplace. Spanish J Legal Med 46: 146-152.
58. Chang D, Xu H, Rebaza A, Sharma L, Dela Cruz CS (2020) Protecting health-care workers from subclinical Coronavirus infection. Lancet Resp Med 8: e13.

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