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The Essential Points Regarding Laboratory Biosafety to Prevent the Spread of SARS-CoV-2

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Abstract

A current biosafety and biosecurity crisis, SARS-CoV-2/COVID-19, threatens public health, making it crucial to assess and follow optimal laboratory conditions to prevent any contamination and spread of the lethal virus. Much medical staff have been lost to the COVID-19 pandemic. The dimensions of laboratory biosafety were examined in this study to reduce risks associated with COVID-19 treatment. In addition, this research primarily focuses on assessing laboratory biosafety regarding emerging coronaviruses. This research will determine which aspects need to be addressed to address the risks and implement them in the correct order and at the right time to be as educational as possible.

Keywords: SARS-CoV-2, Laboratories, Containment of Biohazards, Biosecurity

1. Context

Multiple health facilities in Wuhan, Hubei province, China, reported pneumonia cases of unknown cause in late December 2019. These patients showed similar symptoms to those with Middle East respiratory syndrome (MERS) and severe acute respiratory syndrome (SARS), such as chest discomfort, fever, coughing, bilateral lung infiltration, and dyspnea. Among the first 27 documented hospitalized patients, Huanan Seafood Whole Sale Market, a wet downtown market, appeared to be the most common epidemiological source (1-3). Coronaviruses, especially COVID-19, are novel pandemic infectious diseases with extreme mortality and morbidity rates. Comorbidities and their symptoms are associated with Coronaviruses. SARS-CoV-2 causes a mortality death rate compared to the MERS and SARS-CoV (1, 4, 5).

Risks have been posed by air traffic, trade, and numerous human migration, between China and other nations (6). Some African nations were particularly vulnerable to the introduction and spread of COVID-19 (7, 8). Travelers from China have primarily brought COVID-19 infected individuals to other nations, such as the United States of America (USA). Thailand reported the first COVID-19 infected case outside mainland China. Egypt was the first country, which reported an issue on the African continent (5, 6).

The COVID-19 pandemic has put further pressure on nations' health systems to invest extensively in disease diagnosis, care, control, and monitoring of zoonotic risks (9). However, laboratory capacity was inadequate in low-income countries, and these facilities were poorly maintained (10). Since 2020, almost all countries on Earth have been affected by the emerging Coronavirus outbreak; many people have died. This high-risk mutant virus infected a large number of people. In addition, many ICU workers, including doctors and nurses, died in 2020 due to infection with this emerging virus (11).

This disease is airborne, so it affects many people quickly. Moreover, the ideal treatment option was ambiguous, and there were no appropriate treatments at the initial stages, and prevention was the only way to combat this emerging virus. As a result, taking preventive measures and adhering to health protocols could decrease the number of cases (1). Therefore, well-established biosafety, biosecurity laboratories, and adopting appropriate One Health approaches are needed for the diagnosis and treatment of infectious pathogens in including SARS-CoV-2/COVID-19, which is accompanied with deadly outcomes (11).

The importance of biosafety practice and engineering controls are the four pillars of biosafety that must be used for effective and safe practices in clinical and laboratory settings in general (12). COVID-19 diagnostic challenges require a risk assessment and bio-risk management measures. The resource-poor settings require safe, cost-effective, and improvised methods of handling clinical samples from COVID-19 patients in laboratories. Suitable personal protective equipment (PPE) and suitable alternatives are available for selection. Disinfection of lab areas and safe disposal of clinical samples from such patients are also critical (13-15).

2. Important Characteristics of Coronavirus

A large positive-sense-RNA genome is found in both MERS-CoV and SARS-CoV. The two viruses belong to = the Coronavirus genus of the *Coronaviridae* family in the Nidovirales order (16). MERS-CoV and SARS-CoV have similar coding strategies as all viruses in Nidovirales, and two-thirds of the RNA structure is translated into two huge proteins. As a result, the virus produces polyproteins, and the whole genome is transcribed into an mRNA subgenomic nested set. Two polyproteins, including pp1ab and pp1a, encode 16 nonstructural proteins that comprise the viral replicase–transcriptase complex (RTC) (17, 18). Two proteases break down the polyproteins: 3C-like protease (3CLPro; nsp5) and papain-like protease (PLPro; nsp3). The exoribonuclease (ExoN) function of nsp14 is a distinctive characteristic of coronaviruses, which can preserve a huge RNA genome without accumulating detrimental mutations. MERS-CoV and SARS-CoV transcribe 9 and 12 subgenomic RNAs, respectively (19). In addition to which are envelope (E), membrane (M), nucleocapsid (N), and spike (S), various accessory proteins encoded by these genes do not take part in viral replication; however, these proteins influence on the host's innate immune system in unknown ways (20, 21).

Emerging viral infections are types of diseases which infect new hosts. These novel diseases could represent new geographical spread pattern, and could modify their pathogenesis course. Also, these infections might be caused by pathogens, which were not previously identified as pathogenic agents (22). Global health is at risk from many emerging infectious diseases (8). The human disease risk factors review identified 1,415 types of infectious organisms known to cause human illness Taylor et al. In this group of 175 organisms, 77 (44%) were considered new pathogens, and viruses and prions comprised the largest taxonomic group. The highest relative risk for emergence appears among viruses and all taxonomic group microorganisms (8, 23, 24).

Foshan reported the first case of SARS in November 2002 in China. Within two months of the outbreak, more than 300 cases had been reported in mainland China, of which around one-third involved healthcare workers. The outbreak spread from Hong Kong to Vietnam, Canada, and a few other countries after infected individuals traveled there (17). The World Health Organization (WHO) established an international network of laboratories in March 2003 to determine the causal agent for SARS. In early April that year, a remarkable global effort led to identifying and isolating SARS-CoV (25). At the end of July 2003, whena total of 8,096 cases and 774 deaths were reported in 27 countries, no more infected cases were detected, and SARS was declared over. From December 2003 to January 2004, there were five additional zoonotic cases of SARS, but no human cases since then. Medical interventions did not end the SARS pandemic, but infection control measures did (2). Recently, certain SARS-CoV-like viruses can infect human cells in bats without further adaptation, which suggests that SARS could re-emerge (5, 26).

3. Laboratory Biosafety and Laboratory Biosecurity

Biosafety and biosecurity measures should be included in the laboratory's assessment criteria for laboratories' biorisk. A specific objective and management strategy are needed for the assessment (27). Creating an integrated management team that implements risk policies, rules, and regulations for the operational laboratory level is vital to successfully implementing these technologies (28). Some restrictions and limitations should be followed by government authorities, along with how to manage liquid and solid waste (29, 30). It is necessary to establish management and biorisk measures with appropriate physical facilities that assure a safe work environment, safeguard the product (diagnostics, research, and/or vaccines), and protect the environment as well as the biological pathogen. This can be achieved by emphasized social distancing, which could control the epidemic curve and attenuate health system demands (28, 31).

Nevertheless, scarcity will likely become a reality since the US is so late in its mitigation efforts. A World War II-type mobilization could increase the production of ventilators, PPE, and other vital equipment that could become in short supply (31, 32).

Suspected samples should be exerted at the primary phase in a biosafety cabinet (BSC) by experienced personnel in the standard site of biosafety level 2 (BSL-2). In all circumstances, national guidelines related to the laboratory biosafety should be considered. All procedures should be exerted based on risk evaluation because of minimal available data on the risk posed by COVID-19 (28, 32, 33).

Management of specimens for COVID-19 molecular examinations needs BSL-2 or equivalent facilities, such as an automatic door-locking system and separate hand and eye wash sinks. The BSL-2 laboratories should have access to a decontamination site, e.g., an autoclave (34).

All laboratories that handle SARS-CoV-2 virus-carrying specimens (sputum, throat swabs, nasopharyngeal/oropharyngeal swabs, and stool) should follow reasonable microbiological procedures, laboratory practices, and universal precautions (35, 36).

Sufficient microbiological laboratory techniques as well as international precautions should be considered in all laboratories handling exceptional specimens (such as nasopharyngeal swabs, throat swabs, oropharyngeal swabs, sputum and stool because these specimens might be contaminated with SARS-CoV-2. Laboratory personnel should be supervised by knowledgeable professionals about infectious agents and established procedures while working with suspected patient samples (29, 37, 38).

Coronaviruses are primarily associated with respiratory infections that cause symptoms similar to the common flu. Respiratory samples, such as clinical specimens from the upper/lower respiratory tracts, will be used for detection, depending on the patient's symptoms and condition. The SARS-CoV-2 incubation period is about 5 days; however, it might differ widely based on the illness severity (27, 30). Only well-trained personnel should be involved in the appropriate specimen collection, packaging, storage, and transport, guaranteeing that sufficient standard operating procedures are by the national or the WHO guidelines (39).

Laboratories diagnosing COVID-19 should have well-trained staff in biosafety measures. The accurate and rational use of PPE and proper hand hygiene could help decrease the spread of pathogens. Although PPE is considered as an initial prevention strategy, it should not be wholly relied upon to stop the transmission of viruses. The PPE efficacy depends on the correct handling of PPEs by experienced personnel, proper hand hygiene, and related human factors (31). An immunization policy for influenza might help protect laboratory workers and reduce the staff's suspicion of getting an infection in such emergencies (11, 33). Scientific reports about laboratory-acquired infections (LAIs) are rare, and numerous reports about traditional research laboratories were published between 1982 and 2016 (27).

Percutaneous inoculation, inhalation of aerosols, direct contact with adulterated/infected surfaces, and ingestion are the most common routes of infection. The laboratory staff investigates the infective dose for humans, which differs according to the inoculation route. The most-reported LAIs are pathogenic bacterial microorganisms, and virus-related LAIs have increased recently. Laboratory biosafety also involves staff and program management, transportation and information security, and material accountability (39). A BSL consists of an initial protective barrier, i.e., safety equipment, and a secondary protective barrier, i.e., safety sites (40). There are four biosafety levels (BSLs) for protection: BSL-1, BSL-2, BSL-3, and BSL-4, according to the standard facilities and infections and deadly agents they work on. According to PPE for healthcare systems, laboratories must be committed to the guidelines in the specific biosafety level they work on (31, 33, 38).

According to recent studies, asymptomatic individuals might be as high as 50 - 75% and may have a similar viral load in the upper respiratory system as symptomatic patients. Countries should use a biosecurity checklist. This list needs endless revision, updates, and customization to national guidelines. A biosecurity culture is required to successfully implement the policies, a scientific community, and a committed community (15, 40).

4. General Recommendations for Laboratory Staff

Lab workers were among the first people in the world to be vaccinated. Based on the results of the various studies, the vaccination has reduced the mortality rate morbidly, but still, people can be infected by SARS-CoV-2 (41).

One of the most critical aspects of COVID-19 is that healthcare workers involved in COVID-19 laboratories are at the highest risk of contracting the disease (42). Hence, laboratory personnel should maintain social distancing since asymptomatic colleagues can infect others. Furthermore, good hand hygiene should be practiced. The laboratory staff should be monitored daily, and the suspected person should be quarantined. Among all laboratory equipment, PPEs including a lab coat or gown, face shield, face mask, goggles, gloves, and head cap should be worn (38). Utilizing covers in hospitals and laboratories is necessary because the coronavirus can spread to persons while talking. PPE should always be used within the laboratory to avoid infection (15, 38).

Although N95 masks are suggested for all laboratory procedures that are correlated with the production of aerosol droplets, there was a global shortage of N95 masks. Surgical masks are recommended if the N95 mask is unavailable. PPE donning, doffing, and decontamination protocols should be taught to all personnel in the event of a spill. More caution should be exercised when removing PPE because contamination is possible (15). Vortexing and centrifugation during the extraction of nucleic acid might lead to the production of aerosols; therefore, it is suggested to use sealed rotor caps used during centrifuging, and contamination should be prevented. During centrifugation, the lids should be tightly closed. It is suggested to utilize plastic centrifuge tubes instead of glass tubes because glass tubes might break, and if possible, centrifuges should be utilized inside a BSC class II. Each laboratory should consider a risk evaluation, recognize possible hazards, train laboratory personnel, and develop standard operating procedures to avoid the spread of COVID-19 before processing relevant samples (5, 33). Different guidelines during the COVID-19 pandemic have been published regarding PPE and laboratory equipment.

5. Considerations Regarding COVID-19 Samples

According to the declaration of the WHO, all specimens during the pandemic must be considered potentially infectious. Thus, all laboratory personnel should use proper PPE while collecting and storing (5, 37). Personnel who handle samples should be trained in spill decontamination. The sample should be located in leak-proof sample bags, secondary containers with a detached sealable pocket for sample storage: A lab request form as well as a plastic biological hazard bag with proper labeling on the specimen's container. Biosafety requirements must be followed depending on the model being handled and transported. The sample should not be delivered using pneumatic tube systems. The patient's complete biodata should be submitted in the lab request form, including name, date of birth, and age, and the lab should be notified as quickly as possible when a sample is transferred (29, 33).

6. COVID-19 Sample Collection and Processing

COVID-19 samples should be handled according to BSL-2 guidelines. They must wear PPE such as gloves, masks, and face protectors to avoid infection. Samples should be correctly classified and labeled based on their pathogenicity, and the storage material should not be compromised. When the storage material becomes damaged or leaks, the personnel must immediately execute the BSL-3 emergency procedures (32). The surface of the storage material should be disinfected with sodium hypochlorite, alcohol, or other disinfectants before processing and handling. Using BSC class II in COVID-19's diagnostic laboratory is crucial to protect personnel, products, and the environment from infectious agents. Staff should wear eye protection, a face protector, a mask, gloves, and a laboratory coat. That team should check the centrifuge for any leaks or damage of the sample. The laboratory manager should validate the BSC before working with COVID-19 specimens. Sometimes there is a need to assess the sample more, so the sample should be stored in a divided area to avoid contamination (35, 37).

7. Conclusions

This review gives a complete summary of biosafety recommendations used in handling COVID-19 samples worldwide. Although guidelines should differ from nation to country depending on their environment and laboratory setup, there should be specific alterations or upgrades. According to all prior findings, SARS-CoV-2 is classified as a risk group of 3 organisms. Biosafety procedures should be followed when handling, processing, and transporting these samples. The government or other relevant authorities should guarantee that these principles are followed in laboratories. Furthermore, exceptional training and awareness programs should be provided for healthcare professionals to appropriately employ PPE and biosafety measures in their working environment.

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Footnotes

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