THE ROLE OF MEDICAL LABORATORY SCIENTIST IN COVID-19 PANDEMIC

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ABSTRACT

Background: The new coronavirus disease (Covid-19) has infected more than five hundred million (545,226,550) people and leaving more than six million (6,334,728) people dead in about 180 countries worldwide. The role of medical laboratory scientist cannot be over emphasized in an effort to curtail the covid-19 pandemic. According to CDC, 70% of informed medical decisions are based on laboratory results used in treating and management of patients.

Aim: The aim of this review work is to elucidate the critical role of medical laboratory scientist in containing the scourge of ravaging COVID-19 pandemic.

Methodology: For this review, online databases like PubMed, Google Scholar search and Web of Science were searched for articles related to the keywords of the topic of the article.

Results: The role of medical laboratory scientist cannot be over emphasized in diagnosis of disease conditions especially covid-19 pandemic. According to CDC, 70% of informed medical decisions are based on laboratory results used in treating and management of patients. Medical Laboratory Science practice involves the analysis of human specimen like body fluids, excretions and various body swabs samples for the purpose of medical laboratory diagnosis, treatment and research. WHO emphasizes "**detect, protect and treat**" to break the chain of transmission of SARS-COV-2 and COVID-19.As disease detectives, their role in the fight against the COVID-19 pandemic include, Collecting samples, Processing samples, Etiological diagnosis of SARS-CoV-2, Management of patient response to treatment, Epidemiological Surveillance, Production of covid-19 vaccine and Generation of Data.

Conclusion: Medical Laboratory Science is the bedrock of diagnostic medicine and the role of Medical Laboratory Science in containing any pandemic cannot be relegated to the background, not now or in the future.

Keywords: Covid-19, Role, Medical laboratory Scientist, pandemic, SARS-COV-2.

INTRODUCTION

The World Health Organization through its Director-General, Tedros Adhanom Ghebreyesus, officially declared the Coronavirus Disease – 2019 (COVID-19) as pandemic on March 11, 2020 (WHO, 2020). The disease was spreading so fast that any count of confirmed cases and deaths quickly becomes out dated.

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So far, globally, the new coronavirus has infected more than five hundred million (545,226,550) people and leaving more than six million (6,334,728) people dead in about 180 countries (WHO, 2022). Beyond animal to human transmission, the virus is able to spread from person-to-person regardless of geographical location (CDC, 2019).

The health system of many countries has been overwhelmed by the pandemic, with many losing a significant number of their health professionals in the fight against the virus. While doctors and nurses are so visible at the front lines and are being applauded for the gallant role they are playing in the recovery of hundreds of thousands of COVID-19 patients, the world knows little about those behind their successes, the Medical Laboratory Scientists (MLS). Medical laboratory science is the bedrock of diagnostic medicine and the role of the MLS in containing any pandemic cannot be overemphasized.

Medical Laboratory Science is the profession of Medical Laboratory Scientist. The role of medical laboratory scientist cannot be over emphasized in diagnosis of disease conditions especially covid-19 pandemic. According to CDC, 70% of informed medical decisions are based on laboratory results used in treating and management of patients. Medical Laboratory Science practice involves the analysis of human specimen like body fluids, excretions and various body swabs samples for the purpose of medical laboratory diagnosis, treatment and research (Obeta *et al*., 2021).WHO emphasizes "**detect, protect and treat**" to break the chain of transmission of SARS-COV-2 and COVID-19 (WHO, 2020).As disease detectives, their role in the fight against the COVID-19 pandemic include, Collecting samples, Processing samples, Etiological diagnosis of SARS-CoV-2, Management of patient response to treatment, Epidemiological Surveillance, Production of covid-19 vaccine and Generation of Data.

Etiology of COVID-19 Pandemic

A new strain of coronavirus called the COVID-19 virus (also known as, *the Severe Acute Respiratory Syndrome Coronavirus 2, SARS-CoV-2*) has been implicated as the culprit of this strange pneumonia that started in Wuhan megacity of China (Zhu *etal., 2*020). It is an enveloped non-segmented positive sense single-stranded RNA virus in the family *Coronaviridae*. The virus pathogenicity has been linked to the envelope which promotes viral assembly and release. In appearance, the virus looks like a crown under the electron microscope (Figure 1), hence the name, "*Corona"*. Like other coronaviruses, the COVID-19 virus genome is about 400-500nm in size and encodes structural proteins (example, spike glycoprotein and accessory proteins), as well as non-structural proteins such as RNA-dependent RNA polymerase, helicase, papain-like protease and 3chymotrypsin-like protease (Chen *et al.,* 2020)

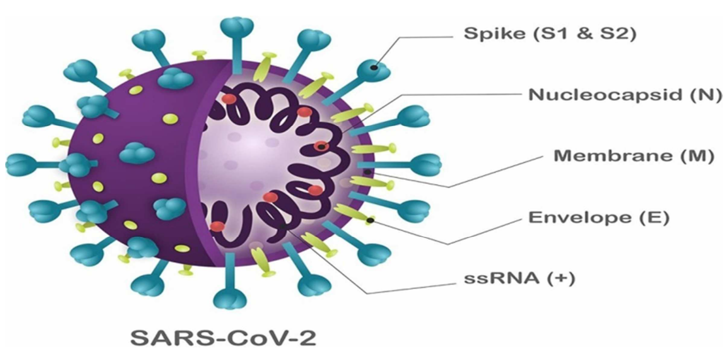

Figure 1: Structure of SARS-CoV-2 virus (Kumar *et al.,* 2020)

Transmission of COVID-19 Virus

Although, the first cases of the COVID-19 were linked to consumption of seafood animals, as well as bats and snakes, the ongoing human-to-human transmission is mainly through respiratory droplets from infected individuals, contact with contaminated objects and surfaces and social activities like hand-shaking, hugging and kissing (Majumdar and Mandl, 2020). The virus is spread in droplets or droplet nuclei released from the nose and mouth of an infected person when they sneeze or cough. A single cough may produce about 3,000 droplets, while a sneeze can generate as many as 10,000 droplets (Van Doremalan *et al.,* 2020).

Once the virus becomes airborne, it may remain suspended in the air for up to 8 hours depending on the prevailing environmental conditions such as temperature and relative humidity (CNBC, 2020). Anyone within two (2) meters of the cough or sneeze of an infected person may take in the respiratory droplets into his or her airway and become infected. Otherwise, the viral particle drops about 10 feet after been discharged from an infected person and may fall on other people's clothing and surfaces around them. Studies have shown that the virus is capable of surviving for a varied period of time depending on the surfaces: human hands (510 minutes), Paper (3-4 hours), Copper (4 hours), fabrics (6-12 hours), metal surface (12 hours), cardboard (up to 24 hours), and up to 72 hours on plastic and stainless steel (CNBC,2020; Van Doremalan *et al.,* 2020). The virus remains on these surfaces for the stipulated periods waiting to be picked up by people's hands when they touched such surfaces and then touch their eyes, ears, nose or mouth, from there the virus can find its way into the respiratory tract of the victim, where it then initiates an infection. China in the middle of the pandemic commenced disinfecting and isolating used banknotes as the WHO warned that banknotes may serve as vehicle for the spread of COVID-19 virus. In fact, there are some evidences that the virus is also shed for longer period in fecal matter, so poor toilet hygiene is a predisposing factor to COVID-19 (BBC News, 2020). Being heat labile, the virus does not tolerate the sunlight. It gets inactivates at temperature 26-27^{o}C *in vitro*, hence the climate of each geographical region affects its transmissibility. The viral envelope is sensitive to organic solvent, hence the use of alcohol-based sanitizer for prevention and control (Liu *et al.,* 2020).

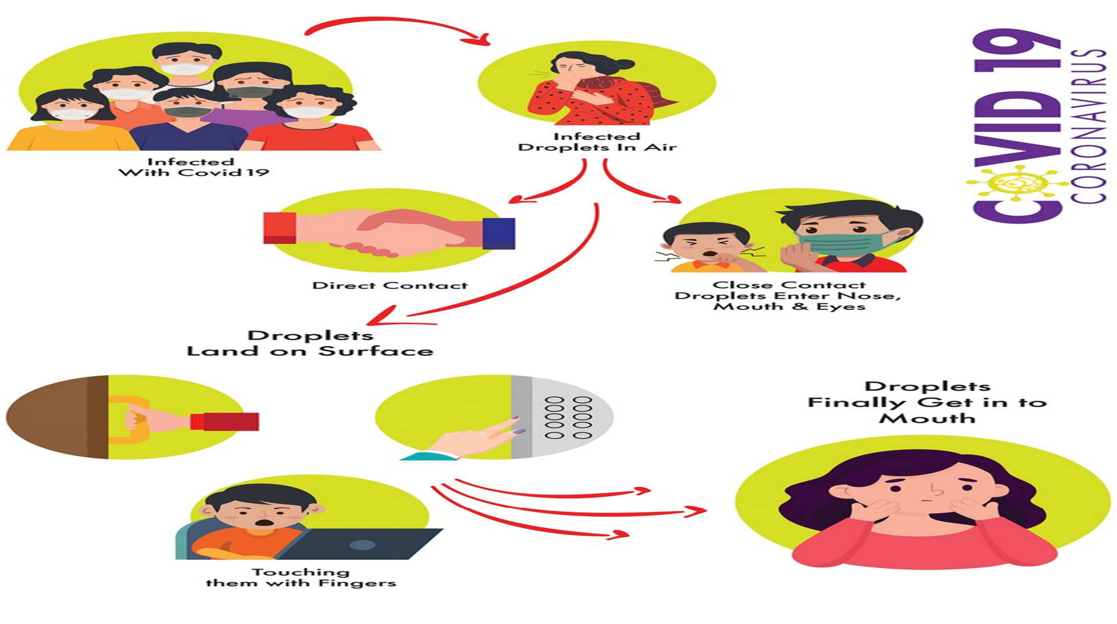

Figure 2: Mode of transmission of SARS-Cov-2 virus (Umakanthan *et al.,* 2020)

Pathogenesis and Clinical Manifestations of COVID-19

The period that lapses between the disappearance of the COVID-19 viral particle within the infected host cell and the reappearance of its off spring within same cell is termed "latency". It is also referred to as "dormancy" because there is no expression of symptoms at this stage. On the other hand, the period that lapses between the disappearance of the COVID-19 viral particle within the host cell and the re-appearance of its off spring in the clinical specimens of the host is termed "Incubation" and is characterized by symptoms. The virus has an incubation period which ranges from 0-14 days (with an average of 4.1 days) post exposure. Interestingly, an incubation period of up to twenty-one (21) days has been recorded in some patients (Chen *et al.,* 2020; Huang *et al.,* 2020).

On day 0, the virus comes into contact with the epithelial surface of nasopharynx of the host. On day 1-2 the virus localized in the epithelium tissue where it replicates and start shielding into the lymph nodes by day 3-4. This results into viremia where the infection spread into different organs through the blood stream from the lymph nodes by day 57. Viral shedding in infected persons may last up to 28 days or more (Smith 2020).

The disease is associated with atypical pneumonia characterized by high fever (45%), sore throat (30%), dry cough (65-80%), chest pain and difficulty in breathing (20-40%), diarrhea (10%) amongst other clinical manifestations (Zhou *et al.,* 2020). In the first 72 hours (Day 1-3) post-exposure, the virus first multiply in the throat, and the infected person may show symptoms similar to common cold. There could be slight sore throat, but no fever and tiredness. By Day 4, the sore throat is a little more pronounced with hoarse voice. There is slight loss in appetite, with mild diarrhea. The body temperature is around 36.5^{o}C. In addition to sore throat and hoarse voice, Day 5 is characterized by slight fever (36.5 to 36.7^{o}C), body weakness and joint pain.

By Day 6, the patient present with cough accompanied by mucus or dry cough, sore throat with painful swallowing, as well as diarrhea and vomiting. Day 7 is characterized by pronounced fever (37.4 to 37.8^{o}C) amongst other signs and symptoms. By Day 8-9, the fever is more intense (38^{o}C or higher), the dry cough is more severe and persistent, with breathing difficulty, as well as chest pain (Li 2020; Hussin *et al.*, 2020).

Risk Factors of COVID-19

The virus is believed to be more infectious than its counterparts (SARS and MERS). International travel, as well as lack of proper entry screening at airports and seaports are largely responsible for the importation of the COVID-19 virus from the epi-centre (Wuhan, China) to other countries of the world. Identified risk factors include: Recent travel to any high risk country during the past 14 days, direct and close contact or exposure to an infected COVID-19 patient. The elderly, the immunocompromised, as well as those with underlying condition including asthma, diabetes, obesity, hypertension, liver and kidney problem are at greater risk of the disease (Suganthan 2019; Zhou *et al.*, 2020).

The Role of Medical Laboratory Scientists in the COVID-19 Pandemic

The Medical Laboratory Scientist (MLS), also referred to as the Clinical Laboratory Scientist or Biomedical Laboratory Scientist, is a vital healthcare detective, uncovering and providing laboratory information from laboratory analysis that assist physicians in patient's care (Uchejeso *et al.*, 2020). These health professionals use different biomedical instrumentation and technology, computers, and methods requiring manual dexterity to perform laboratory testing on clinical specimens including blood, urine, feces, semen and aspirates amongst others (Akuyam 2014).

Areas of specialization in the field of Medical Laboratory Science disciplines includes clinical chemistry, medical microbiology (Virology, Bacteriology, Parasitology and Mycology), Hematology/blood group serology, Immunology, Histopathology, and Molecular Biology. Medical Laboratory Science professionals generate accurate laboratory data that are needed to aid in detecting infectious pathogens like bacteria or viruses, cancer, heart attacks, diabetes, as well as drug poisoning. In addition, they monitor testing quality and consult with other members of the healthcare team for a better health outcome of the patient (Olson *et al.*, 2019; ASCLS, 2020). A Medical Laboratory Scientist is a "disease detective," helping to pinpoint the etiology of disease through the examination and analysis of blood, tissue and other body fluids. He/she also monitor disease and treatment progression, as well as develop vaccines to combat infectious diseases.

WHO emphasizes "**detect, protect and treat**" to break the chain of transmission of SARS-COV-2 and COVID-19. Early medical laboratory testing and immediate treatment significantly decrease future COVID-19 cases. Medical laboratory assessment reveals diagnoses, confirms or rules out prognosis based on signs and symptoms, determines severity, monitors treatment responses or complications in COVID-19. Covid-19 pandemic have made the role of medical laboratory scientist more evident globally today than ever before (WHO, 2020). Specific roles of medical laboratory scientist in combating COVID-19 include the followings:

Collecting samples: Medical laboratory professionals are helping to collect samples from patients, often through a nose-swabbing procedure that is; nasopharyngeal swabs, oropharyngeal swabs, throat swabs, saliva, sputum, bronchoalveolar lavage fluid, conjunctival swabs, rectal swabs, whole blood, serum/plasma, stool, and urine (WHO, 2022).

Processing samples: At smaller clinics and laboratories, medical laboratory professionals typically need to get the samples ready for safe transport to other laboratories where the actual testing takes place using triple-layered packaging method. As the name suggested, any package used to contain an infectious substance must be comprised of three layers. The primary receptacle, containing the infectious substance, must be watertight, and impermeable to the substance held within (i.e. leakproof – for liquid, or sift-proof – for solids). The primary receptacle should be appropriately labelled as to content. The primary receptacle must not become punctured, broken, weakened or affected by contact with the infectious substance.

A second watertight, leakproof or siftproof container should then be used to enclose and protect the primary receptacle, and its absorbent material.

A third, outer layer of packaging is used to protect the secondary container from physical damage while in transit. It must therefore be of an appropriate strength for the weight, size and composition of the inner packages to be protected. At least one surface of the outer packaging must have a minimum dimension of 100 mm × 100 mm (Figure 3).

Specimen data forms, letters, supplementary documentation and other types of information that identify or describe the infectious substance should be placed between the secondary container and outer layers of packaging. If necessary, these documents may be taped to the secondary container (WHO, 2022).

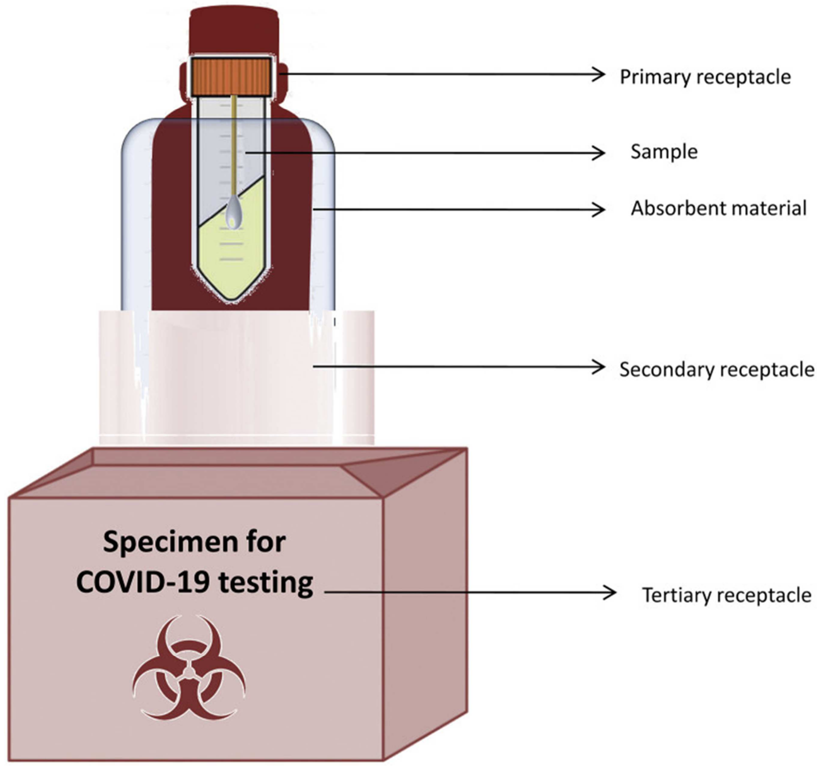

Figure 3: Triple-layered packaging for sending infectious samples (Karthik *et al.*, 2020).

- **Etiological diagnosis of SARS-CoV-2:** Medical laboratory scientists play a pivotal role in etiological diagnosis through reverse transcription-polymerase chain reaction (RT-PCR) tests (Corman, *et al.*, 2020). The medical laboratory methods and technologies applied in testing COVID-19 includes: Virological cell culture test, Polymerase Chain Reaction (PCR). Magnetic Induction Cycler (MIC) and Thermocycler RT-PCR, (gold standard). Immunological testing (antigen detection) and COVID-19 genomic sequencing (Obeta *et al.,* 2021). Antigen detection in the diagnosis of covid-19 involves direct detection of SARS-COV-2 viral proteins (antigens) in nasal swab and other respiratory secretions using lateral flow immunoassays (RDTs).Specimen is collected in viral transport medium (VTM) and the test done according to manufacturer procedures. It has the advantages of being Faster and less expensive, Used for primary case detection in symptomatic and asymptomatic individuals suspected to be infected, for contact tracing and to monitor trends of disease incidence in communities. The disadvantages includes, decrease sensitivity and specificity compared to NAATs and there is need for NAATs confirmation in low transmission (WHO, 2021).
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- **Management of Patient Response to Treatment:** Medical Laboratory scientist plays a crucial role in monitoring co-morbidities, diagnosing complications and assessment of treatment responses. It is evident that medical laboratory parameters have been adequately employed to access diagnosis like: Increased neutrophil, aspartate aminotransferase, alanine aminotransferase, C-reactive protein, lactate dehydrogenase and urea. Decrease in procalcitonin, albumin, and white blood cells like leukocytes, and lymphopenia and eosinopenia have been noted among COVID-19 patients. Reduction in aspartate aminotransferase, alanine aminotransferase, creatinekinase and dehydrogenase indicates response to treatment (Kelly-Cirino*et al.*, 2019).
- **Epidemiological Surveillance:** Medical Laboratory Scientist play an important role in assessing the spread of the disease and prevalence in the community. The role of the Medical Laboratory Scientists in a pandemic situation goes beyond just testing to know who is infected and who is clean, the dynamics of the spread of the disease, its pathogenesis, genetic evolution, prevention and control measures must also be investigated (Wilson, 2019). The MLS play a critical role in disease surveillance (Ejilemele, and Ojule, 2004). They conduct periodic pathogenicity and immunogenicity studies to detect the emergence of new serotypes of the COVID-19 virus due to mutation, as well as test for the development of herd immunity in the community.

Production of Covid-19 vaccine: Medical Laboratory Scientists play a leading role in vaccine development and production through viral culture, testing for antibodies in covid-19 patient's serum and other sophisticated molecular detection of antigen (WHO, 2020).The COVID-19 vaccines that are currently the most advanced are manufactured using four different approaches. Inactivated vaccines which contain non-living, non-replicating bacterium or virus that has been inactivated using either heat and/or chemicals. Messenger RNA (mRNA) vaccines are nothing but genetically engineered mRNA that instruct cells to make the specific protein found on the surface of infecting bacteria/virus (S protein in case of COVID-19 virus).

Viral vector vaccine- In this type of vaccine, genetic material from the COVID-19 virus (mRNA coding for spike protein) is placed in a modified version of the different viruses that act as a genetic material carrier inside the cell (viral vector). Once cells translate the code into proteins (Spike protein) and display it on cell surfaces, the immune system develops the immunological response by producing antibodies against COVID-19 antigen, and if an individual gets infected with the COVID-19 virus later, the antibodies can be produced at a faster rate by cells due to memory generated by the vaccine. They will fight against the virus and neutralize, rendering the person free from infection. Lastly protein Subunit Vaccine contains only the part of a virus subunit which is used to stimulate the immune system, the vaccine is called protein subunit vaccine. As mentioned above, this type of COVID-19 vaccine contains harmless S proteins and generates an immunological response. All vaccines, irrespective of their type, work by teaching our bodies to recognize and fight the pathogen safely. They encourage our immune that if we encounter the infection later, the immune system knows how to defend against it (CDC, 2021).

Generation of Data: Generation of valid data for healthcare planning and research. Buck of the data used in healthcare planning and intervention are generated from laboratory records and field work during the course of the pandemic.

Medical laboratory science professionals generate accurate laboratory data that are needed to aid in detecting infectious pathogens like bacteria or viruses, cancer, heart attacks, diabetes, as well as drug poisoning (Ibeh *et al.*, 2020).

CONCLUSION

Medical Laboratory Science is the bedrock of diagnostic medicine and the role of medical laboratory science in containing any pandemic cannot be relegated to the background, not now or in the future. All healthcare providers remain in the dark until the release of the medical laboratory test result on any new public health challenge, COVID-19 as an example (only a subject of suspicion).

RECOMMENDATIONS

Adequate construction and update of Medical Laboratory facilities in use for COVID-19 and other diseases of public health concern needed. Government should provide life insurance for all Medical Laboratory professionals. Train and retrain all Medical Laboratory professionals to be able to face future pandemic. There is paramount need to activate all the newly constructed molecular laboratories across the country by the Nigerian Centre for Disease Control(NCDC) and onward accreditation by Medical Laboratory Science Council of Nigeria (MLSCN).Optimization of molecular laboratory for other analysis like viral load, monkey pox, cholera and Lassa fever outbreak.

REFERENCES

Adhikari S P, Meng S, Wu Y, Mao P,Ye R X, Wang Q Z, Sun C , Sylvia S, Rozelle S, Raat H and 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. *Infectious Diseases of Poverty*,**9**:29-43.

Akuyam S A. (2014). The role of medical laboratory diagnosis in quality healthcare delivery system and its problems, challenges and prospects in Nigeria. *J Med Lab Sci.,***23**:7-16.

ASCLS. (2020). Becoming a Clinical Laboratory Professional. The American Society for Clinical Laboratory Science https://www.ascls.org/what-is-amedical-laboratory-science professional. (Assessed 26 March 2020).

BBC (2020). News. COVID-19: How long does the coronavirus last on surfaces? 2020. https://www.bbc.com/future/article/20200317-covid-19-how-long-does-thecoronavirus- last-on-surfaces.

CDC, (2021). Understanding how vaccines work: The immune system—the body's defense against infection. Accessed 10th Aug 2021: https://www.cdc.gov/vaccines/hcp/conversations/understanding-vacc-work.html

CDC. (2020). Coronavirus: 2019 Novel Coronavirus. Center for Disease Control and Prevention;

Chen Y, Liu Q, and Guo D. (2020). Emerging coronaviruses: Genome structure, replication, and pathogenesis. *J. Med. Virol.***92(4)**:418-423.DOI: 10.1002/jmv.25681.

CNBC. (2020). Coronavirus lives for hours in air particles and days on surfaces, new US study shows. .https://www.cnbc.com/2020/03/18/coronavirus-lives-for-hours-in-airparticles- and-days-on-surfaces-newus-study-shows.html

Corman VM, Landt O, Kaiser M, Molenkamp R, Meijer A, Chu DK, Bleicker T, Brünink S, Schneider J, Schmidt ML, Mulders DG, Haagmans BL, van der Veer B, van den Brink S, Wijsman L, Goderski G, Romette JL, Ellis J, Zambon M, Peiris M, Goossens H, Reusken C, Koopmans MP, and Drosten C. (2020). Detection of 2019 novel coronavirus (2019-nCoV) by real-time RT-PCR. *Euro Surveill.* **25(3)**:2000045. doi: 10.2807/1560-

CSSE- JHU. Coronavirus: COVID-19 Global Cases by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University as at April 02, 2020. https://gisanddata.maps.arcgis.com/apps/opsdashboard/index.html#/bda7594740fd40299423467b48e9ecf6. DOI:10.13140/RG.2.2.15563.13606.

Ejilemele A A, and Ojule, A.C. (2004). Health and safety in clinical laboratories in developing countries: safety considerations. *Niger. J. Med.*,**13**:182-188.

Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y, Zhang L, Fan G, Xu J, Gu X, Cheng Z, Yu T, Xia J, Wei Y, Wu W, Xie X, Yin W, Li H, Liu M, Xiao Y, Gao H, Guo L, Xie J, Wang G, Jiang R, Gao Z, Jin Q, Wang J, and Cao B. (2020). Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *The Lancet.*; **395**(10223):497506.

Hussin A. Rothana, Siddappa N. and Byrareddy. (2020). The epidemiology and pathogenesis of coronavirus disease (COVID-19) outbreak. *Journal of Autoimmunity.* DOI:10.1016/j.jaut.2020.102433.

Isaiah NnannaIbeh, Seyi Samson Enitan, Richard Yomi Akele and Christy ChinweIsitua (2020). A Review of the COVID-19 Pandemic and the Role of Medical Laboratory Scientists in containment *Journal of Medical Laboratory Science,* 2020; 30 (1): 68-89 http://jomls.org; info@jomls.org

Karthik K, AravindhBabu RP, Dhama K, Chitra MA, Kalaiselvi G, Alagesan Senthil kumar TM, Raj GD (2020). Biosafety Concerns During the Collection, Transportation, and Processing of COVID-19 Samples for Diagnosis. *Arch Med Res.* 2020;51(7):623-630. doi: 10.1016/j.arcmed.2020.08.007.

Kelly-Cirino C D, Nkengasong J, Kettler H, Tongio I, Gay-Andrieu F, Escadafal C, Piot P, Peeling R W, Gadde R, Boehme C (2019). Importance of diagnostics in epidemic and pandemic preparedness. *BMJ Glob Health*,**4**:e001179. doi:10.1136/bmjgh-2018001179.

Kumar S, Nyodu R, Maurya V.K,and Saxena S.K. (2020). Morphology, Genome Organization, Replication, and Pathogenesis of Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2). Coronavirus Disease 2019 (COVID-19). 2020 Apr **30**:23–31. doi: 10.1007/978-981-15-4814-7_3. PMCID: PMC7189391.

Li X, Geng M, Peng Y, Meng L, and Lu S. (2020). Molecular immune pathogenesis and diagnosis of COVID-19. *Journal of Pharmaceutical Analysis*, DOI: 10.1016/j.jpha.2020.03.001.

Liu T, Hu J, Lin L, Zhong H, Xiao J, and He G. (2020). Transmission dynamics of 2019 novel coronavirus (2019nCoV). BioRxiv, .919787; doi: 2020.

Majumdar M, and Mandl K. (2020). Early transmissibility assessment of a novel coronavirus in Wuhan, China. Preprint. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3524675.

Obeta M. Uchejeso, Nkereuwem S. Etukudoh, Okoli C.andChukwudimma (2021). Nigerian Medical Laboratory Diagnosis of COVID-19; from Grass to Grace as Chapter 5 of Intelligent Computing Applications for COVID-19: Predictions, Diagnosis, and Prevention (Ed.) Saba and Rehman, CRC Press Tailor and Francis Group.

Olson H, Ronayne C, Anakin M, Meldrum A, and Rich A. (2019). Working together in clinical pathology: An interprofessional education initiative for dentistry, oral health, and medical laboratory science teachers and students. *Med. Ed. Publish,* 2019; https://doi.org/10.15694/mep.2020.000 009.1.

Smith K. (2020). Problems of coronavirus pathogenesis and medications actually used. 2020, preprint, DOI:10.13140/RG.2.2.15563.13606.

Uchejeso M.O, Maduabuchi M K, Bassey O.I, and Mary-Jane O.N. (2019). Improving quality and cost diminution in modern healthcare delivery: The role of the Medical Laboratory Scientists in Nigeria. *Int J Bus Manage Invent*.**8**:819.

Umakanthan S, Sahu P, Ranade AV, Maryann M Bukelo, Joseph Sushil Rao, Lucas Faria Abrahao-Machado, Samarika Dahal, Hariand Kumar, Dhananjaya KV. (2020). Origin, transmission, diagnosis and management of coronavirus disease 2019 (COVID-19). *Postgrad Med J:*;**96**:753–758.

Van Doremalen N, Bushmaker T, Morris D H, Holbrook M G, Gamble A, Williamson B N, Tamin A, Harcourt J L, Thornburg N J, Gerber S I, Lloyd Smith J O, de Wit E, and Munster V J.(2020). Aerosol and Surface Stability of SARSCoV-2 as Compared with SARS-CoV1**.** *New England Journal of Medicine*, DOI: 10.1056/NEJMc2004973.

WHO,2022. COVID-19 Dashboard June 2022.

WHO, (2021). Guidance on regulations for the transport of infectious substances 2021-2022. Geneva: World Health Organization; 2021. License: CC BY-NC-SA 3.0 IGO.

WHO, (2020). The World Health Organization Director-General's opening remarks at the media briefing on COVID-19 - 11 March 2020. https://www.who.int/dg/speeches/detail/who- director-general-s-openingremarks-at-the-media-briefing-oncovid-19---11-march-2020.

Wilson M L. (2019). Pathology and laboratory medicine in universal health coverage. *J Lab Precis Med*., **4**:34. doi:10.21037/jlpm.2019.09.06.

Zhou F, Yu T, Du R, Fan G, Liu Y, and Liu Z. (2020). Clinical course and risk factor for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. *The Lancet*, **395**(10229): 1054-1062. doi.org/10.1016/S01406736(20):30566-3.

Zhu N, Zhang D, Wang W, Li X, Yang B, and Song J, (2020). A novel coronavirus from patients with pneumonia in China, 2019. 2020; *N Engl J Med*., **382**: 727733. DOI: 10.1056/NEJMoa2001017.