LEVEL OF AGREEMENT BETWEEN LUNG ULTRASONOGRAPHY AND CHEST RADIOGRAPHY FINDINGS AMONG CHILDREN WITH PNEUMONIA AT MOI TEACHING AND REFERRAL HOSPITAL

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THESIS PRESENTED IN PARTIAL FULFILLMENT OF THE AWARD OF THE DEGREE OF MASTER OF MEDICINE IN RADIOLOGY AND IMAGING AT MOI UNIVERSITY.

LEVEL OF AGREEMENT BETWEEN LUNG ULTRASONOGRAPHY AND CHEST RADIOGRAPHY FINDINGS AMONG CHILDREN WITH PNEUMONIA AT MOI TEACHING AND REFERRAL HOSPITAL

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DECLARATION

This thesis is my original work and has not been presented in any other university or institution for an award of a degree or any academic credit. No part of this work may be reproduced or transmitted in any form without prior permission from the author and/or Moi University.

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DEDICATION

I dedicate this work to the Almighty God for the gift of life. To my family for their unwavering support and championing me on. To all the radiology registrars and my classmates for their daily words of encouragement and the feeling of togetherness makes all possible.

To you all, I am truly grateful.

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ABSTRACT

Background: Pneumonia is the leading cause of morbidity and mortality among children. Globally, it accounts for over 1,400 per 100,000 childhood mortalities. Chest radiography is known to have a low dose of ionizing radiation although children are more susceptible to the effects of radiation exposure than adults. Ultrasound (US) has no ionizing radiations therefore its safe in children and is portable. The study seeks to explore whether lung ultrasonography (LUS) can be considered as an alternative diagnostic test to chest radiography (CXR) in the management of pneumonia in children.

Objectives: To describe lung ultrasonography and chest radiography findings and determine level of agreement between LUS and CXR findings among children with clinical diagnosis of pneumonia.

Methods: This was a descriptive cross-sectional study conducted at Radiology department, MTRH between1st April 2019 to 31st March 2020. Sample size was determined using Cohen's kappa formula. One hundred and twenty-three consecutive patients aged ≤ 18 years with clinical diagnosis of pneumonia were enrolled. Details of the age, gender, lung ultrasonography and chest radiography findings were recorded in data collection form. Study participants had CXR done and further subjected to LUS examination as per MTRH Protocol. A Mindray M7 ultrasound machine was used. Radiological diagnosis of pneumonia was made as per World Health Organization criteria of 2001 based on either lung consolidation, pleural effusion and/or pulmonary infiltrates. Continuous variables were summarized using median and interquartile range while descriptive statistics were summarized using frequency, percentages, tables and pie charts. Cohen's kappa coefficient statistic was used to determine the level of agreement between CXR and LUS findings and corresponding p-values were recorded. Significance level was set at 0.05.

Results: Median age of study participants was 4 years (IQR 3-8). On CXR, 90 (73.17 %) had lung consolidation, 58 (47.12 %) pleural effusion, 38 (30.89 %) pulmonary infiltrates and 28 (22.76 %) had normal CXR. Among them, 95 (77.24%) were diagnosed with pneumonia on CXR. On LUS, 85 (69.11%) had lung consolidation, 63 (51.22%) pleural effusion and 30 (24.39%) had normal LUS. 93 (75.60%) had diagnosis of pneumonia on LUS. There was a nearly perfect agreement between the CXR and LUS in diagnosis of pneumonia, $\kappa = 0.865$ (95% CI, 0.759 to 0.971), $p < 0.0001$.

Conclusion: Lung consolidation was the commonest radiological finding detected on both CXR and LUS. LUS was better in detection of pleural effusion. There was a near perfect agreement between LUS and CXR in diagnosis of pneumonia.

Recommendations: There is need to consider LUS as a diagnostic alternative to CXR based on nearly perfect agreement between the CXR and LUS in diagnosis of pneumonia, $\kappa = 0.865$ (95% CI, 0.759 to 0.971), $p < 0.0001$.

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LIST OF ABBREVIATIONS

CAP	Community Acquired Pneumonia
CFR	Case Fatality Rate
CI	Confidence Interval
CXR	Chest X-ray
GAPP	Global Action plan for Prevention and control of Pneumonia.
IQR	Interquartile range
LUS	Lung Ultrasound
LRTI	Lower Respiratory Tract Infections
MTRH	Moi Teaching and Referral Hospital
PED	Pediatric Emergency Department
SPSS	Statistical Package for Social Sciences
UNICEF	United Nations Children's Fund
WHO	World Health Organization

OPERATIONAL DEFINITION OF TERMS

A child: Every human being below the age of 18 years (UNICEF, 2017) However, in this study, a child was considered as anyone below 13 years admitted to paediatric ward.

Air bronchogram: Linear, lucent and branching structures representing air in the bronchi upon consolidation of alveoli around them (Organization, 2001).

Clinical criteria for diagnosis of pneumonia: Presence of dyspnea, tachypnoea (of more than 50 breaths/min for children aged 2 to 11 months and more than 40 breaths/min for children aged 12 to 59 months), cough and lower chest in-drawing, oxygen saturation <90 % in room air and central cyanosis (WHO, 2005).

CXR criteria for diagnosis of pneumonia: Consolidation, pleural effusion, pulmonary infiltrates (Child et al., 2005; Organization, 2001; Shimol et al., 2012).

Consolidation: Homogenous and dense opacities in the lungs often containing air bronchograms (Organization, 2001).

Pneumonia: A respiratory infection of the lungs where small air sacs (alveoli) accumulate fluid and pus leading to difficult and painful breaths as well as reduced oxygen intake (WHO, 2020).

Pleural effusion: abnormal accumulation of fluid in the pleural space between the lungs and the chest wall (Organization, 2001).

Pulmonary infiltrates: patchy/linear opacities within the lung parenchyma (Organization, 2001).

CHAPTER ONE: INTRODUCTION

1.1 Background

Pneumonia is a respiratory infection of the lungs where the alveoli accumulate fluid and pus leading to difficult and painful breaths as well as reduced oxygen intake (WHO, 2020). Pneumonia in children is a serious financial and public health issue with a significant effect on morbidity and mortality. According to World Health Organization (WHO), pneumonia is ranked as the commonest infectious disease responsible for the highest number of fatalities in children. The annual incidence of pneumonia in developed countries was reported to be 34 to 40 per 1000 child-year in children below 5 years (Madhi et al., 2013). The reported incidences in the developed countries are mostly of the complicated form of the disease. To manage the reported high cases of the disease in both developing and developed countries, speedy diagnosis and treatment is very important (Urbankowska et al., 2015).

Pneumonia is considered positive in situations where children who were previously healthy, present with frequent or continuous high fever accompanied by chest in-drawing, tachypnoea or any other clinical features suggesting pneumonia (Harris et al., 2011). However, diagnosis using clinical features has been shown to lack specificity because patients may also present with other features such as vomiting, abdominal tenderness and headache which are not suggestive of pneumonia (O'Grady, Torzillo, Frawley, & Chang, 2014). Furthermore, many of the signs and symptoms are present in infectious conditions commonly seen in children as well as mild fever and wheezing accompanied by upper respiratory tract infections (Yilmaz, Özkaya, Gökay, Kendir, & Şenol, 2017).

Diagnosis of pneumonia is predominantly examined using chest x-ray in the conventional day-to-day practice (Alzahrani, Al-Salamah, Al-Madani, & Elbarbary, 2017). Nevertheless, many limitations in using Chest X-ray have been documented such as the risk of repetitive exposure to radiation, poor patient cooperation and unreliable quality of x-ray films (Thukral, 2015).

Since the introduction of ultrasound in 1986 (Weinberg, Diakoumakis, Kass, Seife, & Zvi, 1986), numerous studies demonstrated that it is fast, repeatable, reliable, accurate and does not expose patients to radiation (Biagi et al., 2018; Caiulo et al., 2013; Copetti & Cattarossi, 2008; Ellington et al., 2017; Reissig et al., 2012). Lung ultrasound can also be readily and easily used as a bedside tool for diagnosis. It's easier to use LUS in children due to a shorter thoracic width and a thinner chest wall than in adult patients (Copetti and Cattarossi, 2008).

In a study done by Kyomuhangi in Uganda on accuracy of chest ultrasound in diagnosing pneumonia in paediatric patients found high sensitivity of LUS in detection of pneumonia in children (Kyomuhangi et al.,2019).

The study sought to check whether LUS can be adopted and used as an alternative to CXR as a diagnostic examination for pneumonia in children in Kenya and specifically at Moi Teaching and Referral Hospital, Eldoret.

1.2 Statement of the Problem

Clinical diagnosis of pneumonia is highly sensitive but has poor specificity, hence overuse of antibiotics even in the undeserving cases (Urbankowska et al., 2015). Chest X-ray is considered the imaging modality of choice for pneumonia diagnosis in children for cases that require further evaluation. However, the use of chest x-ray is associated with a number of limitations such as poor patient cooperation, health risks of cumulative radiation exposure in children especially those that require repeated chest radiographs. (Tay, Jones, & Tsung, 2015).

Consequently, there is need for an alternative innovative, widely accessible, radiation-free imaging method that can be reliably used to diagnose childhood pneumonia. This study therefore aims to compare LUS and CXR findings among pediatric patients with clinical signs and symptoms that suggest pneumonia and consider its use as an alternative to CXR.

1.3 Justification

The use of LUS for diagnosis of lung diseases has been known since 1986 but its practice has not been fully embraced (O' Grady et al 2014). Its use in the diagnosis of pneumonia in children should be considered a diagnostic alternative to chest x-ray since it is easily accessible, portable and does not contain ionizing radiation. It is also a necessary ethical choice in protecting children from avoidable radiological exposures. The method is technically advantageous in children than in adults as it offers a shorter thoracic width and a thinner chest wall (Copetti & Cattarossi, 2008). For this reason, some authors have advocated for US to be adopted as the preferred diagnostic method for pneumonia (Shu et al., 1994).

In healthcare settings with advanced imaging equipment, LUS normally functions as a triage instrument or it could be an add-on test preceded by an imaging exam that was non-diagnostic, such as CXR (Tsai, Ngai, Mok, & Tsung, 2014).

Recent data showed that LUS may present an attractive alternative for CXR (Reissig et al., 2012; Shah, Tunik, & Tsung, 2013). Currently, there is no local data showing the use of LUS in diagnosis of pneumonia, thus the need for this study at MTRH. Furthermore, LUS is also not routinely used to diagnose lung diseases. Therefore, the study will form a platform to study the likelihood of a broader use of this technique in children with other lung diseases.

1.4 Research Question

1. What is the level of agreement between lung ultrasonography and chest radiography findings among children with pneumonia at MTRH?

1.5 Objectives

1.5.1 Broad Objective.

1. To determine the level of agreement between lung ultrasonography and chest radiography findings among children with clinical diagnosis of pneumonia

1.5.2 Specific Objectives.

1. To describe chest radiography findings among children with pneumonia at MTRH.
2. To describe lung ultrasonography findings among children with pneumonia at MTRH.
3. To determine the level of agreement between lung ultrasonography and chest radiography findings among children with pneumonia at MTRH.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

2.2 Epidemiology

Globally, pneumonia combined with other LRTIs are the leading causes of morbidity and mortality. According to WHO Child Health Epidemiology Reference Group, clinical pneumonia has a median global incidence of 0.28 episodes per child-year (Rudan et al., 2004).

Pneumonia claims lives of over 800,000 children below 5 years annually (WHO 2018). Globally there are over 1400 cases per 100,000 children affected with pneumonia. South Asia has the highest burden at 2,500 cases per 10,000 children. Central and West Africa has 1,620 cases per 100,000 children. (WHO 2018) South Africa has 0.14 episodes per child year with 11.1% 0f cases defined as severe (Harry, et al., 2017) Kenya has 6 cases per 100 live births below 5years. (UNICEF 2019) As high as 95 % of all clinical pneumonia episodes in children in the whole world occur in low income countries

Epidemiological modelling data from 2010 in Kenya estimates that the annual incidence of acute LRTIs among children is 0.25 episodes per child year where about 11 % progress to severe diseases (Walker et al., 2013). Cross-sectional inpatients studies in Kenya estimated the prevalence of childhood pneumonia at a range of 24 % (data from a rural district hospital in coastal Kenya) to 30 % (data from Kenyatta national hospital) (Berkley et al., 2005; Maina, 2006). The observed high prevalence rate confirms that pneumonia is indeed a leading cause of childhood illness in the country.

Notably, early detection of pneumonia, prevention and treatment remains a challenge in spite of the several strategies that have been implemented to curb this disease including supplementation with vitamin A and zinc, vaccination, breastfeeding exclusively for six months (Wardlaw, Salama, Johansson, & Mason, 2006). Pneumonia can be treated from home with minimal safety concerns. However data shows that the number of children who benefit from an effective regimen at home are about 27 %. Children who miss an effective and timely pharmacological intervention progress towards a more severe illness requiring hospitalization. Often, pediatric admissions from pneumonia are severe and are accompanied with complications such as electrolyte abnormalities, particularly hyponatremia.

2.2 Diagnosis of pneumonia in children

2.2.1 Clinical diagnosis

Pneumonia in children is diagnosed clinically. However, clinical diagnosis is associated with poor specificity (Yilmaz et al., 2017). The WHO criteria for clinical diagnosis of pneumonia include: presence of dyspnea/tachypnoea (≥50 breaths/min 2 to 11 months old children and ≥40 breaths/min 12 to 59 months old children), cough and lower chest in-drawing as well as at least one of the danger signs such as persistent convulsions, vomiting, stridor, inability to drink, unconsciousness, lethargy, severe malnutrition, oxygen saturation below 90 % in room air and central cyanosis (Child et al., 2005).

2.1.2 Chest x-ray diagnosis of pneumonia

Chest X-ray is the most commonly used imaging tool for diagnosing pediatric pneumonia. The X-ray report provides a spectrum of radiological abnormalities, which are normally congruent with the clinical as well as the pathological diagnosis of pneumonia (including complicated and uncomplicated pneumonia as well as mild interstitial changes) (Muller, 2001).

Chest X-ray features of lobar pneumonia include: homogenous, non-segmental consolidation that mostly involve one lobe with air bronchograms. Features of CXR for bronchopneumonia are severity dependent, where the mild form presents as poorly distinct airspace opacities and peribronchial thickening while inhomogeneous patchy areas of consolidation on numerous lobes represents advanced disease (O'Grady et al., 2014).

X-ray features of interstitial pneumonia include cellular infiltrates and edema (in Pneumocystis jirovecii infection), reticular/reticulonodular pattern and septal B lines and ground glass opacities and multifocal consolidation (severe pandemic pneumonia). Lung complications of pneumonia include empyema, abscess and necrotizing lung. On CXR, lung abscess appear as cavities in areas of consolidation while necrotizing pneumonias initially presents as small lucencies within areas of consolidation progressing to larger, fluid filled cavities (Muller, 2001). However, empyema cannot be diagnosed using CXR (O'Grady et al., 2014).

Despite CXR being used for the confirmatory diagnosis of pneumonia, it is associated with several limitations. Interpreting CXR findings is influenced by the experience of the reader and the film quality with researchers demonstrating varying concordance between radiologists, between radiologists and clinicians and between clinicians.

Studies have also demonstrated that CXR findings cannot distinguish between viral and bacterial pneumonia. To overcome certain limitations of CXR such as inter- and intra-observer inconsistency, a group of researchers met with the WHO to develop pediatric criteria for radiologically diagnosed pneumonia. This led to the 2001 publication WHO protocol, Standardization of the interpretation of chest radiographs for the diagnosis of pneumonia in children (Organization, 2001).

The protocol defined the radiologically diagnosed pneumonia as: (a) Significant pathology (presence of consolidation, infiltrate or effusion), (b) End-point consolidation (consolidation of a lobe/entire lung with or without air bronchograms and occasional pleural effusion), (c) Other (non-end-point) infiltrate (interstitial infiltrate featuring peribronchial thickening and atelectasis), (d) Pleural effusion. The protocol necessitates CXR to be collected, scanned and interpreted in an orderly way and specifies the standards for assigning the final finding. Two independent practitioners (if possible a radiologist and a pediatrician) interpret each film, but the discordant ones are reviewed by an independent expert panel (O'Grady et al., 2014).

Guo *et al* investigated various types of viral pneumonia and their radiological presentations from 210 pediatric patients. From the study, CXR films in 133 patients showed patchy areas of consolidation bilaterally, 33 films showed interstitial lung disease, 29 films showed diffuse areas of air space consolidation while 15 presented lobar consolidation. Repeat radiographs (after 48 hours) in this study demonstrated that in 33 patients, bilateral patchy areas of consolidation became confluent. The lower lobes were the most common areas of radiographic abnormalities. In addition, lesions were bilateral in most patients (n=195) and unilateral in 15 cases (Guo, Wang, Sheng, Zhou, & Fang, 2012).

Kelly *et al* 2016 in their study demonstrated CXR features of pneumonia in children in 249 pediatric patients (57 % were anterior-posterior and lateral radiographs while 43 % were anterior-posterior). From the study, 76 % of the sampled patients were diagnosed with either consolidation or pulmonary infiltrates. Twenty-eight (11%) patients had pleural effusion, although the vast majorities (96%) of these pleural effusions were small. The final chest radiograph classification was consolidation pneumonia in 35 % of the patients, other infiltrate 42% of the patients. Twenty two percent of the patients showed no significant pathology (Kelly et al., 2016).

John, Ramanathan and Swischuk assessed the Spectrum of radiographic findings in pediatric mycoplasma pneumonia in 2001. Radiographic findings from the study showed focal pulmonary areas of amplified opacity in 83 % of the cases, diffuse or bilateral perihilar areas of increased opacity in 12 % cases while 5 % cases were normal. The focal pulmonary areas of amplified opacity were apparent on the right side in 17 patients, left side in 13 patient and bilateral in 5 patients. Focal lobar involvement was predominant in the lower lobes (28 of 35 patients) than in the upper or middle lobes (7 of 35). In about 17% (n = 7) of the patients, pleural effusions were seen particularly on the left side except for bilateral effusions in one patient. For patients with *M. pneumoniae,* the radiographic patterns observed were variable. There was no clear identifiable pattern of lobar involvement in the study, but the upper lobes were less affected compared to the lower lobes (John, Ramanathan, & Swischuk, 2001).

Mortensson and colleagues compared radiological findings in children of different ages. Their study showed a significant difference in radiological findings according to age distribution. Younger children presented with interstitial infiltrations and

hyperinflation while older children presented with alveolar infiltrations (Wahlgren et al., 2005).

2.2.2 Diagnosis of pneumonia in children using lung ultrasound

Diagnosing pneumonia in children using ultrasound with identification of air bronchograms inside lung consolidation was first published in 1986 by Weinberg *et al* (Weinberg et al., 1986). Advances in technology has availed portable and handheld (bedside) ultrasound machines. However, the use of ultrasound has been limited for a supplemental role in evaluating complicated pneumonia (Kurian, Levin, Han, Taragin, & Weinstein, 2009).

In the pediatric setting, LUS has many likely advantages over other diagnostic imaging methods such as CXR and computerized tomography (CT) scan. Some of the advantages include simplicity and no risk of exposure to radiation. Even though LUS requires to be performed by trained sonographers, other healthcare providers such as doctors, medical students among others can be trained at bedside on its use although cautiously (Royse et al., 2012; Solomon & Saldana, 2014). This increases the potential for diagnostic competences in remote rural setting and likewise, its use as the diagnostic imaging of choice to improve clinical outcome as well as lower antibiotics use (Don, Barillari, Cattarossi, & Copetti, 2013; Riccabona, 2008).

High-resolution linear probes are used to perform LUS to obtain longitudinal as well as transverse sections of lateral, posterior, and anterior chest wall (Cattarossi, 2013). The lateral section is found between the posterior and anterior axillary line. The anterior section sits between the parasternal and anterior axillary line, while the posterior section is found beyond the posterior axillary line (Cattarossi, 2013). A-lines (horizontal artifacts) reflect acoustic impedance at the pleura-lung interface while B-

lines (vertical artifacts) show interstitial or alveolar abnormalities that associate with lung interstitial fluid content. The radiologic features of pneumonia on LUS include air bronchograms, subpleural lung consolidation, pleural lung abnormalities, pleural effusion, and B-lines (Copetti & Cattarossi, 2008). Specifically, B-lines, confluent B-lines, and small areas of sub-pleural consolidation are suggestive of viral pneumonia (Caiulo et al., 2011; O'Grady et al., 2014; Tsung, Kessler, & Shah, 2012).

Several studies have been published in literature comparing the diagnosis of pneumonia in children using CXR and LUS and to an extent, the sensitivity and specificity of the tests. Shah *et al* compared CXR and LUS in 200 patients presenting to an emergency department in New York with suspected clinical signs and symptoms of pneumonia. Study sonologists were physicians working at the emergency department who were taken through a short training before commencement of the study. The sonologists were blinded to the findings of the CXR. The CXR features were reviewed by radiologists who were blinded to the findings of LUS. The reference standard was a visiting pediatric radiologist. Lung ultrasound findings showing lung consolidation with air bronchograms represented a positive case of pneumonia. (Shah et al., 2013).

A study done by Kyomuhangi in Uganda on accuracy of chest ultrasound in diagnosing pneumonia in 280 paediatric patients found high sensitivity of LUS in detection of pneumonia in children. Moreover, he found consolidation as the most common radiological sign in children admitted with pneumonia.(Kyomuhangi et al.,2019).

Copetti *et al* in Italy compared LUS and CXR in 79 children below 16 years presenting with clinical features suggesting pneumonia in Italy (Copetti & Cattarossi, 2008). Out of the 79 children, 53 of them had positive CXR findings, while 60 had positive LUS findings. None of the children had CXR positive findings and LUS negative findings. Of the 7 cases which had negative CXR and positive LUS, pneumonia was confirmed in 4 cases by CT scan. Interestingly, some segments of the lungs are undetectable using LUS such as medial segments of the lungs distant to the chest wall which may be blocked by intervening aerated lung. Moreover, there are no studies showing whether LUS can be used to differentiate between viral and bacterial pneumonia with adequate specificity to inform clinical management. Likewise, there is no published data showing the efficiency of LUS in the continuing management of pneumonia over the course of an illness (O'Grady et al., 2014).

A study by Urbankowska and colleagues in Poland studied 106 children and demonstrated various shapes of consolidation that featured on LUS films. The study showed that about 37 % were oval, 24.7 % were polymorphic, 23.5 % showed complete lung consolidation, 12.3 % were cuneiform and 2.5 % were round. The LUS also demonstrated that respiratory mobility of the lungs was normal in 79 %. However, it was impaired in 19.8 % of the patients and absent in 1.2 % of the patients who had pneumonia. About 76.5 % of confirmed lung consolidations had air bronchograms. In 54.3 % of patients, pleural effusion was confirmed by LUS, while radiologic features of pleural effusion were only seen in 12.1 % of the patients. Significant correlations between the dimensions of pneumonia consolidations demonstrated by LUS in three axes were found. Furthermore, the size of the lesions correlated significantly with the laboratory test results (Urbankowska et al., 2015).

Findings from a retrospective study done in Taiwan aiming to verify the power of LUS pneumonia diagnosis in 163 children, 159 patients were diagnosed with pneumonia. Of the positive cases, consolidation was on the right side in 59.7 % of the cases, 30.2 % on the left and 10.1 % was on both sides. Slightly more than a half (50.9 %) of the patients showed the comet-tail sign. Most of the patients (n=149, 93.7 %) demonstrated positive air bronchogram, while 20.1 % (n = 32) of the patients had a positive fluid bronchogram on the LUS scan. About 28.9 % (n=46) patients showed a vascular pattern within the consolidation and 27.0% (n=43) patients had pleural effusion. A small number of patients (n=12, 7.4 %) patients showed no pneumonia consolidation on chest radiography, but the LUS demonstrated lesions representing pneumonia. However, 2.5 % (n=4) of the patients with negative pneumonia findings on LUS were found to be positive on chest radiography (Ho et al., 2015).

A study by Ho et al., 2015 in Taiwan demonstrated positive rates of the air bronchograms comet-tail sign, fluid bronchograms, pleural effusion, and vascular pattern within the consolidation in 93.7 %, 50.9 %, 28.9 %, and 20.1 % respectively. On follow-up, the mean size of the pneumonia patch in 23 patients decreased from 10.9 cm^2 to 5.5 cm^2, and finally to 2 cm^2 on Day 1, day 3 to 5 and days 7 and 14 respectively. Findings from this study concluded that LUS is a sensitive diagnostic tool for pneumonia identification in children and it can be utilized in checking the prognosis of pneumonia (Ho et al., 2015).

From a study done in China, LUS findings related to infectious pneumonia included, air bronchograms, pleural line abnormalities, interstitial syndrome, and large areas of lung consolidation with irregular margins. The sensitivity of LUS using lung consolidation with irregular margins as the diagnostic feature of neonatal pneumonia

had 100 % sensitivity and specificity (Liu, Liu, Liu, Wang, & Feng, 2014). The study also demonstrated an area under the curve value of 0.94 when compared with radiographically-confirmed clinical pneumonia at 95 % confidence interval. Comparisons from an abnormality seen on the lung ultrasound to a radiographically-confirmed clinical pneumonia increased the sensitivity to 92.2%, but slightly reduced the specificity to 95.2%, giving an area under-the curve (AUC) of 0.94 at 95 % confidence interval (Ellington et al., 2017).

2.2.3 Comparison of Lung Ultrasound findings to chest x-ray findings.

The first cohort study among adults that used LUS to diagnose community-acquired pneumonia with a specificity of 98 % and sensitivity of 94 % was conducted by Reissig et al. The study demonstrated that pneumonia was better detected using LUS (95.7 %) than using CXR (92.6 %) (Reissig et al., 2012).

In a meta-analysis to assess the usefulness of LUS for diagnosing pneumonia in children, eight studies involving 1013 patients were evaluated. The pooled sensitivity and specificity for the diagnosis of pneumonia using LUS were 93 % and 96 % respectively at 95 % confidence interval. The pooled positive predictive value, negative predictive value and diagnostic odds ratio were 25.8 %, 0.07 % and 344 respectively at 95 % confidence interval while the area-under the curve was found to be 0.98 at 95 % confidence interval (Xin, Li, & Hu, 2018).

In Milan Italy, a study conducted to demonstrate the performance of ultrasound in diagnosing community acquired pneumonia in children confirmed 48 cases radiographically. The sensitivity, specificity, positive and negative predictive values of LUS in comparison with CXR were found to be 97.9 %, 94.5 %, 94.0 % and 98.1 % respectively. Interestingly, LUS identified a significantly higher number of cases

due to pleural effusion. However, there was poor concordance of the two methods in identifying the type of pneumonia (Esposito et al., 2014).

Caiulo *et al* in Italy conducted a study for the diagnosis of pneumonia among 102 patients below 16 years of age and with suspected features of pneumonia, using radiologic features on LUS and CXR performed on the same day. Lung ultrasound was performed by an expert pediatric sonographer. The published data shows that pneumonia was positive in 89 patients. Out of the positive cases, LUS was positive in 88 cases while CXR was positive in 81 cases. One patient who had a normal LUS showed a positive CXR whereas eight patients with negative CXR had positive LUS. Pleural effusion was detected in 16 cases using LUS while only 3 cases showed positive pleural effusion features using CXR (Caiulo et al., 2013).

In a study to assess the role of LUS integrated with CXR for the first-line diagnosis of pediatric pneumonia in 84 patients, CXR was positive in 47 pneumonic findings while LUS was positive in 60 pneumonic findings. Of the positive LUS pneumonic findings, 34 showed a characteristic pattern of lung consolidation while 26 showed association of multiple B-lines. One case was negative at LUS because of retroscapular location. Sixty (60) patients were followed up with LUS where 28 patients showed a complete disease regression, 23 patients had a significant reduction in size of consolidation and 9 patients showed disease stability thus requiring adjunctive LUS examinations (Ianniello, Piccolo, Buquicchio, Trinci, & Miele, 2016).

A study done by Urbankowska et al enrolled 106 consecutive children aged between 1 and 213 months with clinical suspicion of pneumonia to determine the utility and accuracy of LUS in the diagnosing and monitoring pneumonia in children. All the children undertook an LUS scan on the day of admission, which was followed by a

CXR. Additionally, 25 children got a lung ultrasound that was performed between the 5th and 7th day, while another 31 children got the same imaging procedure between the 10th and 14th day of admission. There were radiographic signs of pneumonia in 76 children, but the LUS showed a smaller number of 71 positive cases. The lung ultrasound had five cases of false negative, who demonstrated parahilar pulmonary infiltrates through a CXR. There was a nearly unified overall agreement between LUS and CXR diagnosis of pneumonia (Cohen kappa coefficient of 0.89). The LUS performance in demonstration of lung involvement gave a specificity of 100%, sensitivity of 93.4%, negative predictive value 85.7 %, positive predictive value 100 %, and accuracy of 95.3 %. The study demonstrated that LUS is both a sensitive and highly specific diagnostic tool in children with pneumonia and therefore requires consideration as the first imaging test in children with suspected pneumonia (Urbankowska et al., 2015).

A meta-analysis of study that compiled findings from 8 studies, concluded that LUS has high sensitivity (95%) and specificity (93%) in diagnosing childhood pneumonia. The meta-analysis recommended that LUS is a suitable alternative imaging technique that is reliable for the diagnosis of pneumonia in children. It was reported that if LUS was to be adopted to the common clinical practice, or if it was to replace CXR, the radiographers should be wary of the low sensitivity of LUS particularly among patients with perihilar localization of pneumonia (Pereda et al., 2015).

From a study done in 2009 by Iuri et al, 28 consecutive patients with clinical signs of pneumonia aged between 4 months to 17 years undertook both LUS and CXR, subpleural consolidations were seen by both imaging tools in 22 patients. However, LUS was not able to reveal perihilar consolidations which were showed by CXR.

Fifteen cases of pleural effusion were present in LUS scans while in CXR, only 8 cases were present (Iuri, De Candia, & Bazzocchi, 2009).

Guerra et al undertook a study in a pediatric emergency room setting from 2008 to 2012 to analyze the practicality of bedside LUS in detecting lung consolidation among febrile children with respiratory distress. From the first assessment, LUS identified 207 cases of lung consolidation from the total 222 children enrolled, 36.6 percent of them had a liver-like appearance while 36.7 % had associated pleural effusion. On the other hand, CXR was positive for pneumonia in 197 cases with 68.7 showing a parenchymal consolidation and 31.4 % showing focal ground-glass opacity. LUS liver-like consolidation was significantly associated with higher neutrophil counts, longer duration of fever, higher C-reactive protein values and a homogeneous and dense parenchymal consolidation on CXR at 95% confidence interval (Guerra et al., 2016).

In an assessment of the performance of LUS in 143 patients suspected with pediatric pneumonia, ultrasound picked at least one area of consolidation in from a group of 45 patients with positive CXR. The ultrasound identified 54 areas of consolidation from the 59 seen on x-ray. From the 8 patients with negative x-ray, the ultrasound showed 17 areas of consolidation (Claes, Clapuyt, Menten, Michoux, & Dumitriu, 2017).

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Study design

The study was a descriptive cross-sectional study.

3.2 Study Site

This study was conducted at the Radiology and Imaging department (X-ray and US room) at Moi Teaching and Referral Hospital, Eldoret (MTRH).

The hospital is a level 6 hospital located in Eldoret town, Uasin Gishu County which is 310 kilometers North West of Nairobi, the capital city of Kenya. The hospital is a teaching and referral hospital and serves as a teaching hospital for Moi University School of Medicine, Public Health, Nursing, and Dentistry. Other institutions that use this hospital for teaching purpose include University of East Africa, Baraton. School of Nursing and Kenya Medical Training Center (KMTC) Eldoret. MTRH is also a training center for medical, clinical and nursing officer interns. It serves as the main referral hospital for the Western and North Rift regions in Kenya and serving a population of about 24 million people. Apart from radiology and imaging, the facility has several other departments including Surgery, Obstetrics and Pediatrics, Psychiatry, Internal Medicine, Orthopedic Surgery, Gynecology among others.

3.3 Study population

The study involved children aged 18years and below with clinical signs and symptoms suggestive of pneumonia (cough, fever with or without chills, crackles and/or decreased breath sounds, tachypnoea).

3.4 Eligibility criteria

3.4.1 Inclusion criteria

Children aged 18 years and below clinically suspected to have pneumonia, referred to radiology department for CXR.

3.4.2 Exclusion criteria

1. Patients with known malignancy, congenital or acquired heart disease.
2. Patients with CXR from other facilities for the purpose of standardization.

3.5 Sampling Procedure

3.5.1 Sample size

Sample size was estimated using a formula recommended by Watson and Petrie (2010) which estimates the level of agreement using Kappa statistics.

$$n \geq 4\frac{(1-k)}{W^2}\left((1-k)(1-2k)+\frac{k(2-k)}{2\pi(1-\pi)}\right){Z^2}_{1-\alpha/2}$$

Where:

n is desired sample size

W is the maximum acceptable width of Kappa's confidence interval taken as 0.2

${Z^2}_{1-\alpha/2}$ is critical value for standard normal distribution at α-level of significance (α=0.05, $Z_{\alpha/2}$=1.96).

k is the anticipated value of kappa taken as 0.89 (interpreted as almost perfect).

π is the underlying true proportion of positives taken as 0.79 from a study done by Urbankowska et al., (2015).

Substituting for the above estimates

$$n \geq 4\frac{(1-0.89)}{0.2^2}\left((1-0.89)(1-2\times 0.89)+\frac{0.89(2-0.89)}{2\times 0.79(1-0.79)}\right)1.96^2 = 122.2$$

Urbankowska et al., (2015) found prevalence of pneumonia to be 71.7% with almost perfect agreement ($k = 0.89$) between LUS and CXR in diagnosing pneumonia. The sample size required increase as the underlying true proportion of positives increases. Therefore, we used upper bound of 95% CI of 79% to calculate the sample size assuming the underlying true proportion of positives in our study will lie not more than the upper bound.

Cohen's kappa <0 indicates no agreement, 0-0.2 light agreement, 0.21-0.40 fair agreement, 0.41-0.60 moderate agreement, 0.61-0.80 substantial agreement and 0.81-1 almost perfect agreement (Landis and Koch).

3.5.2 Sampling technique

Patients with clinical diagnosis of pneumonia referred for CXR after clinical evaluation by medical officers and clinical officers were consecutively recruited after consenting.

3.6 Study procedure

Clinical team was sensitized prior to the study including radiographers at X-ray room and clinicians at sick child unit and paediatric ward. Postero-anterior and antero-posterior (for under 5 years old) chest radiographs were done to all patients at the radiology department according to MTRH protocol. The radiographs were reported by consultant radiologists blinded to LUS findings.

Eligible patients were recruited after obtaining informed consent from their parents/guardians and assent for children above 7 years. The principal investigator conducted lung ultrasound, after being blinded from the CXR finding and the final diagnosis of pneumonia was confirmed by two independent consultant radiologists at the radiology department. In cases where the two radiologists didn't agree, a 3rd Radiologist had to read the images to break the tie.

Enrollment flow chat

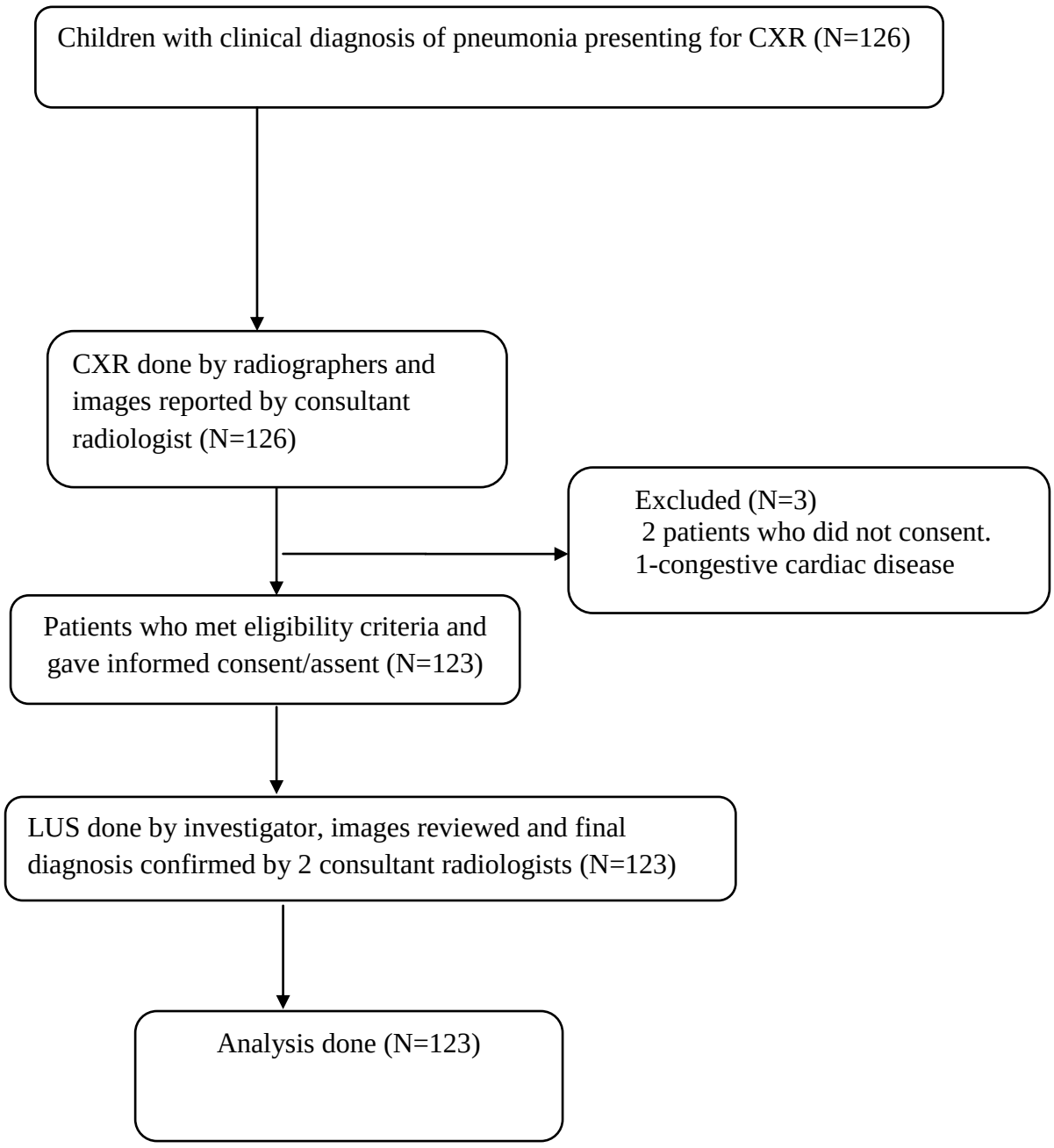


Figure 1: Enrollment flow chat.

3.7 Lung ultrasound scanning protocol for MTRH

Patients were kept in a supine position with chest exposed. A paper towel was used to protect their clothes. Prewarmed coupling gel was applied. The LUS was performed using Mindray M7 ultrasound machine (2016 model) with a linear probe at 7.5 MHz to 12 MHz. Each hemithorax was divided into lateral (between anterior and posterior line), anterior (delineated by parasternal and anterior axillary lines), and posterior (delineated by paravertebral and posterior axillary lines) to cover the whole lung surface. Each region was scanned in longitudinal and transverse plane, medial-lateral and up-down respectively. The lateral and anterior regions were examined in supine decubitus while posterior region was examined in prone decubitus. US preset was optimized for soft tissue studies. Patterns were standardized as normal, consolidation with or without air bronchogram and pleural abnormalities. The principal investigator was aware of clinical suspicion but blinded on CXR.

Interpretation of Chest Radiograph

All patients had Postero-anterior and Antero-posterior (for under 5years old) chest radiograph done according to MTRH protocol.

Chest radiograph was first characterized as normal or abnormal.

If abnormal, one or more of the following signs of pneumonia on chest radiograph were looked for as per WHO criteria:

- ❖ Consolidation
- ❖ Pleural effusion
- ❖ Pulmonary infiltrates

3.8 Data collection and management

3.8.1 Data collection

Data was collected between April 2019 and March 2020.Entry was made in the questionnaires and later transferred to a computer database using double entry to ensure accuracy. All patients' details were kept confidential and data was only available to the investigator and the supervisors via password access. Patients had a copy of their results and had the autonomy over who else could view their scan results. Serial numbers were used in order to protect patients' identity. At the end of each day data collection forms were verified for completeness and coded.

3.8.2 Quality controls

All LUS scans and CXR were done at MTRH in ultrasound and X-ray rooms using an internal standardized imaging protocol. Chest X-rays were done by radiographers while LUS were done by the principal investigator. The images were reviewed by the principal investigator and verified by two senior consultant radiologists. The results were recorded after agreement on the final diagnosis.

3.8.3 Data analysis and presentation

Data was imported into STATA 16 where data cleaning, coding and analysis were done. Data on age was summarized as median and corresponding interquartile range while data on gender was summarized in frequencies and percentages.

To answer objective one and two data on LUS and CXR findings were tabulated as frequencies and corresponding percentages. For objective three, composite variables were created to come up with diagnosis of pneumonia for both LUS and CXR. To determine the agreement between CXR and US findings, Cohen's kappa coefficient statistic was used and the corresponding p-values were reported. Landis and Koch

recommendations were used to classify agreement magnitude with Cohen's kappa of less than 0 used to indicate no agreement, 0-0.2 used for light agreement, 0.21-0.40 indicates fair agreement, 0.41-0.60 indicates moderate agreement, 0.61-0.80 indicates substantial agreement and 0.81-1 indicates almost perfect agreement. The percent level of agreement was also determined and presented. All statistics were performed at 95% level of confidence. The results of this study are presented in form of tables, figures, radiological images, and prose format.

3.9 Ethical considerations

The Institutional Research and Ethics Committee (IREC), Moi University/Moi Teaching and Referral Hospital Ethical granted approval for the study. All patients/guardians were informed about the study and the procedures involved in the study and the possible benefits and harm. Consent was sought from the parents/guardians of the children and assent from children above 7 years. Permission to carry out the study was sought from IREC and the MTRH management. All patients received medical attention as necessary regardless of their willingness/unwillingness to participate in the study. No incentives or inducements was used to convince patients to participate in the study. Patients were allowed to withdraw from the study at any point. The findings were conveyed to the clinicians in standard report attached to the patient's images.

Confidentiality was maintained throughout the study. The data collection forms used neither contained the names of the patients nor their personal identification numbers. Data collecting material were kept in a locked cabinet during the study period.

CHAPTER FOUR: RESULTS

4.1 Demographic information

A total of 123 children with clinical signs and symptoms suggestive of pneumonia were enrolled in the study. Of the 123 patients, the median age was 4 years while the interquartile range (IQR) was between 3 to 8 years. Of the 123 study subjects, 76 (61.79 %) were female while the rest were males as shown in Figure 2. Figure 3 shows the patient age distribution for the study. The age distribution mimics normal curve. When a chi square goodness of fit test was done, there was a statistically significant difference between genders where female were more than males at X^2 (1) = 6.84, p = 0.009.

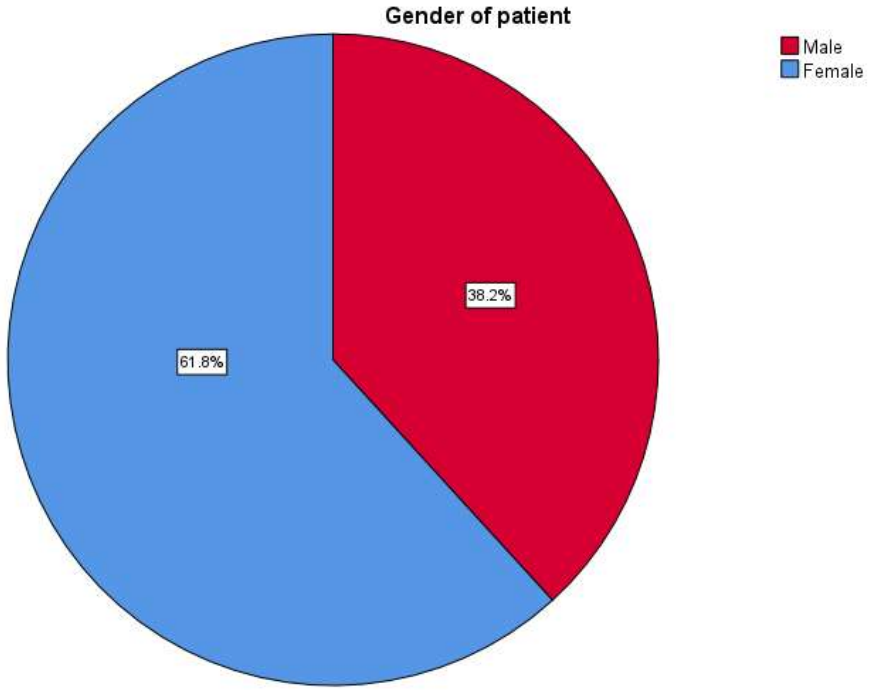


Figure 2: Percentages of the genders.

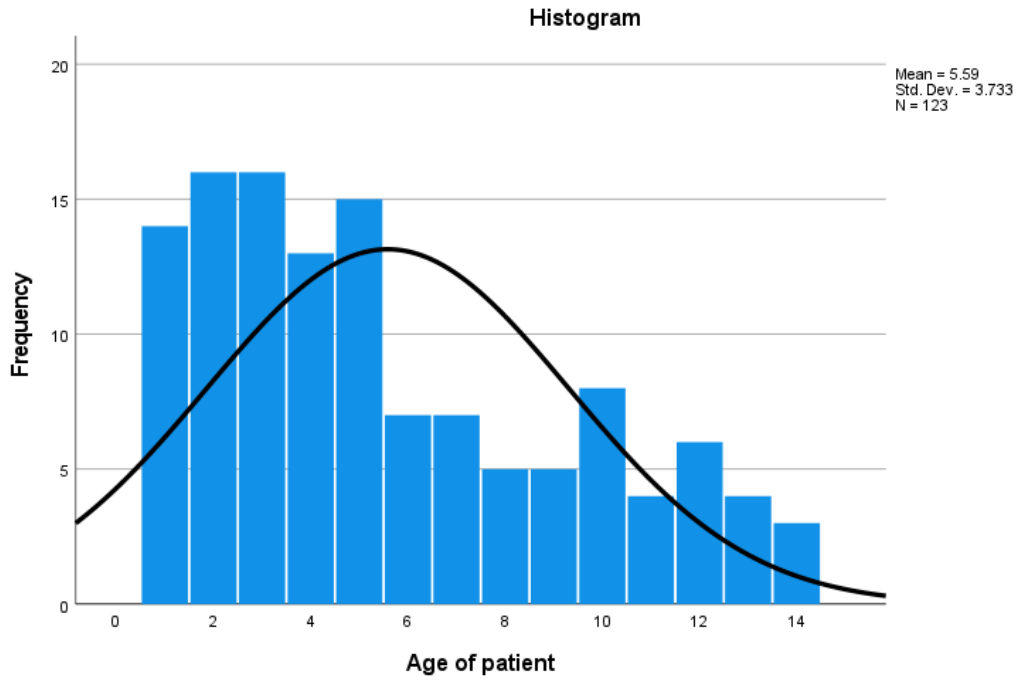


Figure 3: Histogram showing patients age distribution.

4.2 Chest x-ray findings

Table 1 shows the number of positive and negative cases of pneumonia that were diagnosed with CXR. Chest X-ray was positive for pneumonia in 95 (77.2 %). Common chest radiograph findings in patients with pneumonia were lung consolidation accounting for 90 (73.2%), pleural effusion at 57 (46.3 %) and pulmonary infiltrates at 38 (30.9 %). 28 (22.8 %) had normal x-ray findings. Figure 4 shows the percentage of positive and negative cases of pneumonia using CXR.

Table 1: Frequency and percentage of chest X-ray features of pneumonia

CXR Findings	Frequency (n)	Percent (%)
Lung consolidations	90	73.2
Pleural effusion	57	46.3
Pulmonary infiltrates	38	30.9
Normal	28	22.8

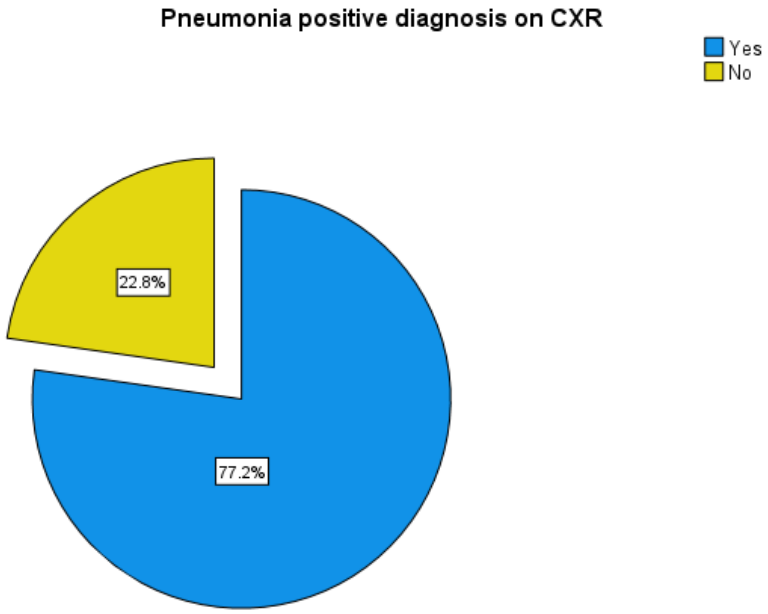


Figure 4: Percentage of positive and negative cases of pneumonia using chest X-ray.

4.3 Lung ultrasound findings

Positive cases for pneumonia in LUS were 93 of the 123 subjects (75.6 %). Common LUS finding was lung consolidation accounting for 85 (69.1 %) of the findings. LUS detected more pleural effusion cases at 63 (51.2 %). Thirty (24.4 %) patients had normal LUS findings as shown in Table 2 while Table 3 shows the frequency and percentage of observed LUS features of pneumonia. Figure 5 shows the percentage of positive and negative cases of pneumonia using LUS.

Table 2: Frequency and percentage of lung ultrasound features of pneumonia in children

Lung Ultrasound findings	Frequency (n)	Percent (%)
Lung consolidations	85	69.1
Pleural effusion	63	51.2
Normal LUS	30	24.4

Table 3 shows LUS findings for patients who had pulmonary infiltrates on CXR. The patients presented with consolidation and effusion 32(84.21%), consolidation alone 5(13.16) and pleural effusion 1(2.63%). None of the patients had pulmonary infiltrates as the only finding.

Table 3: Lung ultrasound findings for those with pulmonary infiltrates on CXR (n = 38)

Findings	Frequency	Percentage
Consolidation and Effusion	32	84.21
Consolidation	5	13.16
Pleural effusion	1	2.63

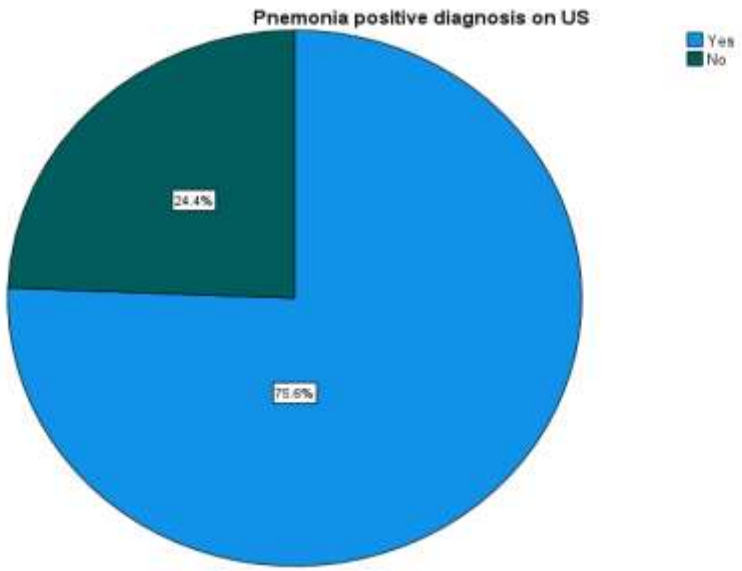


Figure 5: Percentage of positive and negative cases of pneumonia using lung ultrasound.

4.4 Level of agreement between CXR and LUS findings

Cohen's κ was run to determine if there was agreement between CXR and LUS outcomes on lung consolidation as shown in Table 4. The percentage agreement was 95.9%. There was nearly perfect agreement between the CXR and LUS in the diagnosis of lung consolidations, $\kappa = 0.901$ (95% CI, 0.817 to 0.985), $p < 0.0001$.

Table 4: Level of agreement between chest X-ray and lung ultrasound on lung consolidation

Lung consolidations	**US**		**Measurement of agreement**		
CXR	Positive	Negative	Kappa (k)	95% CI	P value
Positive	85	5	0.901	0.817, 0.985	<0.0001
Negative	0	33			

Kappa = **(**Percent agreement observed**)** __ (Percent agreement expected by chance)

100% - (Percent agreement expected by chance alone)

Table 5: Level of agreement between chest X-ray and lung ultrasound on pleural effusion feature

Pleural effusion	**US**		**Measurement of agreement**		
CXR	Positive	Negative	Kappa (k)	95% CI	P value
Positive	57	0	0.903	0.827, 0. 979	<0.0001
Negative	6	60			

There was nearly perfect agreement between the CXR pleural effusion diagnosis and US pleural effusion diagnosis, $\kappa = 0.903$ (95% CI, 0.827 to 0.979), $p < 0.0001$. The percent agreement was at 95.1 % (table 5)

Table 6: Level of agreement between diagnosis of pneumonia using chest X-ray and lung ultrasound

Diagnosis of Pneumonia	**US**		**Measurement of agreement**		
CXR	Positive	Negative	Kappa (k	95% CI	P value
Positive	91	4	0.865	0.759- 0.971	.000
Negative	2	26			

There was nearly perfect agreement between the CXR positive pneumonia diagnosis and LUS positive pneumonia diagnosis, $\kappa = 0.865$ (95% CI, 0.759 to 0.971), $p < 0.0001$. The percentage agreement was at 95.1 % (table 6).

SAMPLE IMAGES

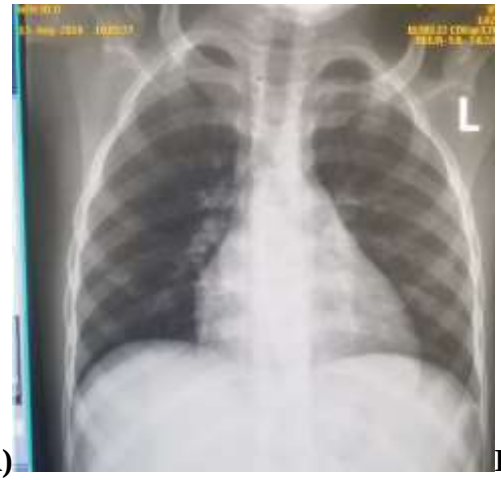
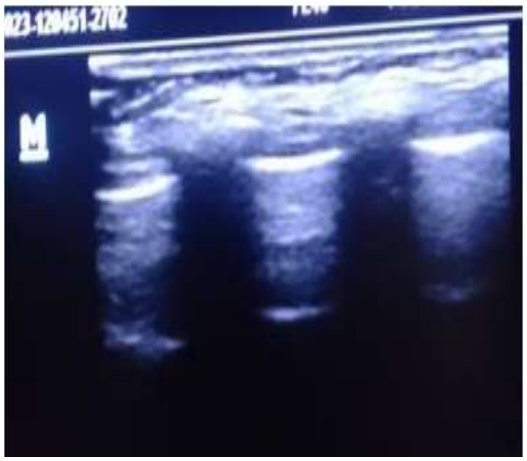
A)  **B)** 

Figure 6: (A case with normal radiological findings): An 8-year-old M who presented with clinical diagnosis of pneumonia. A; shows normal AP chest x-ray findings. B; shows normal lung ultrasound findings.

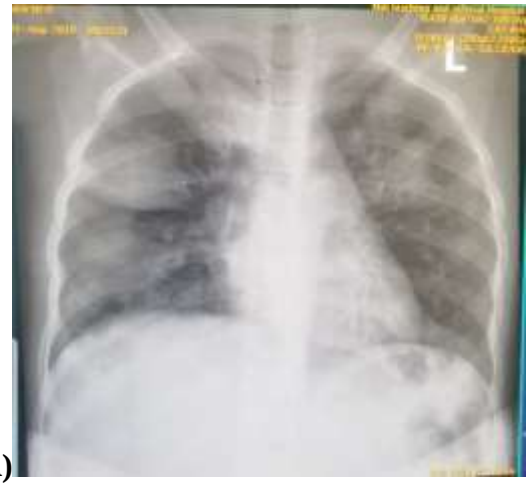
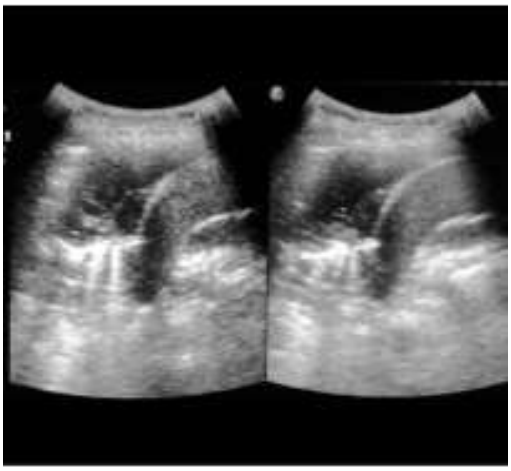
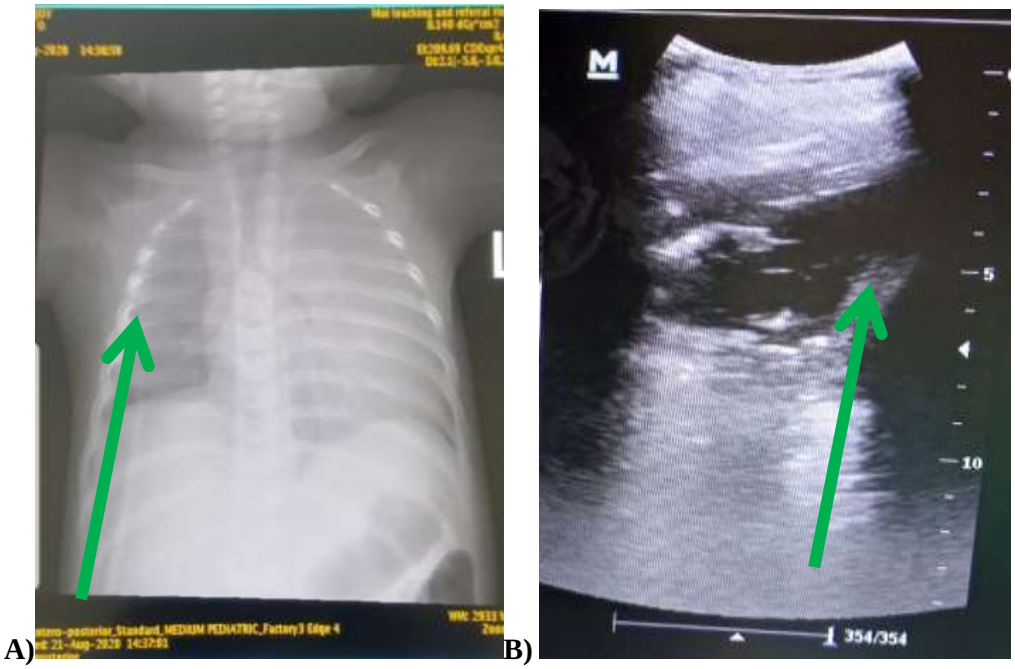
A)  **B)** 

Figure 7: CXR and LUS. A 10-year-old female patient who presented with clinical diagnosis of pneumonia. A; Chest x-ray showing right and left upper lobe consolidation. B; lung ultrasound showing lung consolidation.



A) B)

Figure 8: (A case of consolidation and pleural effusion). A 2-year-old male presented with clinical diagnosis of pneumonia. A; chest radiograph demonstrating left lung consolidation silhouetting the left cardiac border and pleural effusion blunting the left costophrenic angle. B; Lung ultrasonography demonstrates pleural effusion.

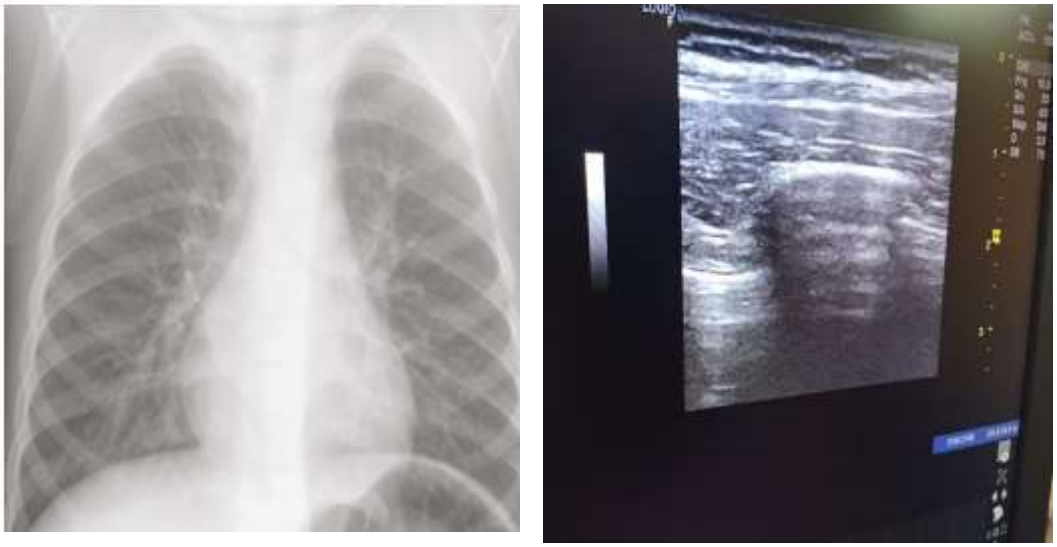
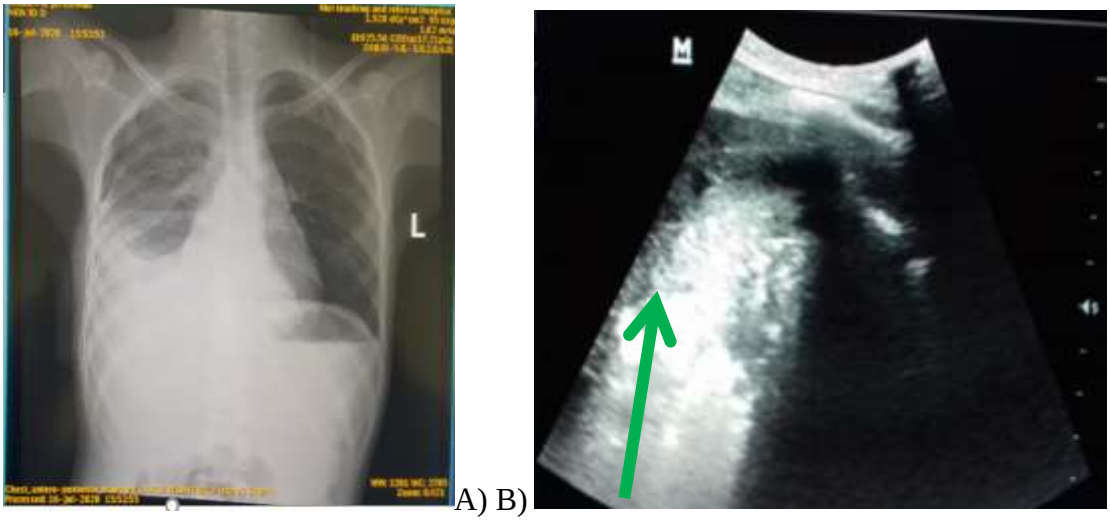


Figure 9: (A case of abnormal CXR and normal LUS) A 7-year-old male, presented with clinical diagnosis of pneumonia. A) CXR demonstrated pulmonary infiltrates B) normal lung ultrasound.



A) B)

Figure 10: (A case of abnormal CXR and LUS) A 4-year-old male, presented with clinical diagnosis of pneumonia. A) CXR demonstrated right sided pleural effusion A) lung ultrasound demonstrates pleural effusion.

CHAPTER FIVE: DISCUSSION

5.1 Introduction

5.2 Demographics

Most patients were female at 76 (61.8 %) while 47 (38.2 %) were male. The median age was 4 (IQR: 3 - 8), this is in keeping with the WHO findings that pneumonia is a major infectious cause of health threat worldwide and a common cause of death in children especially those <5 years of age (Deantonio et al., 2016). This could be owing to the fact that the immune system of children <5 years of age is immature and while most healthy children are able to surmount the infection with their natural defenses, some have compromised immune systems exposing them to a higher chances of acquiring pneumonia (Deantonio et al., 2016).

Our findings concur with those of a retrospective cohort study conducted in China where majority were females at 53 %. On the contrary Hassen et al 2019 conducted a hospital-based study in Ethiopia Hawassa university on 122 children between 3 months and 14 years and found a median age of 10.0 months (IQR: 6.75–24.0), with the majority of the study participants 76 (62.3 %) being male. The difference in these two studies could have come about due to difference in geographical location (Hassen et al., 2019).

5.3 Chest x-ray findings

Majority of the patients 95 (77.2%) had pneumonia with lung consolidation being the most common at 90 (73.2%) cases.

This is in keeping with a study by Caiulo et al, 2013 in Italy who showed abnormal CXR findings in 91% cases with consolidation being the most observed finding at 82.0%. (Caiulo et al., 2013).

Ianniello et al (2016) in Rome, Italy; Biagi et al 2018 in Bologna, Italy in their studies showed abnormal CXR in 83% with consolidation being the most common in 33 (70.2 %) and 24/25 (96 %) cases respectively (Biagi et al., 2018; Ianniello et al., 2016). the proportion being slightly lower than the proportion of 97.8% found in a study in Poland among children with clinically suspected pneumonia.

However, the findings differ with those of Biagi et al (2018) in Italy who found higher cases of consolidation at 96 % and Kelly et al (2016) in Botswana found lower cases of consolidation at 35%. The differences could have been because Kelly did a cohort study on patients under treatment which could have led to patient's recovery hence the reduction in cases with consolidation.

The second most commonly observed feature in the study was pleural effusion accounting for 57 (46.3 %) cases. This was comparable with a study by Caiulo et al 2012 in Italy who found pleural effusion as the second most commonly observed radiographic finding at 33.4% and Ianniello et al 2016 in Rome, Italy where pleural effusion was the second observed feature however the cases of pleural effusion 6 (18.2%) contrasted with the current study because he did a follow up on his patients hence the reduction in cases with pleural effusion.

Pulmonary infiltrates were the third observed feature in 38 (30.9 %) cases. Similarly, Kelly et al (2016) in Botswana demonstrated 42% cases of his study participants with pulmonary infiltrates. On the contrary Caiulo et al 2012 Italy found 9% study participants with pulmonary infiltrates, which was attributable to the CXR projecting gives a summation image resulting from superimposed normal and abnormal or partially affected lobules. Geographical location of the study also explains the differences.

Chest X-ray was positive for pneumonia in 77.2 % (95 out of 123 patients) of the study population. The findings in this current study however differ from those in a study in the southern region of Ethiopia among paediatric patients with severe pneumonia where only 48.4 % of the study participants had radiological evidence of pneumonia (Hassen et al., 2019). Similarly, a low proportion of 44 % of children reviewed in Gambia had radiographic findings indicative of pneumonia (Enwere et al., 2007; Rathman et al., 2003). This is probably because of the study design/methodology and that the study subjects might have had early pneumonia which could not be identified by CXR.

5.4 Lung ultrasound findings

In this study, 93 (75.6%) cases had pneumonia on LUS with subpleural consolidation being the most common in 85 (69.1 %) patients followed by pleural effusion at 63 (51.2 %). This is in keeping with Luri et al 2009 and Pereda et al 2015, who found lung consolidation to be the most observed finding on LUS in their study. This is probably because of the similarity in study design with the present study (Pereda et al., 2015). On the contrary, Yilmaz et al (2017) in Turkey demonstrated subpleural consolidation 142 (95.3%) as the second common feature in their study on point of care lung ultrasound in children with CAP. Chavez et al (2015) did a prospective study in Peru and Nepal and found 15% study participants with subpleural consolidation. Liu et al (2014), in Beijing studies a smaller population of 40 and all had subpleural consolidation at 100%. Giulio et al (2015) in Italy found 92.8% study participants with consolidation. This can be explained that Chavez did longitudinal scans only; no oblique or transverse scans hence decreased the sensitivity of the procedure.

Pleural effusion accounted for 63 (51.2 %). It compares well with a study by Reali et al (2013) who found 50% of study participants to have pleural effusion and contrasts Yilmaz et al (2017) in Turkey who observed 3.4% cases of pleural effusion in his study participants. Liu et al (2014) in Beijing found 20% of study participants to have pleural effusion. Yilmaz conducted the ultrasound with the patient lying in a supine position and on one side (normally the left), which could have made them to err in picking cases of pleural effusion.

Lung ultrasound did not pick pulmonary infiltrates. Similarly, in all other studies none picked pulmonary infiltrates.

5.5 Comparison between chest X-ray and lung ultrasound findings

In the present study, the diagnostic features of LUS in detecting pediatric pneumonia were almost similar to those of CXR. CXR detected about 73.2 % of lung consolidations, 47.2 % of pleural effusion and 30.9 % of pulmonary infiltrates which were all a positive indicator of pneumonia. Lung ultrasound on the other hand detected about 69.1 % of lung consolidation and about 51.2 % of pleural effusion. these findings show that lung consolidation was the most observed finding for the diagnosis of pneumonia in both methods. However, CXR identified a higher percentage of patients with consolidations 90 (73.2 %) as compared to LUS which identified 85 (69.1 %). Similar findings showing high percentage of lung consolidation by Urbankowska et al 2015 were observed, where CXR detected 97.8 % of lung consolidation and 89.0 % were detected by LUS (Urbankowska et al., 2015). Copetti and Cattarossi (2008) in Italy found higher percentages of lung consolidation on CXR at 70% as compared to LUS at 62%. However, contrary to this findings, a study by Ho and colleagues in Taiwan found more consolidations in LUS at 97.5% of the patients compared to 92.6% on CXR, indicating LUS to be more sensitive in

detecting consolidations compared to CXR in their study (Ho et al., 2015). The slight observed variations are likely to be due to the retrospective study done by Ho et al and differences in the observers as the interpretation of US and CXR findings rely more on the interpretation made by the radiologists and how the procedure was conducted..

Kyomuhangi et al, did a study in Uganda on accuracy of LUS in diagnosis of children with pneumonia and the findings differed with the ones in the present study. They demonstrated that LUS identified a higher percentage of patients with consolidations at 149 (59.0 %) compared to CXR which identified 82 (32.5 %). Similarly, studies by Copetti et al and Boursiani et al differed with the present study where a higher percentage of consolidations were detected by LUS compared to CXR. The difference was because there was significant variation in intra and interobserver agreement among radiologists on same CXR images interpretation and features used for diagnosis of pneumonia.

LUS demonstrated pleural effusion in 63 (52.1 %) patients compared to 58 (47.2 %) by CXR in the present study. These findings are comparable to Bazzocchi et al findings in a study to evaluate usefulness of LUS in children suspected to have pneumonia who demonstrated pleural effusion in 15 (46.9%) patients using LUS compared to CXR that showed in 8 (36.4%) patients. Similarly, Urbankowska et al found that pleural effusion was demonstrated by LUS in 54.3 % patients while CXR demonstrated 12.1 % of patients.(Iuri et al., 2009; Urbankowska et al., 2015). This can be explained by the fact that LUS can detect effusions as small as 20 mL while CXR can only detect a volume of 200mL pleural effusion in patients in the orthostatic position with volume decrease in supine position (Prina, Torres, Roberto, & Carvalho, 2014)

5.5.1 Level of agreement between CXR and LUS findings

As shown in table 6 in the present study, the level of agreement between chest radiograph and lung ultrasound in the diagnosis of pneumonia was 95.1% with a Kappa statistic of 0.865 indicating a nearly perfect agreement between the two.

The Cohen kappa coefficient is often used in assessing the level and extent of agreement between two tests whereby a value of greater than 0.81 indicates perfect agreement, whereas a kappa of 0 indicates agreement was by chance (Viera and Garrett 2005)

Similar finding was reported in a study by Urbankowska et al (2015) in Poland (k=0.89) where the study found out that the level of agreement between CXR and LUS in diagnosing pneumonia was nearly perfect (k = 0.89) and accuracy of 95.3 %.

Biagi et al (2018) Italy equally showed a near perfect agreement with a kappa (k = 0.93) and therefore recommended that lung ultrasound could be reliably used an alternative to CXR in diagnosing pneumonia among children.

On the contrary, Stadler et al 20017 in Cape Town, South Africa showed substantial agreement with kappa values of (k = 0.64 to 0.89) the study was a meta-analysis based on bigger populations.

While almost perfect agreement was found in our study for lung consolidation between CXR and US, the study by Smargiassi et al in Rome Italy found no agreement between CXR and US for lung consolidations with there being disagreement in 12 of the 24 patients (Smargiassi et al., 2019). However, the differences might be associated with the differences in the study populations.

5.6 Study limitation

Our study didn’t have a gold standard. CT is the gold standard for diagnosing pneumonia. However, due to the costs and ethical reasons associated with exposure to higher amounts of radiations CT could not be done.

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

1. CXR findings were lung consolidation, pleural effusion and pulmonary infiltrates. Lung consolidation was the commonest radiological finding detected on CXR in children admitted with pneumonia.
2. LUS findings were lung consolidation and pleural effusion. It demonstrated LUS is better in detection of pleural effusion.
3. The level of agreement between LUS and CXR was near perfect with kappa (k=0.86) hence LUS can be used as an alternative to CXR in diagnosis of pneumonia.

6.2 Recommendation

Use of LUS as a diagnostic alternative to CXR based on the near perfect level of agreement demonstrated kappa (k=0.86)

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APPENDICES

Appendix I: Consent Form

English Version

Investigator: My name is Dr Loyce Kwamboka. I am a qualified doctor, registered by the Kenya Medical Practitioners and Dentists Board. I am currently pursuing a Master's degree in Radiology and Imaging at Moi University. I would like to recruit you into my research which is to study the diagnostic accuracy of chest ultrasonography among pediatric patients with pneumonia compared with chest x-ray in Eldoret.

Purpose: this study will aim to compare lung ultrasound and chest radiography findings among pediatric patients with clinical diagnosis of pneumonia at MTRH

Procedure: children presenting with features suggestive of pneumonia referred for chest ultrasound and chest x-ray will be recruited for the study after the consent has been obtained. They will be interviewed by using a structured questionnaire and the chest ultrasound will be performed. Data will be collected on data collection forms. Data collecting material will be kept in a locked cabinet in the office of the principal investigator during the study period.

Benefits: There will be no direct benefits of participating in this study. Study subjects will be accorded same quality of management as non-study subjects

Risks: There are no anticipated risks to the participants attributable to this study.

Confidentiality: All information obtained in this study will be treated with utmost confidentiality and shall not be divulged to any unauthorized person

Rights to Refuse: Participation in this study is voluntary, prospective participants have freedom to decline enrollment or withdraw at any point during the study. This

study has been approved by the Institutional Research and Ethics Committee (IREC) of Moi University/Moi Teaching and Referral Hospital.

Sign or make a mark if you agree to take part in the study

Parent/Guardian: …… Investigator: ……... Date:

Swahili Consent Form

Mtafiti: Jina langu ni Dkr Loyce Kwamboka William. Mimi nidaktarialiyehitimu nakusajiliwa na bodi ya Kenyaya Madaktari naMadaktari wa meno.Kwa sasanatafutashahada ya uzamili katikaRadiologiana ImagingkatikaChuo Kikuu cha Moi.Ningependakusajili mtoto wakokatikautafiti wanguambao ni wa kujifunza usawa wa matokeo ya ultrasonograf ya kifua katika watoto wanaojitokeza katika MTRH wakiwa na ugonjwa wa pneumonia.

Kusudi: Utafiti huu utachunguza usawa wa matokeo ya ultrasonograf na xrayya kifua katika watoto walio na ugonjwa wa pneumonia.

Utaratibu: Watoto,wazazi na/au walezi wao wataelimishwa kuhusu ugonjwa wa pneumonia. Watoto watatayarishwa kwa ajili ya utafiti wa ultrasonograf na xray ya kifua baada ya idhini kupatikana. Watashughulikiwa kwa kutumia dodoso la muundo na ultrasonograf itafanyika. Data zitakusanywa kwenye fomu za ukusanyaji data. Hifadhi zitakazotumika katika ukusanyaji wa data zitawekwa katika kabati iliyofungwa na mpelelezi mkuu katika kipindi cha utafiti.

Faida: Hakutakuwa na faida ya moja kwa moja ya kushiriki katika utafiti huu. Wanaofanyiwa utafiti watakuwa na haki na kupewa matibabu sawa na wale ambao hawatahusishwa na utafiti huu.

Hatari: Hakuna hatari inayotarajiwa kwa washiriki inayotokana na utafiti huu.

Usiri: Habari zote zitakazopatikana katika utafiti huu zitawekwa kwa usiri mkubwa na wala hazitatolewa kwa mtu yeyote asiyehusika na utafiti.

Haki za Kuepuka: Kushiriki katika utafiti huu ni kwa hiari yako, kuna uhuru wa kukataa kusajiliwa au kutoka wakati wowote. Utafiti huu umepitishwa na Utafiti wa

Taasisi na Kamati ya Maadili (IREC) ya Chuo Kikuu cha kufundishia Moi na Hospitali ya Rufaa.

Tia sahihi au kufanya alama kama unakubali kushiriki katika utafiti

Mgonjwa: .....Mpelelezi: ..... Tarehe: .....

Appendix II: Assent Form
English version

Information

This informed assent form is for above 7 years of age who have clinical diagnosis of pneumonia and are scheduled for lung ultrasound and chest radiograph.

What is medical research?

Medical research is when doctors collect information to get new knowledge about disease or illness. This helps doctors find better ways of treating diseases and helping children or people who are sick.

What is this research study about?

A study will be conducted on children below 14 years of age with clinical suspicion of pneumonia where the participant's lung ultrasound findings will be compared to chest x-ray findings. This information will influence the consideration of lung ultrasound use as an alternative to CXR in the diagnosis of pediatric pneumonia. This will be of help for children by avoiding radiation exposure.

Who is doing this research?

My name is Dr Loyce Kwamboka William and I'm a medical doctor. I'm currently studying for my second degree (Masters in Medicine) in Radiology & Imaging at Moi University.

What will happen to me in this study?

I will invite you to be part of this study. If you agree to participate in this study, your x-rays and ultrasounds will be reviewed, and pneumonia findings recorded. You will then be followed up and treatment initiated.

There are no risks or benefits of participating in this study and you will be given the same medical care as the children who are not in the study. You can choose whether or not you would like to participate in the study. I have discussed this with your parent(s)/ guardian(s) and they know we are asking for your permission to be part of the study. In case you refuse to be part of the study you will not be forced to even if your parents agreed for you to participate.

In case of any questions, feel free to ask, I will be happy to assist.

Certificate of assent

Do you understand this research study and are willing to take part in it?

Yes: ……... No: ……...

Has the researcher answered all your questions?

Yes: ……... No: ……...

Do you understand that you can pull out of the study at any time?

Yes: ……. No: …….

I agree to take part in the study.

OR

I do not wish to take part in the study and I have not signed the assent below.

_____

Only if child assents:

Name of child _____

Child's thumb print:

Date: _____

Kiswahili version

Fomu hii ya idhini ni ya watoto walio umri wa miaka chini ya kumi na nne ambao wameonwa na daktari na ugonjwa wa pneumonia kugundulika.

Utafiti wa matibabu ni nini?

Utafiti wa matibabu ni wakati madaktari wanapopata taarifa ili kupata ujuzi mpya kuhusu magonjwa. Hii husaidia madaktari kupata njia bora za kutibu magonjwa na kusaidia watoto au watu ambao ni wagonjwa.

Utafiti huu unahusu nini?

Utafiti huu unahusisha watoto walio na ugonjwa wa pneumonia. Katika utafiti huu, ugonjwa wa pneumonia kwenye x-ray utafananishwa na katitaka ultrasound ya kifua ili kuamua kama ultrasound ya kifua inaeza tumika kwa niaba ya xray. Hii itakuwa ya manufaa kwa watoto kwa kuwa hakutakuwa na radiations kutokana na ultrasound.

Nani anafanya utafiti huu?

Jina langu ni Dkt. Loyce Kwamboka William na mimi ni daktari aliyehitimu. Kwa sasa ninajifunza kwa shahada yangu ya pili (Masters in Medicine) katika Radiologia & Imaging katika Chuo Kikuu cha Moi.

Nini kitatokea kwangu katika utafiti huu?

Nitakualika kushiriki katika utafiti huu. Iwapo utakubali, matokeo yako ya x-ray na ultrasound yataangaliwa na kurekodiwa. Baada ya huu utafiti matibabu yataanzishwa katika ward ya watoto.

Hakuna hatari au faida za kushiriki katika utafiti huu na utapewa huduma sawa ya matibabu kama watoto ambao hawatashiriki kwenye utafiti. Unaweza kuchagua kama ungependa kushiriki katika utafiti huu. Nimezungumza na mzazi na/au mlezi wako na

anajua tunaomba ruhusa yako kushiriki katika utafiti. Ikiwa unakataa kuwa sehemu ya utafiti huwezi kulazimishwa hata kama wazazi wako walikubali kushiriki.

Ikiwa kuna maswali yoyote, jisikie huru kuuliza, nitafurahia kusaidia.

Hati ya kukubali

Je unaelewa utafiti huu na uko tayari kushiriki?

Ndio: ..... La: .....

Je, mtafiti alijibu maswali yako yote?

Ndio: ..... La: .....

Je unaelewa kwamba unaweza kuondoka kwa utafiti huu wakati wowote?

Ndio: ……. La: ……

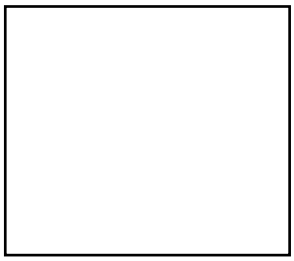
Nakubali kushiriki katika utafiti huu

AU

Sitaki kushiriki katika utafiti huu na sijasaini idhini hii _____

Ikiwa tu mtoto ataidhinisha:

Jina la mtoto: ……...

Alama ya kidole cha mtoto: 

Tarehe: ……

Appendix III: Data Collection Form

Instructions

1. All sections to be filled accordingly.

2. Writings should be clear and legible.

3. To be filled in by the principal investigator or assistant once the patient's parent or guardian has given consent for their child to be involved in the study and assent obtained children aged below 14 years.

IP/OP No: ……

Serial No: ……...

Date: ……...

PART 1: DEMOGRAPHIC DATA

1. DOB/ Age …….....

2. Gender ……

3. Residence ……...

4. Contact No: ……...

PART 2: RADIOLOGICAL FINDINGS

SECTION A: Chest X-ray findings

Lung consolidation……

Pleural effusion…….

Pulmonary infiltrates…….

Normal ……..

SECTION B: Chest ultrasound findings

Lung consolidation…….

Pulmonary infiltrates……

Pleural effusion…….

Normal……

Appendix IV: IREC Approval

MU/MTRH-INSTITUTIONAL RESEARCH AND ETHICS COMMITTEE (IREC)

MOI TEACHING AND REFERRAL HOSPITAL
P.O. BOX 3
ELDORET
Tel: 33471/2/3

MOI UNIVERSITY
COLLEGE OF HEALTH SCIENCES
P.O. BOX 4606
ELDORET

Reference: IREC/2018/325
Approval Number: 0003208

31st January, 2019

Dr. Kwamboka Loyce William,
Moi University,
School of Medicine,
P.O. Box 4606-30100
ELDORET-KENYA.

INSTITUTIONAL RESEARCH & ETHICS COMMITTEE
31 JAN 2019
APPROVED
P. O. Box 4606-30100 ELDORET

Dear Dr. Kwamboka,

RE: FORMAL APPROVAL

The MU/MTRH- Institutional Research and Ethics Committee has reviewed your research proposal titled: -

"Comparison between Lung Ultrasonography and Chest Radiography Findings among Children with Pneumonia at Moi Teaching and Referral Hospital".

Your proposal has been granted a Formal Approval Number: ***FAN: IREC 3208*** on 31st January, 2019. You are therefore permitted to begin your investigations.

Note that this approval is for 1 year; hence will expire on 30th January, 2020. If it is necessary to continue with this research beyond the expiry date, a request for continuation should be made in writing to IREC Secretariat two months prior to the expiry date. You will be required to submit progress report(s) on application for continuation, at the end of the study and any other times as may be recommended by the Committee.

Furthermore, you must notify the Committee of any proposal change (s) or amendment (s), serious or unexpected outcomes related to the conduct of the study, or study termination for any reason. You will also be required to seek further clearance from any other regulatory body/authority that may be appropriate and applicable to the conduct of this study.

Sincerely,

DR. S. NYABERA
DEPUTY-CHAIRMAN
INSTITUTIONAL RESEARCH AND ETHICS COMMITTEE

cc CEO - MTRH Dean - SOP Dean - SOM
Principal - CHS Dean - SON Dean - SOD

Appendix V: Hospital Approval

An ISO 9001:2015 Certified Hospital

MOI TEACHING AND REFERRAL HOSPITAL

Telephone :(+254)053-2033471/2/3/4
Mobile: 722-201277/0722-209795/0734-600461/0734-683361
Fax: 053-2061749
Email: ceo@mtrh.go.ke/directorsofficemtrh@gmail.com

Nandi Road
P.O. Box 3 – 30100
ELDORET, KENYA

Ref: ELD/MTRH/R&P/10/2/V.2/2010

6th February, 2019

Dr. Kwamboka Loyce William,
Moi University,
School of Medicine,
P.O. Box 4606-30100,
ELDORET-KENYA.

APPROVAL TO CONDUCT RESEARCH AT MTRH

Upon obtaining approval from the Institutional Research and Ethics Committee (IREC) to conduct your research proposal titled:-

"Comparison between Lung Ultrasonography and Chest Radiography Findings among Children with Pneumonia at Moi Teaching and Referral Hospital".

You are hereby permitted to commence your investigation at Moi Teaching and Referral Hospital.

MOI TEACHING AND REFERRAL HOSPITAL
CEO
APPROVED
06 FEB 2019
P. O. Box 3 - 30100, ELDORET

06/02/2019
DR. WILSON K. ARUASA, *MBS*
CHIEF EXECUTIVE OFFICER
MOI TEACHING AND REFERRAL HOSPITAL

cc - Senior Director, (CS)
- Director of Nursing Services (DNS)
- HOD, HRISM