SPECTRUM OF CHEST CT FINDINGS IN CONFIRMED COVID-19 PATIENTS AT KENYATTA NATIONAL HOSPITAL

PRINCIPAL INVESTIGATOR:

DR. MUHORO W. MIRIAM

H58/12678/2018

DEPARTMENT OF RADIOLOGY

A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT FOR THE AWARD OF MASTER OF MEDICINE IN DIAGNOSTIC IMANGING AND RADIATION MEDICINE, FACULTY OF HEALTH SCIENCIES, UNIVERSITY OF NAIROBI.

LIST OF INVESTIGATORS

Principal Investigator:

Dr. Miriam W. Muhoro

Masters of Medicine Student**,** Department of Diagnostic Imaging and Radiation Medicine, Faculty of Health Scinces, University of Nairobi..

Supervisors:

Dr. Nelson Mukora Kimani

Senior Lecturer, Department of Diagnostic Imaging and Radiation Medicine,
Consultant Radiologist, Faculty of Health Sciences, University of Nairobi

Dr. Eunice Omamo

Consultant Radiologist, Department of Diagnostic Imaging and Radiation Medicine,
Kenyatta National Hospital.

DECLARATION

I, Dr. Miriam Wanjiku Muhoro, do hereby declare that this proposal is my original work and that it has not been presented at any other academic institution to the best of my knowledge.

Dr. Miriam Wanjiku Muhoro

Signature:  **Date:** 15th Nov 2022

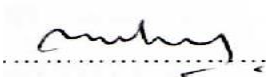
APPROVAL BY SUPERVISORS

This research proposal has been submitted with my approval as a University supervisor;

Dr. Nelson Mukora Kimani,

Senior Lecturer, Department of Diagnostic Imaging and Radiation Medicine,

Faculty of Health Sciences, University of Nairobi.

Signature:  **Date:** 17.- Nov - 2022

Dr. Eunice Omamo,

Consultant Radiologist, Department of Diagnostic Radiology,

Kenyatta National Hospital.

Signature:  **Date:** 21/11/2022

DEDICATION

This book is dedicated to my husband Joseph Thiongo , my daughters Talia Wanjiru, Tamara Kirigo and my mother Lucy Wairimu for their unwavering support, patience and inspiration.

ACKNOWLEDGEMENT

Thanks are due to:

My supervisors; Dr. Nelson Mukora Kiman and Dr. Eunice Omamo, for their guidance, advice, and support during the conduct of this study.

Kenyatta National Hospital – University of Nairobi Ethics and Research Committee for approving the study to proceed.

To many others who contributed in one way or the other, I remain highly indebted.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

ACE2	Angiotensin-converting enzyme 2
ARDS	Acute Respiratory Distress Syndrome
CFR	Case fatality Ratio
CO-RADS	COVID-19 Reporting and Data System
COVID-19	Coronavirus disease-19
CT	Computed Tomography
CFR	Case Fatality Rate
GGO	Ground Glass Opacification
HRCT	High resolution Computed Tomography
KNH	Kenyatta National Hospital
KNH/UON –ERC	Kenyatta National Hospital /University of Nairobi Ethics and Research Committee
(MERS)-CoV	Middle East respiratory syndrome coronavirus
2019Ncov	2019 Novel coronavirus
NAAT	Nucleic Acid Amplification Test
PACS	Picture Archiving and Communication System
PE	Pulmonary Embolism
RNA	Ribonucleic Acid
RT-PCR	Reverse transcription-polymerase chain reaction
(SARS)-CoV	Severe acute respiratory syndrome coronavirus
SARS-CoV-2	Severe acute respiratory syndrome coronavirus 2
SARS-CoV-2 Antigen-RDT	SARS-COV-2 Antigen detecting rapid diagnostic Test
TMPRSS2	Transmembrane protease serine 2
URT	Upper respiratory tract
WHO	World Health Organisation

DEFINITION OF TERMS

Air Bronchogram:	Air-filled bronchi on a background of high-attenuation lung
Central Distribution of Pulmonary Lesions:	Predominantly lung hilum, involving mainly the central two-third of the lung
Consolidation:	Homogeneous opacification of the lung parenchyma that has obscured the underlying pulmonary vessels.
Crazy-Paving Pattern:	Ground Glass Opacification (GGO) with superimposed interlobular and intralobular septal thickening,
Enlarged Subsegmental Vessel:	Vessel diameter greater than 3 mm,
Ground Glass Opacification (GGO)-:	Hazy areas of increased attenuation that does not obscure underlying pulmonary vessels
Linear Opacities:	Disordered arrangement of coarse linear or curvilinear opacities or fine subpleural reticulation.
Mediastinal Lymphadenopathy:	Lymph node greater than 10mm in short-axis diameter.
Peripheral Distribution of Pulmonary Lesions:	Predominantly sub-pleural, involving mainly the peripheral one-third of the lung,
Pulmonary Nodule:	A round opacity, well or poorly defined, less than 3.0 cm in diameter
Reversed Halo Sign:	Central area of ground-glass opacity surrounded by a denser crescent or ring-shaped peripheral airspace consolidation of at least 2 mm in thickness

ABSTRACT

Background: Coronavirus disease-19 (COVID-19) is a viral disease that has rapidly spread worldwide. Identifying individuals with suspected Coronavirus disease-19 (COVID-19) is important in terms of isolation of positive patients. The reverse transcription-polymerase chain reaction (RT-PCR) test is the standard confirmation tool used for diagnosing severe acute respiratory syndrome coronavirus 2. However, chest computed tomography (CT) is a key tool to use when there is evidence of worsening respiratory status. It determines the baseline pulmonary status and detects any pre-existing cardiopulmonary abnormalities or alternative diagnoses. Chest CT is also used as a problem solver in patients who have clinical features of COVID-19 but have a negative RT-PCR test. CT performed for other reasons may incidentally detect common or atypical features of COVID-19 pneumonia.

Aim: This study aimed to determine the spectrum of chest computed tomography (CT) findings in confirmed Coronavirus disease-19 (COVID-19) patients at the Kenyatta National Hospital (KNH).

Methodology: A retrospective cross-sectional study was conducted at Kenyatta National Hospital, Radiology department

Study Duration: One year from 1st May 2020 to 31st May 2021.

Study Population: Patients with reverse transcription-polymerase chain reaction(RT-PCR) confirmed Coronavirus disease-19 (COVID-19) who had undergone chest CT at the Kenyatta National Hospital (KNH) either 5 days before the positive reverse transcription-polymerase chain reaction(RT-PCR) test and up to 5 days after the positive reverse transcription-polymerase chain reaction(RT-PCR) test.

Sample Size: A total of 138 CT of patients with RT-PCR confirmed COVID-19 who had undergone chest CT at the Kenyatta National Hospital (KNH) either 5 days before the positive RT-PCR test or up to 5 days after the positive RT-PCR test were recruited into the study

Data Management: Demographic and clinical features of the patients were presented as frequencies and percentages for categorical data, and as means with standard deviation or median with interquartile range for continuous data. The CT chest patterns and distribution of chest CT findings of COVID-19 and the CO-RADS score were analyzed and presented as frequencies and percentages. Patients' demographics were presented as mean, range, and percentages.

Statistical Analysis: Data analysis was done using Statistical Package of Social Sciences (SPSS) version 25. Results was presented in the form of text, tables, graphs, and charts.

Results : A total of 138 patients with COVID-19 PCR positive were included in this study. Their ages ranged between 26 and 87 years. The median age was 50 years (IQR, 41 to 60 years). The male-to-female ratio was 1.6:1. There were 84 males (60.9%) and 54 females (39.1%). The proportion of males was statistically significantly more than females, p = 0.011. Out of the 138 study participants, 128 (92.8%) had positive chest CT imaging findings, while 10 (7.2%) did not show any lung abnormalities. Of the positive chest CT studies, mixed ground-glass opacification with consolidation(50%) was the most common pattern of chest CT findings, followed by pure Ground glass opacities (GGOs) pattern (44.2%), interlobular septal thickening (36.7%), and vascular thickening (30.5%). Less common patterns included fibrosis (19.5%), pleural thickening(12.5%), and crazy paving(10.2%) . Rare findings consisted of pulmonary nodules(5.5%), air-filled lesions(5.5%), pleural effusion(5.5%), pure consolidation(3.9%), and tree in the bud(1.6%). Bilateral affection was seen in 124 out of 128 cases (96.9%). Peripheral distribution was noted in 84/128 (65.6%) and posterior predominance was seen in 93/128 (72.7%). There was no lobar predilection. There was no statistically significant difference ($p = 0.587$) between the proportion of the upper lobes affected and the lower lobes affected. The most common CO-RADS category was category 5; 105/138 (76.1%).

Conclusion: COVID-19 tends to have typical imaging patterns on chest CT. The most common CT chest findings were bilateral, multifocal, posterior ground-glass opacities with or without consolidations. There was no lobar predominance. Recognition of this pattern of chest involvement is highly suggestive of COVID-19 infection and thus will have an impact on clinical decision-making and patient management. Overall, CT imaging is valuable in assessing complications and for follow-up.

1.0 CHAPTER ONE: INTRODUCTION

The causative agent for COVID-19 is severe acute respiratory syndrome coronavirus2 (SARS-CoV-2)], a novel beta coronavirus (1,2) that mainly affects the respiratory system. Past pandemics caused by coronaviruses (CoVs) comprise the severe acute respiratory syndrome (SARS)-CoV and the Middle East respiratory syndrome (MERS)-CoV.

On December 31st, 2019, a group of patients developed viral pneumonia in Wuhan City, China. They had a common connection with the Wuhan seafood market that deals with selling fish and live wild animals. It was determined that the 2019 Novel Coronavirus (2019-nCoV) caused this viral pneumonia (3). COVID-19 is likely a zoonotic disease. The intermediate animal or zoonotic source is most likely an animal species handled by people. However, the animal reservoir has not been identified. Humans and bats have limited close contact, so the most likely reservoir is a domesticated animal or wild animal (4). The route of spread is via interhuman transmission, mainly through direct, airborne, or respiratory droplet transmission (5).

The disease rapidly spread worldwide and on March 11th, 2020, the World Health Organization characterized it as a pandemic. According to WHO, on January 19, 2021, there were 93.4 million cases of COVID-19 worldwide, with 2.03 million deaths. Africa had 2.3 million cases, while Kenya had 99,162 cases and 1,731 deaths.

The standard confirmation tool for diagnosing COVID-19 is an RT-PCR test of a respiratory specimen (6,7). The RT-PCR results are variable and are dependent on the viral load, the type of specimen, sampling technique, transportation, and duration of symptoms (8–11). It has a sensitivity of 70% and a specificity of 95% (12), while chest CT is 97% sensitive and 25% specific (13).

Computed tomography (CT) scanning is a method of acquiring a cross-sectional image of the body by using X-rays. The cross-sectional image is reconstructed from measurements of the attenuation coefficient of the X-ray beam in the section of the body irradiated. In comparison to conventional radiographs, it can detect pathology that a conventional radiograph might have missed, it lacks superimposition of tissues seen in radiographs, and it has higher contrast due to the elimination of scatter (14,15).

Computed tomography (CT) of the chest evaluates the mediastinum, heart, airways, lungs, soft tissues, and bones (16). The two main methods of acquiring the cross-sectional images are (16) Standard CT, which deals with the evaluation of the mediastinum and gross evaluation of the lungs, and has a slice thickness of 5 mm. The second method is High-resolution CT (HRCT), which evaluates the lung's secondary lobule and has a slice thickness of 0.625 to 1.25mm. The most common reason for a CT chest is to evaluate primary lung disease, a solitary pulmonary nodule, cardiac disease, trauma, pleural, pericardial, and lung parenchymal disease (17).

Chest CT scan is the preferred imaging modality in the management of COVID-19. A low-dose chest CT is recommended unless in the detection of pulmonary embolism which requires a CT pulmonary angiogram. The common characteristics of COVID-19 on chest CT include ground-glass opacification with lung consolidation, primarily located peripherally and in the lower lobes (18).

Chest CT scan has a role in screening for coronavirus disease 2019, especially in patients who have features of COVID-19 but have a negative RT-PCR test. It is used in the assessment of complications, prognosis of COVID-19, and in determining alternative diagnoses (19–21).

In diagnosing COVID-19, chest CT has a sensitivity of 97%, a specificity of 25%, an accuracy of 68%, a positive predictive value of 65%, and a negative predictive value of 83% (13).

The study was intended to find out the spectrum of Chest CT findings in COVID-19 disease in our locality.

2.0 CHAPTER TWO: LITERATURE REVIEW

2.1 Pathophysiology

Coronaviruses are enveloped single-stranded positive-sense RNA viruses, members of the coronaviridae family. The coronavirus RNA genome is approximately 31kb. They infect different types of hosts and are associated with several respiratory and gastrointestinal tract infections(22). Coronaviruses are made up of 4 structural viral proteins; spike, membrane, envelope, and nucleocapsid. The Spike protein has a transmembrane trimetric glycoprotein sticking out from the viral surface, this dictates the virus heterogenicity and the specific host it interacts with. The spike protein has two subunits, the S1 subunit used for binding to the host cell receptor and the S2 subunit

used for the fusion of the virus and the host cell membranes. SARS-CoV entry receptor is Angiotensin-converting enzyme 2 (ACE2) (24,25).

A study by Yun Chen et al showed that the SARS-CoV-2 entry receptor is ACE2 (23). ACE2 receptors are located in the lungs, heart, gut, vessels, kidneys, brain, and testis. The vulnerability of the lungs by the virus might be due to the wide surface occupied by the epithelial cells of the alveoli(24).

The process of viral entry of SARS-CoV-2 includes binding to the ACE2 receptor then protein cleavage among the spike protein subunits using the receptor transmembrane protease serine 2 (TMPRSS2), this results in fusion between the virus and cell membrane. This is followed by the virus releasing its content, it replicates and infects other cells. (27). SARS-CoV-2 infects the nasal epithelium first (28). According to Supinda Bunyavanich ACE2 receptors in the nasal epithelium are lower in children, explaining why children are less infected with COVID-19 (29)

2.2 Clinical Manifestations of COVID-19

The COVID-19 incubation period is 1-14 days with a mean of 5-7 days and a peak viremia that occurs before the onset of symptoms(25). According to a study done by Stephen A. Lauer et al (2020), 97.5% of symptomatic individuals show symptoms by day 11.5 of being infected (26).

The clinical manifestation of COVID-19 varies. The predominant clinical symptoms are fever 80.4%, tiredness 46%, cough 63.1%, and sputum production 41.8%. Other symptoms are Myalgia, loss of appetite, chest pressure, and difficulty in breathing (27). Smell (41.0%)and taste dysfunction (38.2%) are also relatively common(28) . Less common symptoms are headache, diarrhea, vomiting, nausea, sore throat, chills, and abdominal pain. Asymptomatic individuals account for 11.9% of patients (27).

COVID-19 illness severity ranges from mild illness to critical illness (29,30). Mild to moderate illness range from mild clinical symptoms to mild pneumonia(81%). Severe illness includes difficulty breathing, SPO2<94%, or evidence of > 50% of the lungs are involved(14%). Critical illness is failure of the respiratory system, shock, or multiorgan system failure (5%).

The overall case fatality ratio (CFR) according to a study done by Jennifer M. McGoogan et al was 2.3%(30).

COVID-19 is relatively more common in males, a meta-analysis done by Jieyun Zhu et al showed that males accounted for 56.9% (27) and most cases occur in patients aged 30 to 79 years (87%)(30).

2.3 Risk Factors for Severe Disease

Advancing age increases the risk for developing severe disease, COVID-19 complications, and dying. According to the largest data analyses conducted in China involving 72,314 patient records, the case fatality rates increased with advancing age. The case fatality rate was 14.8% in people aged 80 years and older,8.0% in people aged 70–79 years, 3.6% in individuals aged 60–69 years,1.3% in 50–59-year-old's,0.4% in 40–49 year old's and 0.2% for individuals aged less than 40 years. Other risk factors include pre-existing conditions such as CVS disease, cancer (30), liver disease, obesity, and chronic kidney disease. (21).

2.4 Case Definition for COVID-19 by WHO

The case definition according to WHO includes a suspected, probable and confirmed case(31).
Suspected case is defined as:

- An individual who meets the clinical and epidemiological criteria
- An individual with severe acute respiratory pulmonary disease
- Asymptomatic person not meeting epidemiologic criteria but SARS-CoV-2 Antigen-RDT is positive

Probable case is defined as:

- A person who meets the clinical criteria of COVID-19 and who is a contact of a probable or confirmed COVID-19 case
- A suspect case who has features of COVID-19 on imaging
- A person with a sudden loss of smell or loss of taste due to an unknown cause.
- Unexplained death in a patient with respiratory distress and who was a contact of a COVID-19 probable or confirmed case.

A confirmed case is determined when:

- An individual with a positive RT-PCR test
- An individual with a positive SARS-CoV-2 Antigen-RDT and either is a suspect or probable case
- An individual without symptoms but has a positive SARS-CoV-2 Antigen-RDT and a contact of a probable or confirmed case.

A COVID-19 contact is any individual who has been exposed to a proven COVID-19 person within 2 days before the confirmed case started having symptoms to 10 days after the symptoms started (36)

2.5 Diagnostic Confirmation of COVID-19

COVID-19 RT-PCR is a Nucleic acid amplification test (NAATs) that detects unique viral sequences and is the gold standard confirmation test for diagnosing SARS-CoV-2 infections. The virus in the upper respiratory system can be detected 1-3 days before the symptom starts and its concentration is highest during the onset of symptoms. (7,32).

The median duration of viral shedding in the study by Lin Q et al was 17 days. The shortest duration was 6 days and the longest duration was 47 days(33). The presence of viral RNA for a prolonged duration does not necessarily indicate prolonged infectiousness (7).

According to World Health Organization, the RT-PCR test is performed by use of an Upper respiratory specimen in the early stages of the infection, in patients who are asymptomatic or have mild illness. Lower respiratory specimens are used late in the course of infection or in patients who have clinical features suggestive of COVID-19 but have a negative upper respiratory specimen RT-PCR test.

RT-PCR has a sensitivity of 70% and a specificity of 95%(12). False-negative results are mainly due to poor sampling technique, especially of a nasopharyngeal specimen, and improper timing of sample collection in relation to onset of disease. False-positive results may occur due to contamination of the reagents and technical errors(34).

RT-PCR test takes time before the results are available(16). According to Lauren Ching et al testing time depend on the technology and can range from 50 minutes to around 14 hours(35).

2.6 Chest CT in COVID-19 Infection

2.6.1 Role of chest imaging in COVID-19

The Fleishner society is a multinational interdisciplinary medical society for thoracic imaging and diagnosis. Its goal is to use thoracic imaging to advance the study of chest pathologies. It was established in 1969 by eight radiologists whose primary professional interests were chest imaging. The society was named in memory of Felix Fleischner a renowned chest radiologist(36,37)**.**

A global agreement Statement from the Fleischner Society was published on the utilization of chest imaging for certain situations in the management of COVID-19 (38). These situations include:

Patients who are asymptomatic or have mild respiratory symptoms, chest imaging is not indicated except in situations where they are at risk for disease progression.

Imaging is indicated in people who have moderate to severe clinical features of COVID-19 irrespective of their RT-PCR test results. It determines the baseline pulmonary status and detects any pre-existing cardiopulmonary abnormalities or alternative diagnoses.

Imaging is indicated in patients with COVID-19 whose respiratory status is getting worse.

CT is indicated in COVID-19 patients who after recovery have a functional disability and/or hypoxemia.

RT-PCR test is indicated in patients who have CT features characteristic of COVID-19.

Role of Lung Ultrasound

Lung ultrasound is a bedside method of assessment of COVID-19 patients. It is non-invasive, fast, reproducible, and sensitive in diagnosing a variety of pulmonary pathologies.

According to Karl Jackson et al the potential uses and barriers of lung ultrasound in COVID-19 include(39):

Potential Uses in covid-19

In a resource-limited setting, it's used to rapidly triage and isolate potential COVID-19 patients who present with acute respiratory failure. In patients who are PCR negative and have indeterminate CXR, typical COVID-19 changes on lung ultrasound would imply a false PCR test and thus diagnose COVID-19. In patients who are on mechanical ventilation, lung ultrasound can be used to select ventilation strategy, monitor progress of the disease, detect pneumothorax, and guide any subsequent procedures.

Potential Barriers

This include:

Lack of specialized skills whereby a majority of physicians are not trained on performing a lung ultrasound.

Point of care ultrasound (POCUS) machines are costly and are not readily available in some centers.

Images from Point of care ultrasound (POCUS) are hardly stored in a central data archive system thus are unavailable for future analysis

According to WHO lung ultrasound has limited evidence on its diagnostic accuracy, however, when used by skilled personnel lung ultrasound can be an additional or alternative imaging modality in cases such as women who are pregnant or in children. Point of care lung ultrasound requires the operator to be close to the patient for a long duration and thus need certain infection prevention and control precautions(40).

Role of Chest Radiography

Chest radiography is mostly the first imaging modality of choice in assessing COVID-19 probable or confirmed cases. It is not sensitive in diagnosing COVID-19 and a negative chest radiograph does not exclude COVID-19 infection. The indication for chest radiograph in COVID-19 include(41):

In the emergency department in a patient with symptoms suggestive of COVID-19 pneumonia and the RT-PCR test is unavailable, typical findings on chest radiograph increase the patient's pretest probability of having COVID-19. Lung ultrasound can suggest an alternative diagnosis to the clinical symptoms such as pneumothorax, pulmonary edema, pleural effusion, lung mass, or atelectasis. It can detect COVID-19 pneumonia and its complications in a patient who initially had a negative RT-PCR test but later developed worsening of symptoms. A chest radiograph is indicated in COVID-19 patients who develop worsening symptoms.

According to WHO compared to CT chest, chest radiography has a lower sensitivity but might potentially have a higher specificity. It requires fewer resources, the radiation dose is lower, monitoring of disease progress it can easily be done consecutively, and it can be done using a portable radiographic unit thus minimizing the chance of cross-infection due to transporting the patient(40).

Roles of Chest CT In COVID-19

These roles include(21):

It acts as a diagnostic tool in patients who have clinical features of COVID-19 but have a negative RT-PCR test.

If there is suspicion of alternative diagnoses, a Chest CT scan plays a role too.

Incidentally, common or atypical characteristics of COVID 19 pneumonia may be spotted in CT performed for other reasons.

CT has a role in clinical progress evaluation especially in patients who are deteriorating or evaluating the existence of other cardiopulmonary complications of COVID-19.

According to the Canadian Society of Thoracic Radiology, the clinical scenarios requiring a chest CT in Patients with Suspected or Confirmed COVID-19 Infection include(41):

Chest CT with or without contrast is indicated in a COVID-19 patient with suspicion of complications but the chest radiograph is non-contributory. Computed tomography pulmonary angiography(CTPA) is performed when there is suspicion of acute pulmonary embolism (PE).

Low dose chest CT is indicated in immunosuppressed patients or high-risk patients with clinical suspicion of a respiratory infection, but have a negative chest radiograph and there is a delay in RT-PCR results or the test is unavailable. Immunosuppressed patients are patients on chemotherapy, immune therapy, or radiation treatment, and high-risk patients include patients

older than 65, patients, with a disease of the cardiovascular system, diabetes, chronic respiratory disease, and hypertension.

In patients with a negative RT-PCR but have clinical features of COVID-19 or have worsening of symptoms and the chest radiograph is normal, a low dose chest CT is indicated.

Chest CT has a low specificity and a negative chest CT does not exclude COVID-19 infection, It requires the patient to be transported to the imaging department thus increases the risk of transmission to staff and other patients(40,41).

2.6.2 Chest CT Protocol

A nonenhanced CT Chest is recommended in the evaluation of COVID-19 patients. Intravenous contrast may change the patterns of ground glass. A pre-contrast Chest CT is recommended to be performed first in case a CT pulmonary angiogram is required (42).

A low-dose chest CT is recommended since recurrent Chest CT is performed mostly in severe cases, to determine progression or resolution of lung lesions. Patients are of different ages thus risk from exposure to ionizing radiation is a concern with radiation dose being of greater concern in young individuals and infants (43).

Low dose chest CT has equal diagnostic quality and reduces radiation dose by 90% when compared to standard CT. It is recommended as the standard for assessment of the lung parenchyma in COVID-19 due to the ALARA (as low as reasonably achievable) principle. Low dose chest CT is acquired by use of lower kilovoltage settings and interactive or deep learning-based reconstructions to reduce noise. The low-energy component of the x-ray spectrum is reduced by spectral shaping the X-ray beam. Lowering the rotation time of the tube detector system with high pitch and wide collimation values can be used in examinations at risk of motion artifact. However, acquiring low-dose CT depends on the local availability of these technologies(21).

CT images are taken during a single breath-hold at deep inspiration since there is an increase of radiation dose when taken in the expiratory phase and also the suspicion of COVID is not increased by evaluation for air trapping in chest CT(21).

2.6.3 Infection Prevention and Control for Chest CT Imaging in Patients with Suspected or Confirmed COVID-19

WHO guidance on infection prevention and control of chest imaging in patients with confirmed and suspected COVID-19 include(40):

Preparation

Imaging personnel task: Investigate the impact of the procedure on management and whether the imaging can be done at a later time. Evaluate if portable imaging is an option. Assess the risk factors of the patient. Perform hand hygiene and wear protective equipment. Follow the set protocol for imaging and identification of patients

Patient considerations: Avail medical masks to patients and caregivers and ensure the patients observe hand hygiene and when coughing either use a tissue or elbow.

Equipment considerations: Maintain infection and control measures when handling the imaging equipment. The imaging equipment should be regularly cleaned and equipment that is not used should be removed from the room. Equipment that cannot be moved should be covered by plastic or appropriate material.

During examination

Suitable personal protective equipment should be worn and a contact and non-contact radiographer approach employed. If possible only one patient at a time should be attended to in the imaging department. Standard infection prevention and control procedures should be adhered to including minimizing contact and putting up barriers such as covers. Presence of relevant signs at the imaging area such as disinfection in progress, the patient is in, and the last cleaning time.

Post-procedure

Ensuring proper personal protective equipment is worn while transferring the patient from the imaging room. Ensure proper removal of personal protective equipment. The room and medical equipment should be cleaned and disinfected after each patient.

2.6.4 Chest CT Appearance of COVID-19

2.6.4.1 Normal Chest CT Findings

Hugo J. A. Adams reported that 10.6% of known COVID-19 patients with symptoms had normal findings on CT (44). Normal chest findings occur mainly a few days after the start of symptoms although some symptomatic patients in the later stage of the disease have normal findings(45,46). In asymptomatic patients, the incidence of normal chest CT findings is approximately 46%(21,47). False-negative CT Chest is most likely due to low viral loads, confinement of the virus to the upper respiratory tract, and host factors whereby many patients don't produce the inflammatory response required to cause changes on chest CT (21).

2.6.4.2 Chest CT Abnormalities in COVID-19

In a study done by Hugo J. A. Adams et al, the most common chest CT findings in more than 70% of laboratory-confirmed COVID patients include a posterior location (90.0%), ground-glass opacity (81.0%), mostly bilateral distributed(75.8%) followed by left lower lobe in 73.1% then right lower lobe in 72.2% and vascular enlargement (>3 mm) in 72.9%. The lesions are multifocal in 63.2%.

Other CT findings occurring in 10-70% of COVID-19 positive patients are lung consolidation, linear opacity, reticular pattern, crazy-paving, air bronchogram, thick pleura, halo, and reversed halo sign, bronchiectasis, pulmonary nodules, and thick bronchial walls. Less common or rare findings occurring in <10% are pleural effusion, enlarged lymph nodes, tree-in-bud sign, centrally located lesions, pericardial effusion, and lung cavities (44).

In a meta-analysis done by Maria El Homsi et al, peripheral, patchy ground-glass opacities in both lungs, mixed with or not having consolidation were the typical CT features of COVID-19 pneumonia. The Ground glass opacities were round in shape in 54% of the cases (18). The GGOs and consolidative lesions measured more than one centimeter in 91 % of cases(48).

A study in japan by Shohei Inui et al reported that patients with no symptoms have more areas of GGO (80%)than consolidation (20%) while for those with symptoms the percentage of GGO was 63% and consolidation was 38% (47)

Coronavirus Disease 2019 typical pattern on chest CT in Italy was the presence of GGO located posteriorly and peripherally within multiple lobes and associated with a vascular enlargement(49).

A study done in Egypt by Youssriah Yahia Sabri et al (yr) showed that the most common chest CT feature of COVID-19 was ground-glass opacity located peripherally, in both lungs mostly in the lower lobes mixed with or not having consolidation, this is followed by vascular thickening and bronchiectasis(50).

According to studies done by Youssriah Yahia Sabri et al (yr) and Carotti et al (yr). minimal pleural thickening in the posterior lower lobe was the most common COVID-19 associated imaging finding (50,51).

Pleural effusion and mediastinal lymphadenopathy are associated findings and occur in more advanced cases(52). According to a study done in Egypt, a considerable number of young female COVID-19 patients had thymic hyperplasia with most of them having no CT abnormalities. The study suggests that thymic hyperplasia is a viral infection immune response(50).

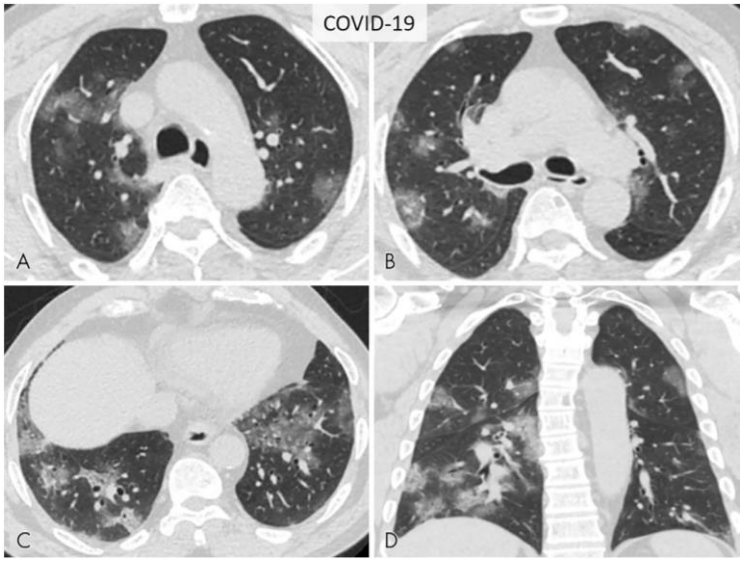


Figure 1: Typical CT findings in a COVID-19 confirmed 77-year-old man. Nonenhanced axial (A–C) and coronal reformatted images (lung window) showing multifocal, rounded, peripheral GGO located in both lungs(53)**.**

According to a study done by Song et al., they noted a difference in rates of GGO and consolidation between the age group less than 50 years and older than 50 years. In individuals younger than fifty years ground glass opacities occurred in 77% while consolidation occurred in 23% of the patients. In people aged more than 50 years, GGO was reported in 55% and consolidation in 45% of the patients. Older patients are likely to have more consolidation and more lung involvement while younger patients are likely to have more GGOs (54). CT chest findings of atypical features of COVID-19 are more likely to be in the elderly compared to the young(4,55).

The differential diagnosis for suspicious COVID-19 chest CT findings includes pathologies that share at least one radiological feature with COVID-19 pneumonia. These include chest CT features such as ground-glass areas, crazy paving, and consolidation(56).

Table 1:Differential diagnosis for suspicious COVID-19 chest CT findings(56)

Pathologies		Ground glass	Crazy paving	Consolidations
Infective pneumonia	Bacterial	R (ATYPICAL)	OD/A	C (TYPICAL)
	Viral	C	OD/A	R
	Fungal: pneumocystis jiroveci pneumonia	C	R	R
	Fungal: angioinvasive aspergillosis	(HALO)	OD/A	C
Cardiovascular	Acute pulmonary oedema	C (INTERSTITIAL)	C (INTERSTITIAL)	C (ALVEOLAR)
	Acute pulmonary embolism and infarctions	C	C	C
	Vasculitis	C (HAEMORRAGE)	C (REABSORPTION)	C (MASSIVE HAEMORRAGE)
Hypersensitivity pneumonia		C	OD/A	R
Eosinophilic pneumonia	Simple pulmonary eosinophilia	C	OD/A	C
	Acute eosinophilic pneumonia	C	C	R
	Chronic eosinophilic pneumonia	R	R	C
Aspiration pneumonia	Fluid-related ab ingestis pneumonia	C	OD/A	C
	Chronic lipoid pneumonia	C	C	C
Alveolar proteinosis		OD/A	C	R

Table 1: Differential diagnosis for suspicious COVID-19 chest CT findings includes pathologies that share at least one radiological feature with COVID-19 pneumonia. These include ground-glass areas, crazy paving, and consolidations. These findings may be either common(C), rare(R), occasionally described/absent (OD/A)(56).

2.6.5 Phases of COVID-19

These stages are based on the length between the start of symptoms and acquisition of the chest CT (57,58). They are:-

(a) early phase (0–5 days): normal or mostly GGO

(b) progressive phase (5–8 days): ground-glass opacities increase and presence of crazy-paving

(c) peak phase (9–13 days): the presence of consolidation

(d) late phase (≥14 days), it involves slow reduction of consolidation and GGO, with the possible occurrence of fibrosis (21,46,58–61).

Imaging findings when present in the early stage are often unilateral(57). A study by Shuchang Zhou et al (yr.) portrayed that in the early phase 16.1 % of patients present with a single lesion mainly in the right lower lobe in 70 % of cases (62).

2.6.6 Diagnostic Performance of Chest CT

CT Chest findings in SARS CoV-2 infection can occur before reverse-transcription polymerase chain reaction testing (RT-PCR) turns positive. RT-PCR sensitivity may range from 42% to 71%, a negative RT-PCR at first in a patient with COVID-19 may take up to 4 days to convert(13,53,63). A study by Hugo J. A. Adams reported a chest CT sensitivity of 94.6% and a specificity of

46.0%(64). CT is not the primary diagnostic tool for COVID 19 but only suggests the diagnosis in certain circumstances. It is thus important to compare chest CT image findings with the patient's clinical history and RT-PCR results(21).

2.6.7 Structured Reporting of Chest CT Findings Related To COVID-19

The radiological Society of North America has provided an organized method of reporting chest CT findings of COVID-19(53). Its goal is to assist radiologists to recognize the finding in COVID-19, improve communication by reducing reporting inconsistency, decreasing uncertainty in reporting outcomes potentially caused by COVID-19 pneumonia between the radiologist and the referring provider, thus allowing for better incorporation into clinical decision making.

The four kinds of standardized COVID-19 reporting include:

Typical appearance

- peripheral based ground glass opacification located in both lungs
- round shaped ground-glass opacification with multifocal distribution
- Features of organizing pneumonia such as reverse halo signs

Indeterminate appearance

The typical COVID-19 appearance is absent and the following features are present

- Ground glass opacification with or without consolidation with no particular distribution and can be multifocal, widespread, or located in one lung or around the perihilar region. They are not round in shape and not peripheral based.
- Few little ground-glass opacities which are not round in shape and not located peripherally.

Atypical appearance

The typical and indeterminate features are absent and the following features are present:

- Consolidation is either in a lung lobe or is segmental and has no ground-glass opacities
- Tiny discrete lung nodules
- Interlobular septal thickening which is smooth and the presence of pleural effusion

Negative for pneumonia

- No CT findings of pneumonia especially the absence of ground glass opacification or consolidation

2.6.8 CO-RADS, the COVID-19 Reporting and Data System

A CT-based framework put in place by the Dutch Radiological Society is used in assessing the suspicion of SARS-CoV-2 pulmonary involvement. It is based on the pattern and spread of the pulmonary abnormalities seen on non-enhanced Chest CT. It ranges from CO-RADS category 0 to CO-RADS category 6. CO-RADS category 0 indicates that the CT images are incomplete or the scan is simply inadequate for assigning a score and CO-RADS category 6 indicates RT-PCR confirmed COVID-19(65,66).

Table 2:CO-RADS Categories and the Corresponding Level of Suspicion for COVID-19 infection (65):

CO-RADS Category	Level of suspicion COVID-19 infection	Chest CT findings
1	Very low	Normal CT scan findings or there are CT findings of a noninfectious origin
2	Low	Findings consistent with other infections incompatible with COVID-19 No typical signs of COVID-19
3	Unsure or indeterminate	Abnormalities indicative of infection, but no clear association with COVID-19
4	High	Findings are suspicious of COVID-19 but are not typical
5	Typical	Typical CT features of COVID-19

SARS-CoV-2 pulmonary involvement is detected by use of the CORADS system in more than 95% of patients, with moderate to severe clinical features,48 hours after the start of symptoms. CO-RADS score of more or equal to 4 has an odds ratio above 25 for the diagnosis of COVID-19(67).

2.6.9 CT Severity Score

On chest CT, the severity of the lung area involved correlates with the severity of the disease(68). This is a scoring framework used to quantitatively estimate pulmonary involvement of COVID-19(69). The 5 lung lobes are individually scored on a scale of 0 to 5,

0. no involvement;

1. less than 5% area involved
2. 5%–25% lung area involved
3. 26%–49% lung area involved
4. 50%–75% lung area involved
5. more than 75% lung area involved.

The total CT score is the addition of the individual lobar scores and ranges from 0 to 25. A CT score ≥ 18 highly predicts short-term fatality (70).

2.7 COVID-19 Complications

2.7.1 Acute Respiratory Distress Syndrome

COVID-19 may quickly advance to ARDS, with elderly patients being more vulnerable. ARDS seen with COVID-19 occurs when pro-inflammatory cytokines cause diffuse alveolar. It is characterized by sudden onset of non-cardiogenic edema, hypoxia, and the need for assisted ventilation. ARDS is the main reason for admission to the intensive treatment unit and the primary cause of death in patients with SARS-COV-2 (21,71–75).

Chest CT findings of ARDS associated with COVID-19 are bilateral lung opacities. The clinical features of ARDS associated with COVID-19 can be unlike those of ARDS resulting from other factors, for example, it can develop later than the one-week upper reference limit. Moreover, the symptoms may be mild in comparison to the level of severity seen on imaging. (75–77).

2.7.2 Pulmonary Embolism

COVID-19 patients are susceptible to thromboembolic episodes due to activation of the coagulation pathway by SARS-CoV-2 or via COVID-19 inflammatory response. These thromboembolic episodes increase the risk of death by fivefold. It has been noted that PE occurs in 17% to 35% of COVID-19 patients who undergo CT pulmonary angiogram and it occurs more in significantly sick individuals (78–82). CT pulmonary angiogram is not routinely done in all patients with COVID-19 thus the exact contribution to mortality is currently not known. CT pulmonary angiography should be taken into consideration in patients who are COVID-19 suspected cases and have clinical features suggestive of PE. (21).

2.7.3 Superimposed Pneumonia

Superimposed pneumonia caused by bacteria or fungi occurs in 10% of COVID-19 patients admitted to a health facility. It can be the cause of mortality in COVID-19 patients with ARDS. Chest imaging and lower respiratory tract cultures are essential in patients with worsening respiratory symptoms to look for superimposed pneumonia(53,76,83–85).

2.7.4 Cardiac Injury

Myocardial injury increases the risk of mortality. Cardiac injury incidence in COVID-19 patients ranges from 12.5-19.7%. Pericardial effusion may signify cardiac injury and it occurs in approximately 5.2 % of COVID-19 patients, who in most cases have a severe or critical illness(21,44,72,84,86–88).

2.8 Chest CT Findings for COVID-19 in the Pediatric Population

Pediatric patients when compared to adults have less positive chest CT findings, fewer lung lobes involved, and lower chest CT severity score(57). The most common chest CT findings in pediatric patients include bilateral peripheral and/ or subpleural located ground-glass opacity with or without consolidation and mainly in the lower lung lobes. The halo sign is present in approximately 50% of the cases. Evolution of chest CT findings in pediatric patients include three phases (57):

- Early phase: the presence of the halo sign
- Progressive phase: progression to ground-glass opacities
- Developed phase: the presence of consolidation

Pediatric patients have along with the bronchovascular bundle more peribronchial thickening and inflammation when compared to adults. They tend to have less crazy paving and reticulations. They rarely have pleural effusion and enlarged lymph nodes(57).

2.9 Role of Artificial Intelligence (AI) In the Interpretation of Suspected COVID-19 Chest CT Imaging Features

Artificial intelligence (AI) has a role in diagnosis, quantification of disease, assessing severity, and determining the prognosis of COVID-19 pneumonia. They are proposals that it's a tool that will reduce radiologists' caseload, make the workflow efficient, increase the diagnostic accuracy, and aid in proper allocation of resources. It also improves the radiologists' performance. Most studies are on the use of Artificial intelligence(AI) in chest CT and chest radiography to differentiate

COVID-19 from non-COVID pneumonia and determining the disease severity. Li et al.developed COVID-19 detection neural network (COVNet) which has a sensitivity of 90% and specificity of 96% in detecting COVID-19(90).

2.10 Study Justification

COVID-19 is a viral disease that has rapidly spread worldwide. Identifying individuals with suspected COVID-19 disease is important in terms of isolation of COVID-19 positive patients.

The gold standard confirmation test for detecting SARS-CoV-2 is the RT-PCR test. However, the RT-PCR test is dependent on various factors such as the viral load, the type of specimen, sampling technique, transportation, and duration of symptoms, and it may take some time (hours to days) before the results are available. Sometimes, the RT-PCR test turns positive after several negative tests in a patient with clinical features and imaging findings of COVID-19. Due to this, the function of chest CT in COVID-19 is continually changing.

CT chest is a key tool to use when there is evidence of worsening respiratory status in people with moderate to severe clinical features and acts as a problem solver in patients who have clinical features of COVID-19 but have a negative RT-PCR test. CT performed for other reasons may incidentally detect common or atypical features of COVID-19 pneumonia. Radiologists need to have adequate knowledge of the CT chest findings of COVID-19 as they play an important role in the management of the patients. Despite having several studies that have previously described chest CT patterns in COVID-19 infection, there has been no such study done in Kenya.

2.11 Research Question

What is the spectrum of chest CT findings of Confirmed COVID-19 patients at KNH?

2.12 Study Objectives

2.12.1 Broad objective

To determine the spectrum of Chest CT findings in Confirmed COVID-19 patients at KNH

2.12.2 Specific Objectives

i. To determine the demographic characteristics of confirmed COVID-19 patients at KNH

ii. To evaluate the patterns and distribution of chest CT findings in confirmed COVID- 19 patients at KNH

iii. To determine incidental chest CT findings in COVID-19 positive patients.

iv. To determine the spectrum of CO-RADS score findings in confirmed COVID-19 patients at KNH

3.0 CHAPTER THREE: METHODOLOGY

3.1 Study Design

A retrospective cross-sectional study

3.2 Study Duration

Over 12 months, review of chest CT done from 1st May 2020 to 31st May 2021

3.3 Study Area Description

The study area was Kenyatta National Hospital (KNH), Department of Diagnostic Radiology. The demographic data was obtained from the patients' files. The Kenyatta National Hospital is the largest referral facility in East and Central Africa. It is the teaching facility housing the University of Nairobi's School of Medicine. The department had handled about 700 patients with COVID-19 undergoing Chest CT. The department from April 2020 to April 2021 had performed 2374 chest CT and 714 HRCT. The demographic data was obtained from the patients' files.

3.4 Study Population

Chest CT of patients with RT-PCR confirmed COVID-19 who had undergone chest CT at the Kenyatta National Hospital (KNH) either 5 days before the positive RT-PCR test or up to 5 days after the positive RT-PCR test.

The 10-day range selected was because the COVID-19 incubation period was considered 1-14 days with a mean of 5-7 days (25).

3.5. Inclusion Criteria

1. Patients 18 years of age and above
2. Patients with RT-PCR confirmed COVID-19 who had undergone chest CT at the Kenyatta National Hospital (KNH) either 5 days before the positive RT-PCR test or up to 5 days after the positive RT-PCR test.

3.6Exclusion Criteria

1. Patients aged less than 18 years

2. CT with severe motion artifacts

3.7 Sample Size Determination

A sample size of 138 CT of patients with RT-PCR confirmed COVID-19 who had undergone chest CT at the Kenyatta National Hospital (KNH) either 5 days before the positive RT-PCR test or up to 5 days after the positive RT-PCR test was used for the study. The sample size was calculated using Fisher's formula(22) ;

$$n = \frac{Z^2 x\ P(1-P)}{d^2}$$

Where,

n = Desired sample size

Z = value from standard normal distribution corresponding to desired confidence level (Z=1.96 for 95% CI)

P = expected true proportion (estimated at 90%, according to a systematic review and meta-analysis study done by Hugo J. A. Adams et al the Pooled prevalence of posterior predilection was 90% (23).

d = desired precision (0.05)

$$n_0 = \frac{1.96^2 x\ 0.9(1-0.90)}{0.05^2} = 138$$

3.8 Recruitment and Consenting Procedures

Patients who met the criteria were recruited from the KNH records and KNH CT records departments. A random sampling method was employed. The CT numbers of patients who met the criteria were listed on a Microsoft Excel spreadsheet, and then using a Microsoft Excel random number generator, the first 138 random numbers were picked. Demographic data were obtained from the patients' files. An informed consent waiver of the retrospective study was requested from the KNH/UON–ERC.

.

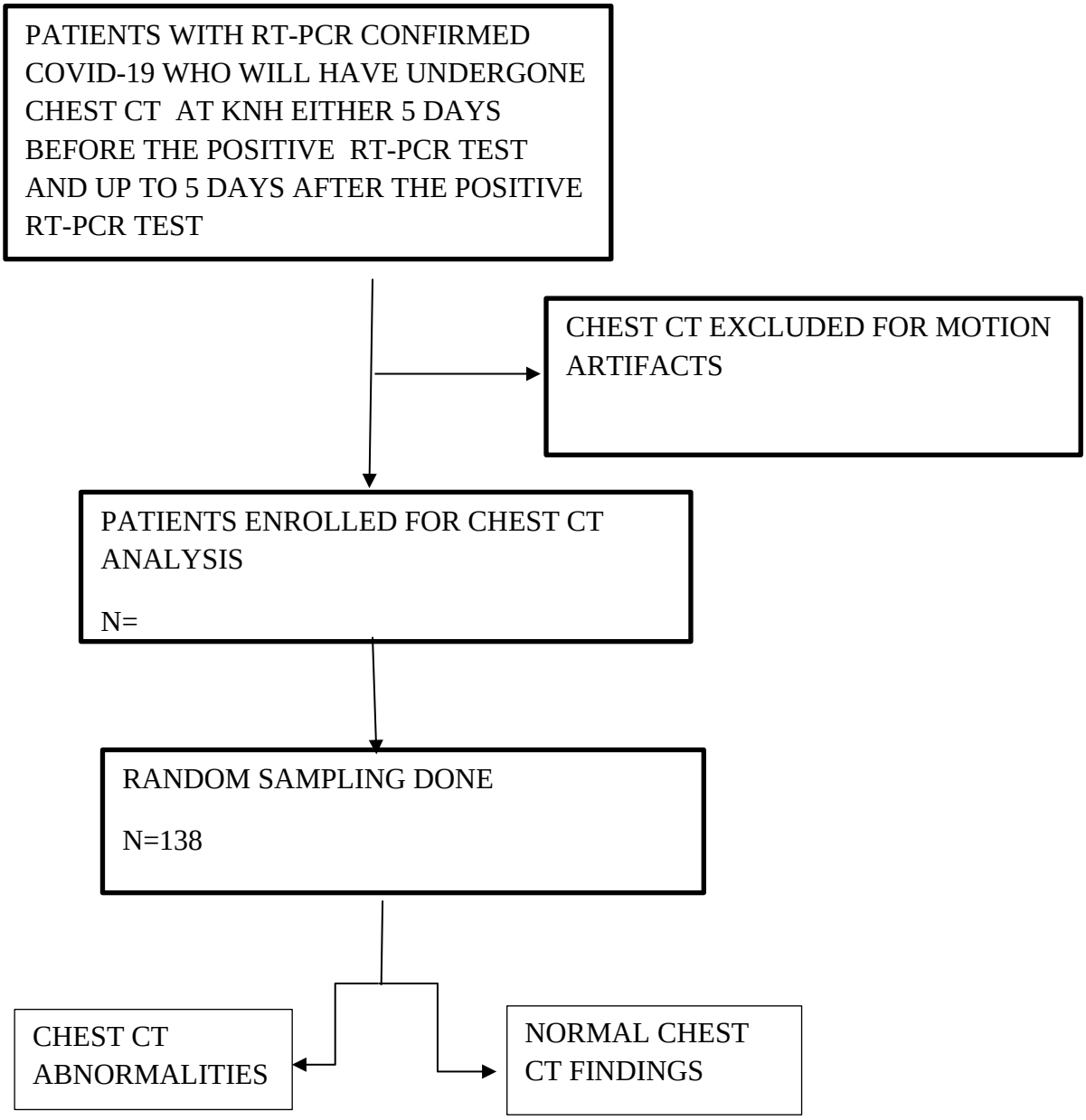

PATIENTS WITH RT-PCR CONFIRMED COVID-19 WHO WILL HAVE UNDERGONE CHEST CT AT KNH EITHER 5 DAYS BEFORE THE POSITIVE RT-PCR TEST AND UP TO 5 DAYS AFTER THE POSITIVE RT-PCR TEST
CHEST CT EXCLUDED FOR MOTION ARTIFACTS
PATIENTS ENROLLED FOR CHEST CT ANALYSIS
N=
RANDOM SAMPLING DONE
N=138
CHEST CT ABNORMALITIES
NORMAL CHEST CT FINDINGS

Figure 2: Flow chart of the patient recruitment process

3.9 Variables

Demographics: age, gender

Clinical Symptoms: dyspnoea, fever, cough,general body malaise

Patterns Of Chest Ct Findings

- Normal Findings
- Abnormal chest CT Findings

Pulmonary findings

Distribution of lesions

- Lung laterality
- Extent:

Lesion location

- ✓ peripheral
- ✓ Peripheral and central
- ✓ Central

Axial Distribution: Predominant Anterior-posterior distribution

- ✓ No axial distribution
- ✓ Anterior
- ✓ Posterior

Incidental Chest CT Findings

CO-RADS classification

3.10 Data Collection Procedures

A structured data collection tool was used to collect the data. Demographic information was obtained from the patients' files. RT-PCR positive results were confirmed from the patients' files, which were accessed from the KNH records department. The chest CT images were obtained from the PACS system for chest CT done using the Neusoft 64 multislice chest CT scanner or from the CT console for chest CT done using the Siemens Somatom Definition AS 128 slice. The CT chest findings were reviewed independently by the primary investigator and were verified by the consultant radiologists.

3.11 Quality Assurance Procedures

The KNH, Department of Diagnostic Radiology, had 2 types of chest CT scanners: Siemens Somatom Definition AS 128-slice CT and Neusoft 64-multislice computed tomography (CT). All studies were done using either of the two CT scanners. Studies were devoid of artifacts secondary to motion.

3.12 Ethical Consideration

The study will be conducted after approval by the Kenyatta National Hospital/University of Nairobi Ethics and Research Committee (KNH/UON – ERC). An informed consent waiver will be requested before taking part in the study. The reasons for the waiver request are as follows: Firstly, the research involves no more than minimal risk to the participants because it involves materials (data, documents, records) that have been collected, and precautions will be taken to ensure that confidentiality is maintained. Secondly, the waiver will not adversely affect the rights and welfare of the participants because procedures are in place to protect confidentiality. Confidentiality will be upheld throughout the study period while handling the patient's information by ensuring serialization of the patient's CT number. Thirdly, information learned during the study will not affect the treatment of participants. Fourthly, the research will be impracticable to do without a waiver.

3.13 Data Management

The collected data was entered and analyzed in SPSS version 25.0. The CT chest patterns and distribution of chest CT findings of COVID-19 and the CORADS score were analyzed and

presented as frequencies and percentages. Patients' demographics was presented as mean, range, and percentages.

Table 3: Patients Demographic characteristics

		Frequency	Percent	Median (IQR)
Age, *(n=138)*				
26 – 35				
36 – 45				
46 – 55				
56 – 65				
65 - 75				
>75				
Gender, *(n=138)*	Male			
	Female			

Table 4: Clinical symptoms

	Frequency	Percent of patients
Difficulty in breathing		
Cough		
General body malaise		
Fever		

Table 3: Chest findings

	Frequency	Percent
Normal		
Abnormal		

Table 5: Pulmonary findings-

	Frequency	Percent of patients,
Mixed ground glass opacification and consolidation		
Ground glass opacification		
Interlobular septal thickening		
Vascular thickening		
Fibrosis		
Pleural thickening		
Crazy paving		
Pulmonary nodule		
Air filled lung lesions		

Pleural effusion
Consolidation
Tree in bud

Table 6: Lung laterality

	Frequency,	Percent
Bilateral		
Unilateral		

Table 7: Lung lobe

	1-25%	26-49%	50-75%	>75%	Total
Left upper					
Right upper					
Right middle					
Right lower					
Left lower					

Table 8: Lung lesion extent

	Frequency	Percent
Multifocal		
Diffuse		
Single/focal		

Table 9: Lung lesion location

	Frequency	Percent
Peripheral		
Peripheral and Central		
Central		

Table 10: Axial distribution

	Frequency	Percent
No axial predominant distribution		
Anterior		
Posterior		

Table 12: Incidental Chest CT Findings

	Frequency	Percent
Incidental findings(specify)		

Table 13: CO-RADS classification

	Frequency	Percent
CO-RADS 1		
CO-RADS 2		
CO-RADS 3		
CO-RADS 4		
CO-RADS 5		

3. RESULTS

Patient's Demographics

A total of 138 RT-PCR positive COVID-19 patients were included in this study. Out of the 138 patients, 84 were males (60.9%) and 54 were females (39.1%), giving a male to female ratio of 1.6:1. The proportion of males who were 84 (60.9%) was statistically significantly more than females 54 (39.1%), p = 0.011. The median age was 50 years (IQR, 41 to 60 years) and the minimum observed age was 26.0 years, while the maximum was 87.0 years old. The patients' demographics are listed in Table 1.

Table 1: Demographic characteristics

		Frequency	Percent	Median (IQR)
Age, *(n=138)*				50.0 (41.0-60.0)
26 – 35		16	11.6	
36 – 45		39	28.3	
46 – 55		33	23.9	
56 – 65		25	18.1	
65 - 75		13	9.4	
>75		12	8.7	
Gender, *(n=138)*	Male	84	60.9	
	Female	54	39.1	

Of the 138 participants, difficulty in breathing was observed in 84 (60.9%), cough in 72 (52.2%), general body malaise, and fever in 14 (10,1%) and 11 (8%), respectively. This is illustrated in Table 2.

Table 2: Clinical symptoms

	Frequency	Percent of patients, *(n=138)*
Difficulty in breathing	84	60.9%
Cough	72	52.2%
General body malaise	14	10.1%
Fever	11	8.0%

Patterns Of Chest CT Findings

Out of the 138 study participants, 128 (92.8%) had positive chest CT imaging findings, while 10 (7.2%) did not show any lung abnormalities despite a positive RT-PCR test. The chest findings

are listed in Table 3.

Table 3: Chest findings

	Frequency	Percent
Normal	10	7.2
Abnormal	128	92.8

Of the 128/138 (92.8%) positive CT studies, mixed ground-glass opacification with consolidation (50%; 64/128) was the most common pattern of chest CT findings, followed by pure GGOs pattern (44.2%; 54/128), interlobular septal thickening (36.7%; 47/128) and vascular thickening (30.5%; 39/128) (Fig 2). Of note, the incidence of interlobular septal thickening as described herein excludes crazy paving (which also has an element of interlobular septal thickening). Other findings included fibrosis (19.5%; 25/128), pleural thickening (12.5%; 16/128), and crazy paving (10.2%; 13/128). Traction bronchiectasis (92% 23/25) was the most common pattern of fibrosis, followed by the reticular pattern (28% 7/25) and honeycombing (20% 5/25). Pulmonary nodules (5.5% 7/128), air-filled lesions (5.5% 7/128), pleural effusion (5.5% 7/128), consolidation (3.9% 5/128), and tree in bud (1.6% 2/128) were among the less common findings. Air-filled lesions included lung cavities (57.1%, 4/7), and lung cysts (42.9%, 3/7). The pulmonary findings are listed in Tables 4,5 and 6.

Table 4: Pulmonary findings

	Frequency	Percent of patients, *(n=128)*
Mixed ground-glass opacification and consolidation	64	50.0%
Ground glass opacification	54	42.2%
Interlobular septal thickening	47	36.7%
Vascular thickening	39	30.5%
Fibrosis	25	19.5%
Pleural thickening	16	12.5%
Crazy paving	13	10.2%
Pulmonary nodule	7	5.5%
Air-filled lung lesions	7	5.5%
Pleural effusion	7	5.5%
Consolidation	5	3.9%
Tree in bud	2	1.6%

Table 5: Fibrosis

	Frequency	Percent of patients, *(n=25)*
Traction bronchiectasis	23	92.0%
Reticular pattern	7	28.0%
Honeycombing	5	20.0%

Table 6: Air-filled lesions

	Frequency *(n=7)*	**Percent**
Cavity	4	57.1
Lung cysts	3	42.9

Lesions distribution

Laterality

Bilateral involvement was seen in 124 out of 128 cases (96.9%), while unilateral involvement was seen in 4 out of 128 cases (3.1%). This is shown in Table 6.

Table 7: Lung laterality

	Frequency, *(n=128)*	**Percent**
Bilateral	124	96.9
Unilateral	4	3.1

Lobes distribution

There was no lobar predilection. The left and right lower lobe involvement were present in 125/128 (20.7%) and 125/128 (20.7%), followed by involvement of the left upper lobe in 120/128 (19.9%), the right upper lobe in 118/128 (19.6%), and the right middle lobe in 115/128 (19.1%). The total upper and lower lobes that were affected were 488, of which the proportion of lower lobes was 250 (51.2%) and the upper lobes were 238 (48.8%), of which there was no statistical difference in their proportions, $p = 0.587$. This is illustrated in table 8.

Table 8: Lung lobe involvement

	Frequency (n=603)	**Percent**
Left upper	120	19.9
Right upper	118	19.6
Right middle	115	19.1
Right lower	125	20.7
Left lower	125	20.7

There was a statistical difference in the degree of involvement of 1-25% of the upper lobes (84+82)/2 = 83) versus 1-25% degree of involvement of the lower lobe (28+25)/2 = 26.5), p<0.001. There was a statistical difference in the degree of involvement of 26-49% of the upper lobes (19+18)/2 =18.5) versus 26-49% degree of involvement of lower lobe (58+61)/2 =59.5), p<0.001. There was a statistical difference in the degree of involvement of 50-75% of the upper lobes (15+15)/2 =15) versus 50-75% degree of involvement of the lower lobe (28+29)/2 =28.5), p=0.043. There was no statistical difference in the degree of involvement of >75% of the upper lobes (2+3)/2 =2.5) versus >75% degree of involvement of lower lobe (11+10)/2 =10.5), p=0.057. The upper lobes demonstrated a lesser degree of involvement (1-25%) relative to the lower lobes which showed a more severe degree of involvement at (26-49%) and (50-75%). This is illustrated in table 9 and figure 2.

Table 9: Lung lobe-

Location of involvement	**Degree of involvement**				
	1-25%	**26-49%**	**50-75%**	**>75%**	**Total**
Left upper	84	19	15	2	120
Right upper	82	18	15	3	118
Right middle	67	30	10	8	115
Right lower	28	58	28	11	125
Left lower	25	61	29	10	125
Total	286	186	97	34	603

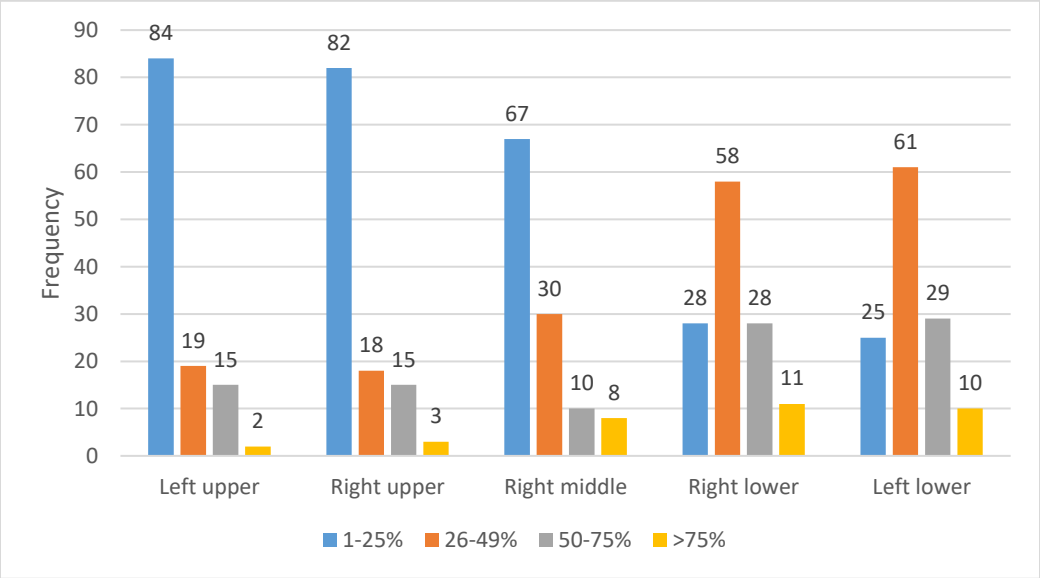


FIGURE 2: Lung lobe distribution of findings

Lung lesion extent

Most of the lesions were multifocal in 90/128 (70.3%), followed by diffuse 36/128 (28.1%) and single/focal 2/128 (1.6%). The total lung lesion extent for multifocal and diffuse observed was 126, of which the proportion of multifocal was 90 (71.4%) and diffuse was 36 (28.6%), of which there was a statistical difference in their proportions, $p < 0.001$. The lung lesion extent is listed in Table 10.

Table 10: Lung lesion extent

	Frequency, *(n=128)*	**Percent**
Multifocal	90	70.3
Diffuse	36	28.1
Single/focal	2	1.6

Lung lesion location

The lesions showed peripheral distribution in 84/128 (65.6%), both peripheral and central in 31.3/128 (31.3%), and central in 4/128 (3.1%). The total for lung lesion location for peripheral only and for peripheral and central was 124, of which the proportion of peripheral only was 84 (67.7%) and peripheral and central was 40 (32.2%), of which there was a statistical difference in their proportions, $p < 0.001$. The lung lesion location is listed in table 11.

Table 11: Lung lesion location

	Frequency, *(n=128)*	**Percent**
Peripheral	84	65.6
Peripheral and Central	40	31.3
Central	4	3.1

Axial distribution

The lesions showed posterior predominance in 93/128 (72.7%), no axial predominance in 32/128 (25%), and anterior predominance in 3/128 (2.3%). The total for axial distribution for no axial predominant distribution and posterior distribution was 125, of which the proportion of no axial predominant distribution was 32 (25.6%) and the posterior was 93 (74.4%), of which there was a statistical difference in their proportions, $p < 0.001$. The axial distribution is listed in table 12.

Table 12: Axial distribution

	Frequency, *(n=128)*	**Percent**

No axial predominant distribution	32	25.0
Anterior	3	2.3
Posterior	93	72.7

INCIDENTAL CHEST CT FINDINGS

Out of the 128 patients with positive chest CT findings, 30 had incidental findings. The most common incidental findings were enlarged main pulmonary artery diameter 13/30 (43.3%), mediastinal lymphadenopathy (6/30 (20.0%), pulmonary thromboembolism (4/30 (13.3%), and cardiomegaly 430 (13.3%). The incidental findings are listed in Table 13.

Table 13: Major incidental findings

	Frequency	**Percent of patients,** *(n=30)*
Enlarged Main pulmonary artery diameter	13	43.3%
Mediastinal lymphadenopathy	6	20.0%
Pulmonary thromboembolism	4	13.3%
Cardiomegaly	4	13.3%
Retrosternal goitre	2	6.7%
Osteolytic lesion	2	6.7%
Rib and sternal fracture	1	3.3%
Chondromatosis	1	3.3%
Cystic bronchiectasis	1	3.3%
Hydronephrosis	1	3.3%
Hepatomegaly	1	3.3%
Empyema thoracis	1	3.3%
Pneumothorax	1	3.3%
Emphysema	1	3.3%
Esophageal malignancy	1	3.3%
Supraclavicular mass	1	3.3%
GEJ stricture	1	3.3%
Calcified fibroadenoma	1	3.3%
Axillary adenopathy	1	3.3%
Splenic calcification	1	3.3%
Renal cysts	1	3.3%

SPECTRUM OF CO-RADS SCORE

The most common CO-RADS category was category 5; 105/138 (76.1%), followed by category 4; 13/138 (9.4%), category 1; 10/138 (7.2%), and category 3 & 2 each having 5/138 (3.6%). Table 13 lists the CO-RADS classification.

Table 14: CO-RADS classification

	Frequency, *(n=138)*	**Percent**

CO-RADS 1	10	7.2
CO-RADS 2	5	3.6
CO-RADS 3	5	3.6
CO-RADS 4	13	9.4
CO-RADS 5	105	76.1

Reference Cases

Case 1:

A 56-year-old man with COVID-19 presented with a history of cough.

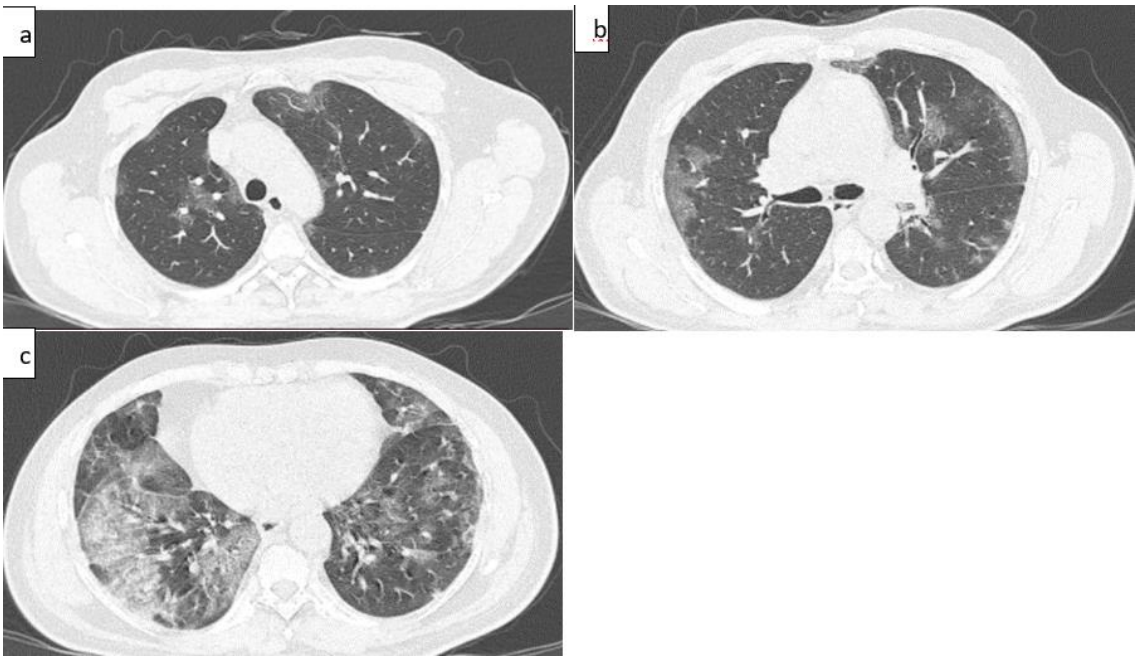


Figure 3

Axial nonenhanced CT images (a, b, c) showing bilateral, subpleural, multifocal GGOS predominantly in the lower lobes.

Case 2:

A 45-year-old male with COVID-19 presented with a cough and difficulty in breathing

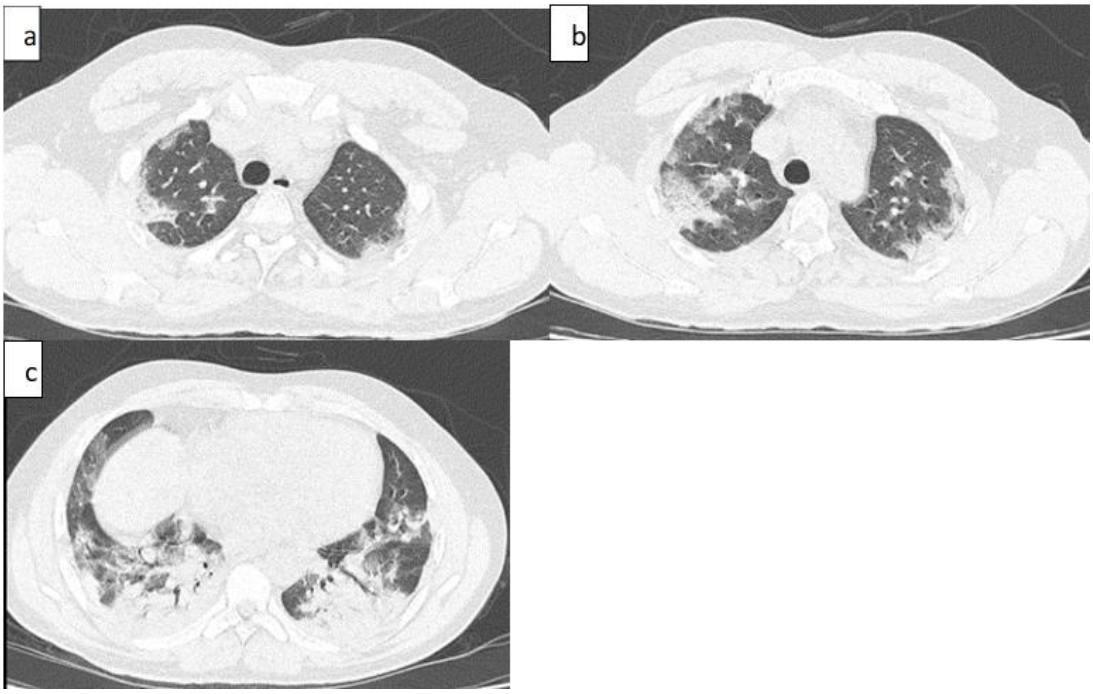


Figure 4

Axial nonenhanced chest CT(a,b,c) showing bilateral, multifocal, subpleural areas of ground-glass opacities with consolidation predominantly in the lower lobes.

Case 3:

A 48-year-old male who presented with general body malaise

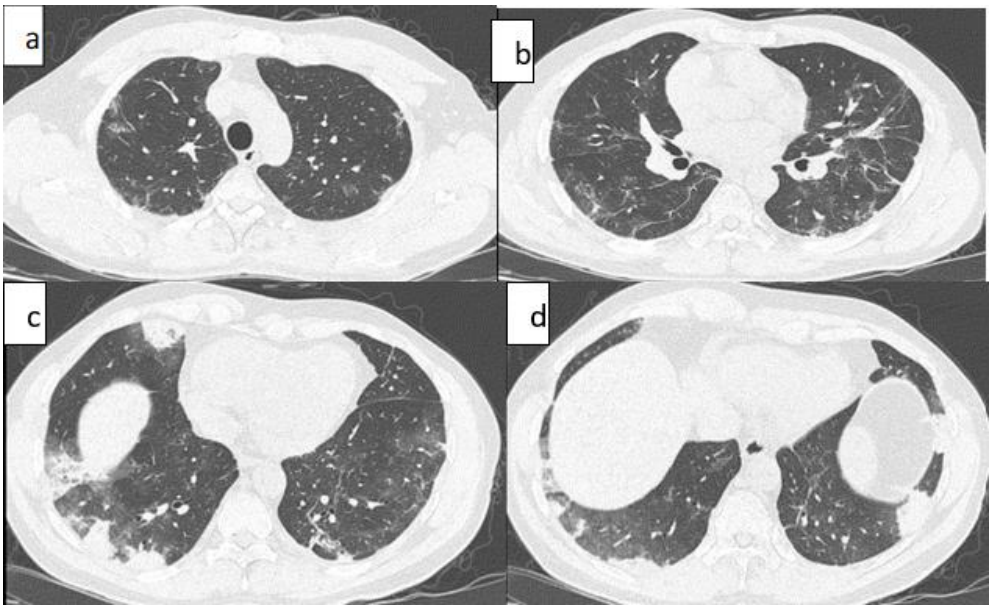


Figure 5

: Axial non-enhanced CT images(a,b,c) showing bilateral, subpleural, multifocal ground-glass opacities with areas of consolidation noted posteriorly in both lower lobes. There are areas of interlocular septal thickening noted bilaterally.

Case 4:

A 68-year-old female with a history of cough and difficulty in breathing

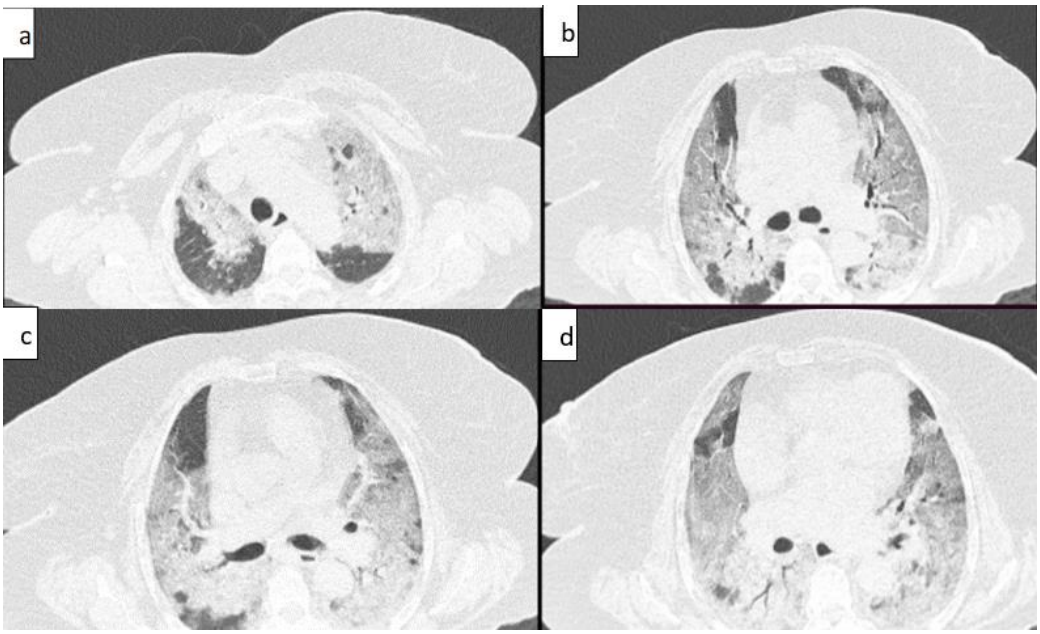


Figure 6

: Axial chest CT images showing bilateral, diffuse mixed ground-glass opacification and consolidation. There are areas of vascular thickening and traction bronchiectasis noted bilaterally

Case 5:

60-year-old female who presented with a history of difficulty in breathing

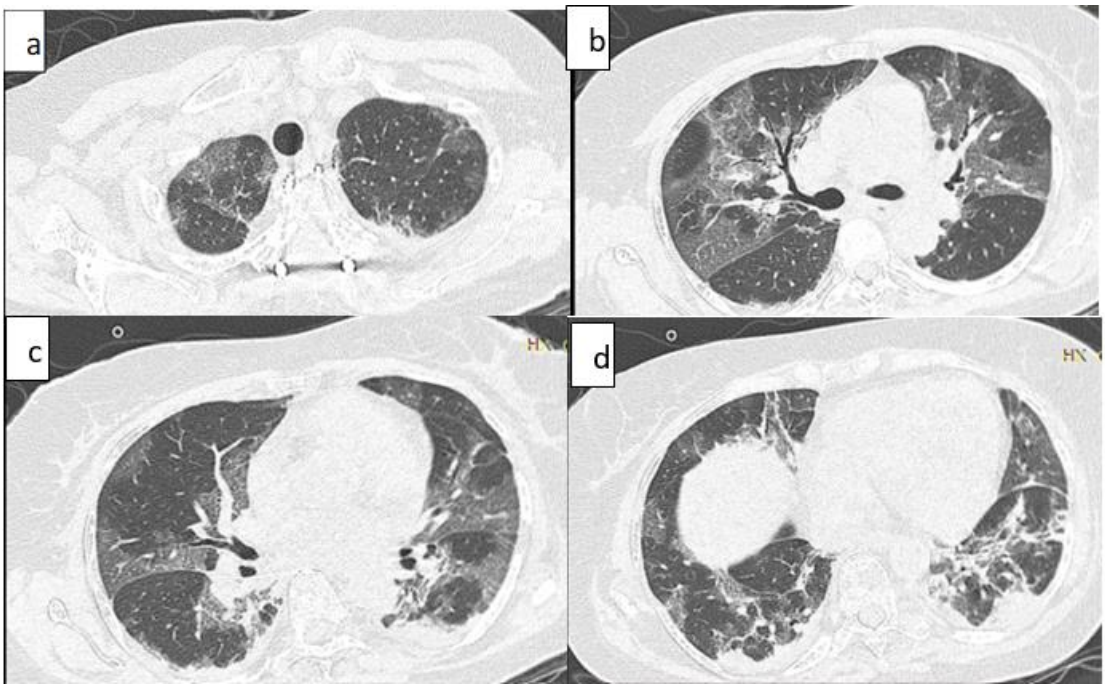


Figure 7

: Non-enhanced CT chest (a,b,c,d) showing bilateral, multifocal, peripheral, ground-glass opacities with areas of consolidation in the lower lobes. There is traction bronchiectasis, vascular dilatation and interlobular septal thickening noted.

Case 6 :

A 54-year-old male who presented with cough and fever

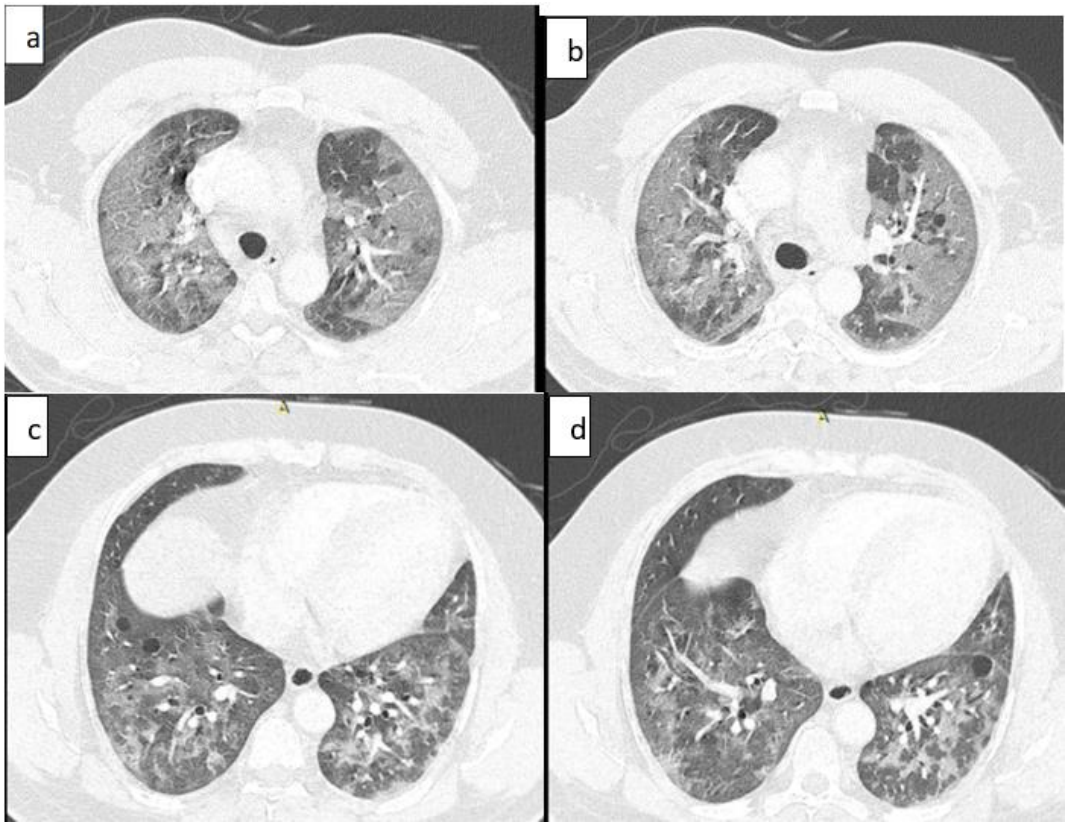


Figure 8

: Axial non-enhanced CT(a,b,c,d) showing diffuse bilateral ground-glass opacification mainly in the upper lobes with bilateral lung cysts

DISCUSSION

In this study, we investigated the chest CT findings of 138 RT-PCR confirmed COVID-19 cases.

The majority of patients were men, males made up 60.9% of all patients, while females made up 39.1%. The median age was 50 years. This was similar to the characteristic findings of COVID-19 patients seen in a study in Wuhan, China, where the median age was 56 years and the proportion of male patients was 62% (24). According to a study by George M. Bwire, the biological differences in the immune systems between men and women may impact their ability to fight infections like SARS-2-CoV-2. Generally, females are more resistant to infections than men, and this is possibly due to several factors including sex hormones, high expression of coronavirus receptors (ACE 2) in men, and lifestyle whereby men have higher levels of smoking and drinking as compared to women. Additionally, women have a more responsible attitude toward the Covid-19 pandemic than men. This includes preventive measures such as frequent hand washing, wearing of face mask, and stay-at-home orders(25).

In our study,7.2 % of the study participants did not show any lung abnormalities despite a positive RT-PCR test, in a study done by Hugo J. A. Adams 10.6% of known COVID-19 patients with symptoms had normal findings on chest CT (44).

Although various CT findings were observed, we found several common characteristic CT patterns. The most common lesion was ground-glass opacities (GGOs), whether in isolation or mixed with consolidation. These observations are most consistent with a systematic review of chest CT findings in 4410 adult patients by Vinneta Ojha et al (26). In our study, mixed ground-glass opacities (GGOs) plus consolidation pattern (50.0%) were the major CT pattern, followed by ground-glass opacities in isolation (42.2%). In a systemic review by Vinneta Ojha et al., ground-glass opacities (GGOs) (50.2%) were the most common major pattern, followed by GGOs with a consolidation pattern (44.4%). The other common lesions in our study included interlobular septal thickening (36.7%) and vascular thickening (30.5%). According to a review of chest CT manifestations of COVID-19 infection done by Maria El Homsi et al (18) interlobular septal thickening accounted for 50.9%, while another systemic review of 4410 patients accounted for 15.5% (26). The prevalence of vascular thickening was similar to a study done in Ghana, West Africa, where vascular thickening accounted for 33.3% (27). The less common lesions included fibrosis mainly traction bronchiectasis (19.5%), pleural thickening (12.5%), and crazy paving (10.2%). According to a study done in Ghana crazy paving accounted for 14.3%(27).

The rare lesions included pulmonary nodules, air-filled lesions, and pleural effusion. This is similar to a review of chest CT manifestations of COVID-19 infection done by Maria El Homsi et al (18) where pleural effusions or thickening, discrete pulmonary nodules, and pulmonary cavitation were rare findings.

In our study, consolidation in isolation was a rare finding, accounting for 3.9%, which is contrary to previous studies such as a review done by Maria El Homsi et al where consolidation accounted for 41.2% (18), a study done in Ghana accounted for 42.9% (27) and a systematic review of chest CT findings in 4410 adult patients by Vinneta Ojha et al (26) accounted for 24.2%.

Bilateral (96.9%), multifocal (70.3%), peripheral (65.6%), and posterior distribution of the opacities (72.7%) were the characteristic features of the distribution of lesions due to COVID-19 in our study. This is consistent with previous studies (28–31). A systematic review of chest CT findings by Vinneta Ojha et al. revealed that bilateral distribution accounted for 84%, peripheral distribution accounted for 68.8%, and the main location of the opacities was posterior (77.7%). In our study, there was no lobar predilection. This is contrary to previous studies where lower lobes were more frequently involved (21,32). According to our study, the upper lobes demonstrated a lesser degree of involvement (1-25%) relative to the lower lobes which showed a more severe degree of involvement at (26-49%) and (50-75%). A study done by Feng Pal et al. showed that the lower lobes were more inclined to be involved with higher CT scores. The CT

scores of bilateral lower lobes, in particular, differed significantly from those of the upper and middle lobes (33).

The most common major incidental findings in our study were enlarged main pulmonary artery diameter 13/30 (43.3%), mediastinal lymphadenopathy 6/30 (20%), pulmonary thromboembolism (4/30 (13.3%), and cardiomegaly (4/30 (13.3%). There is emerging evidence of widespread vascular pathology and thromboembolic events associated with COVID-19 (34). The five chest CT signs of COVID-19 induced pulmonary vascular angiopathy include enlargement of the pulmonary vasculature, pulmonary thromboembolism, pulmonary hypertension, pulmonary vascular "tree-in-bud pattern," and pulmonary infarction (35). According to Antonio Esposito et al.'s study on Chest CT–derived pulmonary artery enlargement, pulmonary small-vessel thrombosis may be the primary cause of pulmonary hypertension in COVID-19 pneumonia. Mild, moderate, and severe MPAD enlargement were found in 58 (9.2%), 101 (15.9%), and 33 (5.2%) patients, respectively. The study found that an increase in the diameter of the main pulmonary artery ($\geq$ 31 mm) was an independent predictor of death in COVID-19 patients (36)

Finally, in our study, the most common CO-RADS category was category 5 (76.1%), followed by category 4 (9.4%). According to a study done by Arthur W. E. Lieveld et al, they found that CO-RADS discriminates excellently between a positive and negative PCR result, with an AUC of 0.91 (CI, 0.89-0.94). A CO-RADS score of more or equal to 4 has a high positive likelihood ratio and a corresponding good positive predictive value in a high-prevalence setting. A score of more or equal to 4 can therefore be used to put a patient in isolation or self-quarantine (37).

6. Study Limitation

This was a hospital single-center study and thus needs further confirmation by multicenter studies. There was a possible selection bias since the most likely imaged patients were the ones with the worst clinical conditions. Only patients with confirmed COVID-19 were included; negative RT-PCR results and infections with other viruses were not included in the study. Finally, the study did not include comorbidities that can cause interstitial lung disease.

7. CONCLUSION

COVID-19 tends to have typical imaging patterns on chest CT. The most common CT chest findings were bilateral, multifocal, posterior ground-glass opacities with or without consolidations. There was no lobar predilection. Recognition of this pattern of chest involvement is highly suggestive of COVID-19 infection and thus will have an impact on clinical decision-making and

patient management. Overall, CT imaging is valuable in assessing complications and for follow-up.

8. RECOMMENDATION

The appearance of COVID-19 on chest CT images follows a typical imaging pattern. This will impact clinical decision-making and result in early isolation, and management, thus reducing spread, morbidity, and mortality. We recommend chest CT for assessing complications and for follow-up of COVID-19 patients.

Recommendation for further studies on COVID-19-induced vascular angiopathy and temporal CT lung changes in patients recovering from Coronavirus Disease 2019 (COVID-19).

REFERENCES

1. Zhu N, Zhang D, Wang W, Li X, Yang B, Song J, et al. A Novel Coronavirus from Patients with Pneumonia in China, 2019. N Engl J Med. 2020;382(8):727–33.
2. Lu R, Zhao X, Li J, Niu P, Yang B, Wu H, et al. Genomic characterisation and epidemiology of 2019 novel coronavirus: implications for virus origins and receptor binding. Lancet. 2020;395(10224):565–74.
3. Lu H, Stratton CW, Tang YW. Outbreak of pneumonia of unknown etiology in Wuhan, China: The mystery and the miracle. J Med Virol. 2020;92(4):401–2.
4. Sheng WH. Coronavirus disease 2019 (covid-19). J Intern Med Taiwan. 2020;31(2):61–6.
5. Rothan HA, Byrareddy SN. The epidemiology and pathogenesis of coronavirus disease (COVID-19) outbreak. J Autoimmun [Internet]. 2020;109(February):102433. Available from: https://doi.org/10.1016/j.jaut.2020.102433
6. Who R, Committee I, East M. Diagnostic testing for SARS-CoV-2. 2020;(September):1–20.
7. Mcfee RB. Disease-a-Month COVID - 19 Laboratory Testing / CDC Guidelines. Disease-a-Month [Internet]. 2020;(xxxx):101067. Available from: https://doi.org/10.1016/j.disamonth.2020.101067
8. Korteweg C, Vermaat M, Borm FJ. Pr es s Pr es.
9. Organi- WH, January F, Control D, Control D, Seafood H, Market W. C or r e sp ondence SARS-CoV-2 Viral Load in Upper Respiratory Specimens of Infected Patients. 2020;1–3.
10. Detection of SARS-CoV-2 in Different Types of Clinical Specimens. 2020;3–4.
11. Li Y, Yao L, Li J, Chen L, Song Y, Cai Z, et al. Stability issues of RT - PCR testing of SARS - CoV - 2 for hospitalized patients clinically diagnosed with COVID - 19. 2020;(March):903–8.
12. Gp JW, Penny F. Interpreting a covid-19 test result. 2020;1808(May):1–7. Available from: http://dx.doi.org/doi:10.1136/bmj.m1808
13. Ai T, Lv W. Correlation of Chest CT and RT-PCR Testing for Coronavirus Disease 2019 (COVID-19) in China : A Report of 1014 Cases. 2020;2019.
14. Mahesh M. Search for isotropic resolution in CT from conventional through multiple-row detector. Radiographics [Internet]. 2002;22(4):949–62. Available from: http://www.ncbi.nlm.nih.gov/pubmed/12110725

15. Computed tomography | Radiology Reference Article | Radiopaedia.org [Internet]. [cited 2020 Dec 7]. Available from: https://radiopaedia.org/articles/computed-tomography
16. Computed tomography of the chest | Radiology Reference Article | Radiopaedia.org [Internet]. [cited 2021 Jan 10]. Available from: https://radiopaedia.org/articles/computed-tomography-of-the-chest
17. Whiting P, Singatullina N, Rosser JH. Computed tomography of the chest: I. Basic principles. BJA Educ. 2015;15(6):299–304.
18. El M, Chung M, Bernheim A, Jacobi A, King MJ, Lewis S, et al. Review of chest CT manifestations of COVID-19 infection. Eur J Radiol Open [Internet]. 2020;7(June):100239. Available from: https://doi.org/10.1016/j.ejro.2020.100239
19. Ufuk F, Demirci M, Sagtas E, Hakkı I, Ugurlu E. The prognostic value of pneumonia severity score and pectoralis muscle Area on chest CT in adult COVID-19 patients. Eur J Radiol [Internet]. 2020;131(July):109271. Available from: https://doi.org/10.1016/j.ejrad.2020.109271
20. Pr es s Pr.
21. Kwee TC, Kwee RM. Chest CT in COVID-19 : What the Radiologist Needs to Know. 2020;(January):1848–65.
22. Perlman S, Perlman S. IMMUNOLOGY AT THE UNIVERSITY OF IOWA T cell-mediated immune response to respiratory coronaviruses. 2014;
23. Chen Y, Guo Y, Pan Y, Joe Z. Biochemical and Biophysical Research Communications Structure analysis of the receptor binding of 2019-nCoV. Biochem Biophys Res Commun [Internet]. 2020;2(xxxx):0–5. Available from: https://doi.org/10.1016/j.bbrc.2020.02.071
24. Verdecchia P, Cavallini C, Spanevello A, Angeli F. European Journal of Internal Medicine The pivotal link between ACE2 de fi ciency and SARS-CoV-2 infection. Eur J Intern Med [Internet]. 2020;76(April):14–20. Available from: https://doi.org/10.1016/j.ejim.2020.04.037
25. Varghese GM, John R, Manesh A, Karthik R, Abraham OC. Clinical management of COVID-19. 2020;(May):401–10.
26. Lauer SA, Grantz KH, Bi Q, Jones FK, Zheng Q, Meredith HR, et al. O RIGINAL R ESEARCH The Incubation Period of Coronavirus Disease 2019 (COVID-19) From Publicly Reported Confirmed Cases : Estimation and Application. 2020;2019.

27. Zhu J, Ji P, Pang J, Zhong Z, Li H, He C. Clinical characteristics of 3062 COVID - 19 patients : A meta - analysis. 2020;(April):1902–14.
28. Agyeman AA, Chin KL, Hons B, Landersdorfer CB, Liew D, Hons M. Smell and Taste Dysfunction in Patients With COVID-19: A Systematic Review and Meta-analysis. Mayo Clin Proc [Internet]. 2020; Available from: https://doi.org/10.1016/j.mayocp.2020.05.030
29. Disease C. Coronavirus Disease 2019 Interim Clinical Guidance for Management of Patients with Con fi rmed Coronavirus Disease (COVID-19). 2020;2019.
30. Jennifer M. Characteristics of and Important Lessons From the Coronavirus Disease 2019 (COVID-19) Outbreak in China Summary of a Report of 72 314 Cases From the Chinese Center for Disease Control and Prevention. 2020;2019.
31. Definitions C. WHO COVID-19 : Case Definitions. 2020;(December):2020.
32. He X, Lau EHY, Wu P, Deng X, Wang J, Hao X, et al. Temporal dynamics in viral shedding and transmissibility of COVID-19. Nat Med. 2020;26(5):672–5.
33. Qi L, Yang Y, Jiang D, Tu C, Wan L, Chen X, et al. Factors associated with the duration of viral shedding in adults with COVID-19 outside of Wuhan, China: a retrospective cohort study. Int J Infect Dis [Internet]. 2020;96:531–7. Available from: https://doi.org/10.1016/j.ijid.2020.05.045
34. Sethuraman N, Jeremiah SS, Ryo A. Interpreting Diagnostic Tests for SARS-CoV-2. JAMA - J Am Med Assoc. 2020;323(22):2249–51.
35. Ching L, Chang SP, Nerurkar VR. COVID-19 Special Column: Principles Behind the Technology for Detecting SARS-CoV-2, the Cause of COVID-19. Hawai'i J Heal Soc Welf. 2020;79(5):136–42.
36. Janower ML. A brief history of the Fleischner Society. Vol. 25, Journal of Thoracic Imaging. 2010. p. 27–8.
37. Fleischner Society | Radiology Reference Article | Radiopaedia.org [Internet]. [cited 2021 Apr 25]. Available from: https://radiopaedia.org/articles/fleischner-society?lang=us
38. Rubin GD, Ryerson CJ, Haramati LB, Sverzellati N, Kanne JP, Raoof S, et al. The Role of Chest Imaging in Patient Management During the COVID-19 Pandemic: A Multinational Consensus Statement From the Fleischner Society. Chest. 2020;158(1):106–16.
39. Jackson K, Butler R, Aujayeb A. Lung ultrasound in the COVID-19 pandemic. 2021;34–9.

40. WHO Guidance Note. Use of chest imaging in COVID-19: a rapid advice guia. World Heal Organ [Internet]. 2020;56. Available from: (WHO/2019-nCoV/Clinical/Radiology_ imaging/2020.1)
41. Dennie C, Hague C, Lim RS, Manos D, Memauri BF, Nguyen ET, et al. Canadian Society of Thoracic Radiology/Canadian Association of Radiologists Consensus Statement Regarding Chest Imaging in Suspected and Confirmed COVID-19. Can Assoc Radiol J. 2020;71(4):470–81.
42. Rodrigues JCL, Hare SS, Edey A, Devaraj A, Jacob J, Johnstone A, et al. An update on COVID-19 for the radiologist - A British society of Thoracic Imaging statement. Clin Radiol. 2020;75(5):323–5.
43. Kang Z, Li X, Zhou S. Recommendation of low-dose CT in the detection and management of COVID-2019. Eur Radiol. 2020;30(8):4356–7.
44. Adams HJA, Kwee TC, Yakar D, Hope MD, Kwee RM. Chest CT Imaging Signature of Coronavirus Disease 2019 Infection: In Pursuit of the Scientific Evidence. Chest [Internet]. 2020;158(5):1885–95. Available from: https://doi.org/10.1016/j.chest.2020.06.025
45. Ding X, Xu J, Zhou J, Long Q. Chest CT findings of COVID-19 pneumonia by duration of symptoms. Eur J Radiol [Internet]. 2020;127:109009. Available from: https://doi.org/10.1016/j.ejrad.2020.109009
46. Wang Y, Dong C, Hu Y, Li C, Ren Q, Zhang X, et al. Temporal Changes of CT Findings in 90 Patients with COVID-19 Pneumonia: A Longitudinal Study. Radiology. 2020;296(2):E55–64.
47. Hertel J, Amendola N, Carrie L, Michael G, Hopkins JT, Nussbaum E, et al. Pr es Pr es. 2013;48(4):528–45.
48. Xiang Y, Yu D, Qin X, Li X, Zhang Q. Clinical and CT manifestations of coronavirus disease 2019. J Xi'an Jiaotong Univ (Medical Sci. 2020;41(4):492–6.
49. Caruso D, Zerunian M, Polici M, Pucciarelli F, Polidori T, Rucci C, et al. Chest CT Features of COVID-19 in Rome, Italy. Radiology. 2020;296(2):E79–85.
50. Sabri YY, Fawzi MMT, Nossair EZ, El-Mandooh SM, Hegazy AA, Tadros SF. CT findings of 795 COVID-19 positive cases: a multicenter study in Egypt. Egypt J Radiol Nucl Med. 2020 Dec 1;51(1).

51. Carotti M, Salaffi F, Sarzi-Puttini P, Agostini A, Borgheresi A, Minorati D, et al. Chest CT features of coronavirus disease 2019 (COVID-19) pneumonia: key points for radiologists. Radiol Medica [Internet]. 2020;125(7):636–46. Available from: https://doi.org/10.1007/s11547-020-01237-4
52. Ojha V, Mani A, Pandey NN, Sharma S, Kumar S. CT in coronavirus disease 2019 (COVID-19): a systematic review of chest CT findings in 4410 adult patients. Eur Radiol. 2020;30(11):6129–38.
53. Simpson S, Kay FU, Abbara S, Bhalla S, Chung JH, Chung M, et al. Radiological Society of North America Expert Consensus Statement on Reporting Chest CT Findings Related to COVID-19. Endorsed by the Society of Thoracic Radiology, the American College of Radiology, and RSNA - Secondary Publication. J Thorac Imaging. 2020;35(4):219–27.
54. Song F, Shi N, Shan F, Zhang Z, Shen J, Lu H, et al. Emerging Coronavirus 2019-nCoV Pneumonia. Radiology. 2019;
55. Chan JFW, Yuan S, Kok KH, To KKW, Chu H, Yang J, et al. A familial cluster of pneumonia associated with the 2019 novel coronavirus indicating person-to-person transmission: a study of a family cluster. Lancet [Internet]. 2020;395(10223):514–23. Available from: http://dx.doi.org/10.1016/S0140-6736(20)30154-9
56. Guarnera A, Podda P, Santini E, Paolantonio P, Laghi A. Differential diagnoses of COVID-19 pneumonia: the current challenge for the radiologist—a pictorial essay. Insights Imaging [Internet]. 2021;12(1). Available from: https://doi.org/10.1186/s13244-021-00967-x
57. Bernheim A, Mei X, Huang M, Yang Y, Fayad ZA, Zhang N, et al. Chest CT findings of coronavirus disease 2019 (COVID-19). J Coll Physicians Surg Pakistan. 2020;295(3):685–91.
58. Pan F, Ye T, Sun P, Gui S, Liang B, Li L, et al. Time Course of Lung Changes On Chest CT During Recovery From 2019 Novel Coronavirus (COVID-19) Pneumonia. Radiology [Internet]. 2020;200370. Available from: http://www.ncbi.nlm.nih.gov/pubmed/32053470
59. Lei P, Fan B, Mao J, Wei J, Wang P. The progression of computed tomographic (CT) images in patients with coronavirus disease (COVID-19) pneumonia: Running title: The CT progression of COVID-19 pneumonia. J Infect [Internet]. 2020;80(6):e30–1. Available from: https://doi.org/10.1016/j.jinf.2020.03.020

60. Pan Y, Guan H, Zhou S, Wang Y, Li Q, Zhu T, et al. Initial CT findings and temporal changes in patients with the novel coronavirus pneumonia. 2020;30:3306(December 2019):4.
61. Guan CS, Lv Z Bin, Yan S, Du YN, Chen H, Wei LG, et al. Imaging Features of Coronavirus disease 2019 (COVID-19): Evaluation on Thin-Section CT. Acad Radiol [Internet]. 2020;27(5):609–13. Available from: https://doi.org/10.1016/j.acra.2020.03.002
62. Zhou S, Wang Y, Zhu T, Xia L. CT features of coronavirus disease 2019 (COVID-19) pneumonia in 62 patients in Wuhan, China. Am J Roentgenol. 2020;214(6):1287–94.
63. Wen Z, Chi Y, Zhang L, Liu H, Du K, Li Z, et al. Coronavirus Disease 2019: Initial Detection on Chest CT in a Retrospective Multicenter Study of 103 Chinese Patients. Radiol Cardiothorac Imaging. 2020;2(2):e200092.
64. Scientiae DC-S, Adams HJA, Kwee TC, Hope MD, Kwee RM, Hja A, et al. Systematic Review and Meta- in the Diagnosis of Coronavirus. 2020;(December).
65. Prokop M, Van Everdingen W, Van Rees Vellinga T, Van Ufford HQ, Stöger L, Beenen L, et al. CO-RADS: A Categorical CT Assessment Scheme for Patients Suspected of Having COVID-19-Definition and Evaluation. Radiology. 2020;296(2):E97–104.
66. The Radiology Assistant : COVID-19 CO-RADS classification [Internet]. [cited 2021 Jan 7]. Available from: https://radiologyassistant.nl/chest/covid-19/corads-classification
67. Paper A. Pr es s Pr es. Photogramm Eng Remote Sens. 2012;78(3).
68. The Radiology Assistant : COVID-19 Imaging findings [Internet]. [cited 2021 Jan 9]. Available from: https://radiologyassistant.nl/chest/covid-19/covid19-imaging-findings
69. Chang YC, Yu CJ, Chang SC, Galvin JR, Liu HM, Hsiao CH, et al. Pulmonary sequelae in convalescent patients after severe acute respiratory syndrome: Evaluation with thin-section CT. Radiology. 2005;236(3):1067–75.
70. Francone M, Iafrate F, Masci GM, Coco S, Cilia F, Manganaro L, et al. Chest CT score in COVID-19 patients: correlation with disease severity and short-term prognosis. Eur Radiol. 2020;30(12):6808–17.
71. Wu C, Chen X, Cai Y, Xia J, Zhou X, Xu S, et al. Risk Factors Associated with Acute Respiratory Distress Syndrome and Death in Patients with Coronavirus Disease 2019 Pneumonia in Wuhan, China. JAMA Intern Med. 2020;180(7):934–43.
72. Salehi S, Abedi A, Balakrishnan S, Gholamrezanezhad A. Coronavirus disease 2019

(COVID-19): A systematic review of imaging findings in 919 patients. Am J Roentgenol. 2020;215(1):87–93.

73. Hirano T, Murakami M. COVID-19: A New Virus, but a Familiar Receptor and Cytokine Release Syndrome. Immunity [Internet]. 2020;52(5):731–3. Available from: https://doi.org/10.1016/j.immuni.2020.04.003
74. Wood C, Kataria V, Modrykamien AM. The acute respiratory distress syndrome. Baylor Univ Med Cent Proc. 2020;33(3):357–65.
75. Li X, Ma X. Acute respiratory failure in COVID-19: Is it "typical" ARDS? Crit Care. 2020;24(1):1–5.
76. Tay MZ, Poh CM, Rénia L, MacAry PA, Ng LFP. The trinity of COVID-19: immunity, inflammation and intervention. Nat Rev Immunol [Internet]. 2020;20(6):363–74. Available from: http://dx.doi.org/10.1038/s41577-020-0311-8
77. Ranieri VM, Rubenfeld GD, Thompson BT, Ferguson ND, Caldwell E, Fan E, et al. Acute respiratory distress syndrome: The Berlin definition. JAMA - J Am Med Assoc. 2012;307(23):2526–33.
78. Helms J, Tacquard C, Severac F, Leonard-Lorant I, Ohana M, Delabranche X, et al. High risk of thrombosis in patients with severe SARS-CoV-2 infection: a multicenter prospective cohort study. Intensive Care Med [Internet]. 2020;46(6):1089–98. Available from: https://doi.org/10.1007/s00134-020-06062-x
79. Oudkerk M, Buller HR, Kuijpers D, van Es N, Oudkerk SF, McLoud T, et al. Diagnosis, prevention, and treatment of thromboembolic complications in COVID-19: Report of the national institute for public health of the Netherlands. Radiology. 2020;297(1):E216–22.
80. Grillet F, Behr J, Calame P, Aubry S, Delabrousse E. Acute Pulmonary Embolism Associated with COVID-19 Pneumonia Detected with Pulmonary CT Angiography. Radiology. 2020;296(3):E186–8.
81. Bompard F, Monnier H, Saab I, Tordjman M, Abdoul H, Fournier L, et al. Pulmonary embolism in patients with COVID-19 pneumonia. Eur Respir J. 2020;56(1):17–20.
82. Klok FA, Kruip MJHA, van der Meer NJM, Arbous MS, Gommers D, Kant KM, et al. Confirmation of the high cumulative incidence of thrombotic complications in critically ill ICU patients with COVID-19: An updated analysis. Thromb Res [Internet]. 2020;191(xxxx):148–50. Available from: https://doi.org/10.1016/j.thromres.2020.04.041

83. Menter T, Haslbauer JD, Nienhold R, Savic S, Hopfer H, Deigendesch N, et al. Postmortem examination of COVID-19 patients reveals diffuse alveolar damage with severe capillary congestion and variegated findings in lungs and other organs suggesting vascular dysfunction. Histopathology. 2020;77(2):198–209.
84. Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. Lancet. 2020;395(10223):497–506.
85. Huttner BD, Catho G, Pano-Pardo JR, Pulcini C, Schouten J. COVID-19: don't neglect antimicrobial stewardship principles! Clin Microbiol Infect [Internet]. 2020;26(7):808–10. Available from: https://doi.org/10.1016/j.cmi.2020.04.024
86. Guzik TJ, Mohiddin SA, Dimarco A, Patel V, Savvatis K, Marelli-Berg FM, et al. COVID-19 and the cardiovascular system: Implications for risk assessment, diagnosis, and treatment options. Cardiovasc Res. 2020;116(10):1666–87.
87. Li K, Wu J, Wu F, Guo D, Chen L, Fang Z, et al. The Clinical and Chest CT Features Associated with Severe and Critical COVID-19 Pneumonia. Invest Radiol. 2020;55(6):327–31.
88. Shi S, Qin M, Shen B, Cai Y, Liu T, Yang F, et al. Association of Cardiac Injury with Mortality in Hospitalized Patients with COVID-19 in Wuhan, China. JAMA Cardiol. 2020;5(7):802–10.
89. Daniel W. Determination of sample size for estimating proportions. In: Biostatistics: A Foundation for Analysis in Health. Stat Med. 1999;183.
90. Cheng Z, Lu Y. Clinical Features and Chest CT Manifestations of Coronavirus. 2020;2019(November):1–6.
91. Chen N, Zhou M, Dong X, Qu J, Gong F, Han Y, et al. Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan , China : a descriptive study. Lancet [Internet]. 2020;395(10223):507–13. Available from: http://dx.doi.org/10.1016/S0140-6736(20)30211-7
92. Sarkodie BD, Mensah YB, Ayetey H, Dzefi-tettey K, Brakohiapa E, Kaminta A. Chest Computed Tomography findings in patients with corona virus disease 2019 (COVID-19): An initial experience in three centres in Ghana , West Africa. J Med Imaging Radiat Sci [Internet]. 2020;51(4):604–9. Available from: https://doi.org/10.1016/j.jmir.2020.09.005
93. Chung M, Zeng X, Jacobi A. CT Imaging Features of 2019 Novel Coronavirus. 2020;

94. Haverich A, Welte T, Laenger F, Vanstapel A, Ph D, Werlein C, et al. Pulmonary Vascular Endothelialitis, Thrombosis, and Angiogenesis in Covid-19. 2020;
95. Hossameldin M, Samir A, Baess AI, Hendawi SS. COVID-19-induced vascular angiopathy : CTPA signs in critically ill patients other than acute pulmonary embolism and high- lung opacity scores. 2021;4.
96. Esposito A, Palmisano A, Toselli M, Vignale D, Cereda A, Maria P, et al. Chest CT – derived pulmonary artery enlargement at the admission predicts overall survival in COVID-19 patients : insight from 1461 consecutive patients in Italy. 2021;4031–41.
97. Lieveld AWE, Azijli K, Teunissen BP, van Haaften RM, Kootte RS, van den Berk IAH, et al. Chest CT in COVID-19 at the ED: Validation of the COVID-19 Reporting and Data System (CO-RADS) and CT Severity Score: A Prospective, Multicenter, Observational Study. Chest [Internet]. 2021;159(3):1126–35. Available from: https://doi.org/10.1016/j.chest.2020.11.026

TIME PLAN

	Dec 2020	Jan 2021	March 2021	April 2021	May-Aug	sept 2021	Oct 2021
Proposal write up	“						
Correction of supervisor’s input		“					
1st submission to KNH-ERC		“					
2ND submission to KNH-ERC& corrections			“				
Final submission				“			
Data Collection					“		
Data entry					“		
Data analysis						“	
Report writing							“
Dissertation submission							“

BUDGET

Item	Unit cost (Ksh)	Quantity	Total cost
Research assistant	-	-	50000
Statistician services	-	-	30000
Ethics review fee	-	-	2000
A4 printing paper	1000	4reams	4000
pens	1000	1 box	1000
Printing cartridge	5000	1	5000
Binding	100	6	600
Folders	200	10	2000
Flash disc	1000	2	2000
Internet cost	1000	10	10000
Contingency			25000
Total			131,600

APPENDICES

Appendix I: Data Collection Form

THE SPECTRUM OF CHEST CT FINDINGS IN CONFIRMED COVID-19 PATIENTS AT KENYATTA NATIONAL HOSPITAL

Patient Demographics and Clinical Data

Patient number: _____

Age:_____

Gender ☐ Male ☐ Female

Clinical symptoms

☐ Fever

☐ Cough

☐ Difficulty in breathing

☐ General body malaise

Days since onset of symptoms: _____

PATTERNS OF CHEST CT FINDINGS

Normal Findings ☐

Abnormal chest CT Findings(Multiple can apply) ☐

Pulmonary

☐ Ground glass opacification

☐ Consolidation

☐ Mixed ground glass opacification and consolidation

☐ Crazy Paving

☐ Vascular thickening

☐ Pulmonary nodule

☐ Tree in Bud

☐ Interlobular septal thickening

☐ Fibrosis :

○ Honey combing	○ Reticular pattern	○Traction bronchiectasis

☐ Air filled lung lesions

○Bullae	○pneumatocele	○cavity	○cysts

☐ Pleural thickening

☐ Pleural Effusion

Non pulmonary findings

☐ Mediastinal lymphadenopathy

☐ Pericardial effusion

☐ Thymic hyperplasia

Distribution of lesions in COVID-19

Involved lungs and lobes

Lung laterality

☐ Bilateral

☐ Unilateral

Lung lobe

Lung Lobes	0%	1-25%	26-49%	50-75%	>75%
Left upper lobe					
Right upper lobe					
Right middle lobe					
Right lower lobe					
Left lower lobe					

Lung lesions Extent

- ☐ Multifocal
- ☐ Diffuse
- ☐ Single/focal

Lesion location

- ☐ Peripheral
- ☐ Peripheral and central
- ☐ Central

Axial DistributionPredominant Anterior-posterior distribution

- ☐ No axial distribution
- ☐ Anterior
- ☐ Posterior

INCIDENTAL CHEST CT FINDINGS

Major (Findings that will affect the management of the patient)

_____

Minor (Findings that will not affect the management of the patient)

_____

CO-RADS CLASSIFICATION

- ☐ CO-RADS 1: COVID-19 highly unlikely (no CT abnormalities consistent with Covid-19: No abnormalities in the lungs or only abnormalities consistent with non-infectious disease)
- ☐ CO-RADS 2: COVID-19 unlikely (abnormalities consistent with infections other than COVID-19)
- ☐ CO-RADS 3: Equivocal/indeterminate (unclear whether COVID-19 is present)
- ☐ CO-RADS 4: COVID-19 likely (abnormalities suspicious for COVID-19)
- ☐ CO-RADS 5: COVID-19 highly likely (abnormalities highly suggestive for COVID-19)

Appendix II: Waiver of Consent

UNIVERSITY OF NAIROBI (UoN)
COLLEGE OF HEALTH SCIENCES
P O BOX 19676 Code 00202
Telegrams: varsity
(254-020) 2726300 Ext 44355

KNH-UoN ERC
Email: uonknh_erc@uonbi.ac.ke
Website: http://www.erc.uonbi.ac.ke
Facebook: ttps://www.facebook.com/uonknh.erc
Twitter: @UONKNH_ERC

KENYATTA NATIONAL HOSPITAL (KNH)
P O BOX 20723 Code 00202
Tel: 726300-9
Fax: 725272
Telegrams: MEDSUP, Nairobi

(To be submitted with Application for ERC Review of Research)
Exempt studies to be defined

KNH-UoN ERC
REQUEST FOR WAIVER OF INFORMED CONSENT
(Not Required for Exempt Studies)

Project Title: __
SPECTRUM OF CHEST CT FINDINGS IN CONFIRMED COVID-19 PATIENTS AT KENYATTA NATIONAL HOSPITAL
_____
_____
_____
____

Principal Investigator and Institutional affiliation: _
Miriam Wanjiku Muhoro, Department of Diagnostic Imaging and Radiation Medicine, University of Nairobi _____

Date: _____

Under special circumstances, investigators may request one of three types of waivers to obtaining written informed consent from research participants.

1. **Alteration of informed consent.**
   With this waiver, the investigator may provide to the participants a consent which does not include or which alters one or all of the required elements. Examples of when this waiver might be applicable would be, when a researcher is conducting secondary data analysis and the participants cannot be located or when requiring informed consent might somehow actually have negative consequences for research participants.
2. **Waiver of parental permission**.
   This waiver would be used in cases where something may be legal for a child to do (i.e. contraception) without parental permission and obtaining parental permission would violate that privacy. An example of this type of waiver would be a survey on children (which would require parental permission) but the survey is about their experience on contraception usage.
3. **Waiver of written documentation** that informed consent was obtained. With this waiver, the investigator would be required to read or provide the informed consent form to a participant, but would not need to obtain the participant's signature on the consent form. Examples of when this waiver might be applicable would be some internet or phone surveys or when signing the form might have some negative consequence for the participant. It must be emphasized that these waivers will be given only when there are compelling reasons for doing so.

The Ethics and Research Committee determines which type of consent applies to your research, but please indicate the type that you are requesting.

☐ **Waiver or alteration of the informed consent process.** *(Complete Section I)*

☐ **Request for waiver of parental permission.** *(Complete Section II)*

☐ **Waiver of written documentation of consent.** *(Complete Section III)*

I. Request for waiver or alteration of the consent process (Not required for Exempt studies)

I believe that this protocol is eligible for waiver or alteration of required elements of the informed consent process because the protocol meets all of the following criteria: (Provide protocol-specific supporting information for each criterion that justifies the findings for the following :)

1. The research presents no more than "minimal risk" of harm to participants.
_ The research involves no more than minimal risk to the participants because it involves materials (data-Chest CT , documents-RT-PCR results, records- demographic data) that have been collected, and precautions will be taken to ensure that confidentiality is maintained.

---

2. The waiver or alteration will not adversely affect the rights and welfare of the participants.

__ The waiver will not adversely affect the rights and welfare of the participants because procedures are in place to protect confidentiality. Confidentiality will be upheld throughout the study period while handling the patient's information by ensuring serialization of the patient's CT number.

3. The research could not practicably be carried out without the waiver or alteration.
In light of the retrospective nature of the study, most patients will have been discharged from the care of the hospital, therefore making it difficult to obtain informed consent. Since the study involves the interpretation of chest CT findings with no patient interaction and no additional investigations or interventions, a consent waiver is most applicable.

4. Whenever appropriate, the participants will be provided with additional pertinent information after participation.
Not applicable

5. Elements of informed consent for which a waiver or alteration is requested and the rationale for each:

- A waiver is requested to access the patients' chest CT for interpretation.
- A waiver is requested to access the patients' medical records to obtain demographic information and clinical symptoms.

6. The research does not involve non-viable neonates:
This research does NOT involve non-viable neonates

7. The research is not subject to FDA and/or national research regulation
This research is NOT subject to FDA/ national regulation

II. Request for waiver of parental permission (Not required for Exempt studies)

I believe that this protocol is eligible for waiver of parental permission because the protocol meets all of the following criteria: (Provide protocol-specific supporting information for each criterion that justifies the findings for one of the following two options :)

Option 1

1. The research presents no more than "minimal risk" of harm to participants.

2. The waiver or alteration will not adversely affect the rights and welfare of the participants.

_____

_____

____

3. The research could not practicably be carried out without the waiver or alteration.

_____

_____

____

4. Whenever appropriate, the participants will be provided with additional pertinent information after participation.

_____

_____

____

5. Elements of informed consent for which a waiver or alteration is requested and the rationale for each:

_____

_____

____

6. The research does not involve non-viable neonates:

_____

_____

____

7. The research is not subject to FDA and/or national research regulation:

_____

_____

____

Option 2:

1. The research protocol is designed for conditions or for a participant population for which parental or guardian permission is not a reasonable requirement to protect the participants (for example, neglected or abused children)

_____

_____

____

2. An appropriate mechanism for protecting the children who will participate as participant in the research will be substituted

_____
_____
____

3. The research is not subject to FDA and/or national research regulation:
_____
_____
___

4. The waiver is consistent with international and national law:
_____
_____
____

III. Request for waiver of written documentation of consent (Not required for Exempt studies and not required when the consent process is waived.)

I believe that this protocol is eligible for a waiver of written documentation of informed consent because the protocol meets one of the following criteria: (Provide protocol-specific supporting information for each criterion that justifies the findings for one of the following two options :) **(NOTE: Even when documentation of informed consent is waived, the investigator is required to give participants full consent information, and to obtain their voluntary consent orally.)**

Option 1

(Example: Conducting interviews with street children engaged in drug abuse. The only record of the name or other identifying information of the participants would be the signed consent form and knowledge of an individual's participation or information provided could lead to potential legal, social, or physical harm.)

Explain*:*

1. The only record linking the participant and the research would be the consent document.
_____
_____
2. The principle risk would be potential harm resulting from breach of confidentiality.
_____
_____

3. Each participant will be asked whether the subject wants documentation linking the participant with the research and the participant's wishes will govern.
_____
_____

4. The research is not subject to FDA and / national research regulation.

Option 2

(Example: Using an anonymous survey consent or conducting telephone interviews with politicians about how constitutional provision for funding of political parties will affecting the campaign process of smaller parties

1. The research presents no more than minimal risk of harm to participants.

_____

_____

2. The research involves no procedures for which written consent is normally required outside of the research context.

_____

_____

Approval (KNH-UoN ERC Chairperson: Check all that apply to indicate that the waiver or alteration is approved and to indicate agreement with the investigators protocol specific findings justifying the waiver.)

☐ Waiver or Alteration of the Consent Process

☐ Waiver of parental permission

☐ Waiver of Written Documentation of Consent

NOTE: To approve a waiver of written documentation of informed consent the investigator must provide a written document describing the information to be disclosed. This document has to include all required and appropriate additional elements of consent disclosure, unless the consent process has been altered.

Chose one of the following when approving a waiver of written documentation:

☐ The investigator must provide a written description of the information provided orally to the participant.

☐ The investigator does not have to provide a written description of the information provided orally to the participant.

APPROVED BY CHAIR KNH-UoN ERC:
Name: _____ Signature _____

Date and Stamp:_____

UNIVERSITY OF NAIROBI
COLLEGE OF HEALTH SCIENCES
P O BOX 19676 Code 00202
Telegrams: varsity
Tel:(254-020) 2726300 Ext 44355

KNH-UON ERC
Email: uonknh_erc@uonbi.ac.ke
Website: http://www.erc.uonbi.ac.ke
Facebook: https://www.facebook.com/uonknh.erc
Twitter: @UONKNH_ERC https://twitter.com/UONKNH_ERC

KENYATTA NATIONAL HOSPITAL
P O BOX 20723 Code 00202
Tel: 726300-9
Fax: 725272
Telegrams: MEDSUP, Nairobi

Ref: KNH-ERC/A/286

9th August , 2021

Dr. Miriam Wanjiku Muhoro
Reg. No.H58/12678/2018
Dept. of Diagnostic Imaging and Rad. Medicine
School of Medicine
College of Health Sciences
University of Nairobi

KENYATTA NATIONAL HOSPITAL APPROVED 09 AUG 2021 KNH/UoN-ERC P. O. BOX 20723 - 00202 NAIROBI

Dear Dr. Muhoro

RESEARCH PROPOSAL: SPECTRUM OF CHEST CT FINDINGS IN CONFIRMED COVID-19 PATIENTS AT KENYATTA NATIONAL HOSPITAL (P67/02/2021)

This is to inform you that the KNH- UoN Ethics & Research Committee (KNH-UoN ERC) has reviewed and **approved** your above research proposal. The approval period is 9th August 2021 – 8th August 2022.

This approval is subject to compliance with the following requirements:

i. Only approved documents (informed consents, study instruments, advertising materials etc) will be used.
ii. All changes (amendments, deviations, violations etc.) are submitted for review and approval by KNH-UoN ERC before implementation.
iii. Death and life threatening problems and serious adverse events (SAEs) or unexpected adverse events whether related or unrelated to the study must be reported to the KNH-UoN ERC within 72 hours of notification.
iv. Any changes, anticipated or otherwise that may increase the risks or affect safety or welfare of study participants and others or affect the integrity of the research must be reported to KNH- UoN ERC within 72 hours.
v. Clearance for export of biological specimens must be obtained from KNH- UoN ERC for each batch of shipment.
vi. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. (Attach a comprehensive progress report to support the renewal).
vii. Submission of an executive summary report within 90 days upon completion of the study.

This information will form part of the data base that will be consulted in future when processing related research studies so as to minimize chances of study duplication and/ or plagiarism.

For more details consult the KNH- UoN ERC website **http://www.erc.uonbi.ac.ke**

Yours sincerely,

PROF. M. L. CHINDIA
SECRETARY, KNH- UoN ERC

c.c. The Principal, College of Health Sciences, UoN
The Senior Director, CS, KNH
The Chair, KNH- UoN ERC
The Assistant Director, Health Information, KNH
The Dean, School of Medicine, UoN
The Chair, Dept.of Diagnostic Imaging & Radiation Medicine, UoN
Supervisors: Dr. Nelson Mukora Kimani, ,Dept. of Diagnostic Imaging and Radiation Medicine, UoN
Dr. Eunice Omamo, Dept.of Diagnostic Radiology, KNH