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Research Article

Comparative Study of Lung Ultrasound Patterns of Clinically Diagnosed Severe Pneumonia and Acute Chest Syndrome among Pediatric Sickle Cell Anemia Patients at Mulago Hospital

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Abstract

Background: Acute chest syndrome (ACS) and severe pneumonia are both common potentially lethal conditions among sickle cell anemia (SCA) pediatric patients. However, both conditions are clinically and radiographically indistinguishable which results in delayed patient diagnosis and management. In this study we compared Lung ultrasound (LUS) patterns among admitted pediatric SCA patients clinically diagnosed with ACS and severe pneumonia at Mulago Hospital.

Methods: This was a comparative cross-sectional study and enrolled 178 admitted SCA pediatric patients below 18 years clinically diagnosed with ACS and severe pneumonia. The study was conducted at ward 16 A Mulago Hospital, Uganda between November 2023 to April 2024. Patient clinical assessment, chest x-ray and LUS were done for all children within 24 hrs of admission. Imaging findings on LUS among the two clinical groups were compared and so were CXR findings. Bivariate and multivariate analysis was done using a modified Poisson model and prevalence ratios at 95% confidence intervals were reported.

Results: All the 178 enrolled children had complete data available for analysis. Overall, (71.4%), were clinically diagnosed with ACS while (28.6%), had severe pneumonia. LUS features among children with clinically diagnosed with ACS included; normal findings (3.1%), mild basal bilateral anechoic pleural effusion (1.6%), pleural thickening (39.4%), diffuse B lines (80.3%), pleural irregularity (88.2%), and subcentimeter consolidations (22.0%). LUS features among admitted pediatric SCA patients clinically diagnosed with severe pneumonia included; mixed pattern (70.6%), consolidation (76.5%), pleural thickening (31.4%), mild to moderate echogenic bilateral basal pleural effusion (37.3%), diffuse B lines (90.2), and pleural irregularity (92.0%).

Conclusion: Lung ultrasound can be considered an add on tool to physical examination in evaluation of pediatric SCA patients with a normal chest radiograph who are clinically diagnosed with severe pneumonia or ACS.

Keywords: *Clinically Diagnosed Acute Chest Syndrome; Clinically Diagnosed Severe Pneumonia; Lung Ultrasound; Pediatrics; Sickle Cell Anemia*

Abbreviations

ACS: Acute Chest Syndrome; CXR: Chest x-ray; LUS: Lung Ultrasound Scan; SCA: Sickle cell anemia; SCD: Sickle cell disease; SPARCo: Sickle Pan-African Research Consortium; SSA: Sub-Saharan Africa; WHO: World Health Organization

Introduction

Sickle cell anemia (SCA) is a severe form of sickle cell disease (SCD) the most prevalent childhood genetic blood disorder [1], in sub-Saharan Africa (SSA) with over 75% cases; and Uganda has one of the highest prevalence at 0.7% [2]. Acute chest syndrome (ACS) is a common potentially lethal complication reported in up to 20% of hospitalized SCA patients due to pulmonary microvascular occlusion [3]. Splenic microvascular occlusion among SCA patients often results into; splenic infarction, functional asplenia, antibody production dysfunction, and poor opsonophagocytosis. Hence increased predisposition to recurrent encapsulated bacterial infections especially *Streptococcus pneumoniae* as compared to healthy peers. This in turn also increases the risk of ACS [4], defined by high morbidity and mortality rates especially in children under the age of 5 years [3]. Plain chest radiograph is the gold standard imaging tool for both ACS and severe pneumonia; however, it's utility is often limited to complicated cases [5], and is the current practice at Mulago Hospital. Despite preventive and therapeutic measures in place, both clinical conditions account for more than 90% morbidity and mortality rates among SCA children < 5 years of age [6].

Currently at Mulago Hospital, diagnosis of the two conditions is based on a high clinical index of suspicion. This entails clinical history, physical examination, blood tests and at times chest radiography [7]. The Sickle Pan-African Research Consortium (SPARCo) standards of care for SCD in SSA [8], is used to diagnose ACS based on clinical presentation with acute onset of chest pain, signs and symptoms of lower respiratory tract disease with or without fever. The management of ACS as per the protocol includes; oxygen therapy, blood transfusion, intravenous cephalosporin and oral macrolide. While severe pneumonia is clinically diagnosed based on World Health Organization (WHO), 2014 guidelines among patients with cough or respiratory distress, plus one or more of the general danger signs, such as: fever, inability to drink; persistent vomiting; convulsions; lethargy; unconsciousness; stridor; severe malnutrition; central cyanosis; or hypoxemia. The management of severe pneumonia among SCA children as per the protocol includes intravenous cephalosporin [9]. However, the two conditions are both clinically and radiographically indistinguishable hence posing a diagnostic challenge. Furthermore, chest x-ray has a relatively low accuracy in children [8], and even lower in critically ill patients [10]. This often results in delayed appropriate timely management of ACS which is potentially more lethal than severe pneumonia [7]. This also predisposes patients to prolonged hospitalization, increased risk of respiratory failure and chronic lung disease. In order to maximize patient survival, the two conditions are medically managed differently [8]. Hence the need for an imaging modality with ability to differentiate the two conditions apart.

Aim of the Study

The main aim of this study was to compare lung ultrasound patterns among admitted pediatric SCA patients clinically diagnosed with ACS and severe pneumonia at Mulago Hospital. This was to bridge the knowledge gap between the use of LUS in our low resource settings as a differentiating tool for the two clinical conditions. Hence aiding clinicians in correlation of abnormal LUS findings with prompt diagnosis and appropriate management of both illnesses.

Materials and Methods

This was a cross-sectional study conducted at ward 16 A of Mulago hospital, Kampala, Uganda. A total of 178 children aged < 18 years admitted with a clinical diagnosis of ACS or severe pneumonia established by a pediatrician on ward 16 A within the last 24 hours were identified and prospectively enrolled between November 2023 to April 2024. Relevant medical history was obtained by qualified research

assistants to help with the inclusion criteria. The parent or guardian of the patient was informed about the study in a language he or she understood best. Informed written consent to include the patient in the study was sought together with relevant socio-demographic information and recorded in the data collection tool.

Each study participant had a CXR (posterior-anterior or anterior-posterior views) performed within 24 hours of admission at the department of radiology at Mulago Hospital using a fixed digital x-ray machine (Model: Digital diagnoist, Manufacturer: Philips, Tube model: SRO33100ROT380, Serial: 254664). CXR was performed to rule out complications requiring intervention or prolonged antibiotic therapy (e.g. effusion, abscess) or findings suggestive of certain etiologies (e.g. pneumatoceles in staphylococcal pneumonia). The films were interpreted by an independent radiologist (author JK with either author GE or FA) in accordance with the WHO criteria for the standardized interpretation of pediatric chest radiographs. If there was a disagreement, a third reader blinded to the initial reports adjudicated. In addition, all radiologists were blinded to LUS findings.

Lung ultrasound was carried out independently within 24 hours of admission by the principal investigator with the guidance of a consultant radiologist who was blinded to the CXR findings. LUS was performed using an Edan U60 diagnostic portable ultrasound machine, with a high frequency and resolution, 7 - 12 MHz, linear array transducer. The scanning technique followed a standardized protocol in both transverse and longitudinal orientations. The chest wall was divided into 6 anatomical regions; anterior, lateral, and posterior lung fields. The anterior region was between the sternal border and the anterior axillary line. The lateral region was between the anterior axillary line and the posterior axillary line. The posterior region was between the vertebral column and the posterior axillary line. Each region was further divided into upper and lower regions. The anterior and lateral regions were examined in supine position with the shoulders fully straightened on the sides, the posterior regions in a sitting up or lateral decubitus positions or their parents' shoulders or while breastfeeding (for the younger babies), to minimize anxiety. The lung was visualized through an intercostal window with the probe placed perpendicular, oblique and parallel to the ribs in the 12 regions [11]. Additional views through the subcostal and intercostal acoustic windows of the liver and the spleen were used to study the lung base and pleural effusion. Diaphragmatic motion was evaluated using intercostal and subxiphoid approaches. Images through the sternum were used to examine the superior anterior mediastinum. In some cases, color Doppler ultrasound was used to evaluate the vascularity of the lung lesions. Results were recorded as positive or negative for the presence of consolidated lung, air bronchograms (dynamic, adynamic), shred sign, tissue like sign, >3 B lines and pleural effusion. Sonographic findings of consolidated lung were characterized by hypoechogenic area of varying size and shape with poorly defined borders containing hyperechoic air bronchograms [6]. Video clips were saved digitally for quality assurance and review by the expert radiologist. The expert radiologist reviewed all studies and was blinded to any previous interpretation. Both investigations were done in the same setting (i.e. one after the other) LUS at pediatric ward 16 A, using a portable machine, and the patients were taken to the radiology department for CXR.

Informed consents were obtained from the participants or parents/guardians who were anonymized. The ethical approval was sought from both the Radiology and Pediatrics departments of Mulago Hospital and the ethical and research committees of School of Medicine of Makerere University (SOMREC) and Mulago hospital. (Mak-SOMREC Study approval number-2023-747). Data from completed questionnaires were entered into a database designed using Epi Info™ software (V7.2, 1600 Clifton Road Atlanta, GA 30329-4027 USA) and analysis was performed with Stata software (v.14, College Station, Texas, USA). Descriptive statistics were generated for participants' characteristics.

The collected data from the study collection tool was double entered using Epidata version 3.1 with range and consistency checks done. Regression analysis using a modified Poisson model was used to determine the association between LUS and CXR findings with a clinical diagnosis of ACS and severe pneumonia. Bivariate analysis was done using Pearson's chi square test and variables with P value

< 0.25 were considered for multivariate analysis. Multivariate analysis was logically done using the backward elimination method and variables that had a P value < 0.05 were considered to have a significant statistical association with a clinical diagnosis of ACS or severe pneumonia. The results were reported as prevalence ratios at 95% confidence interval. Continuous data was summarized using mean and standard deviations, categorical data using proportions and frequencies.

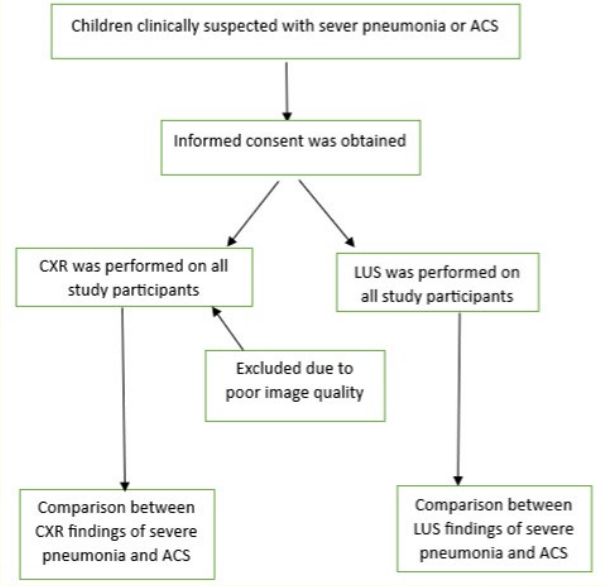

Figure 1: *Study flow chart.*

Results

A total of 178 children aged below 18 years met the inclusion criteria and had complete data available for analysis. 127 (71.4%), were clinically diagnosed with ACS while 51 (28.6%), were clinically diagnosed with severe pneumonia as shown in figure 2.

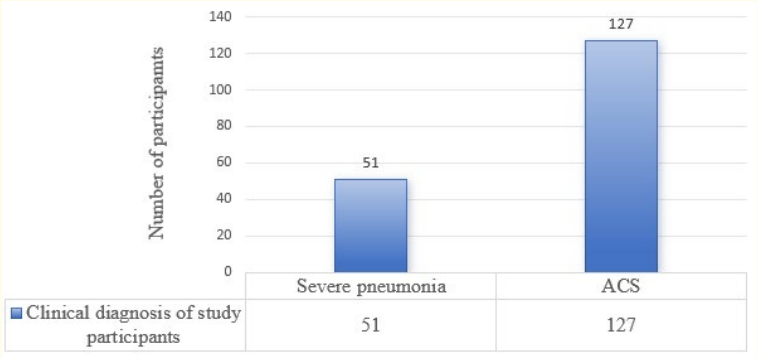

Figure 2: *Bar graph showing the clinical diagnosis of 178 study participants.*

The mean age of the participants enrolled was 7.6 (SD ± 4.6) years with nearly equal sex distribution, (90/178 females, 50.6%), 97.8% were immunized and 94.4% had no chronic illnesses as shown in table 1 and 2 respectively.

Variables	Freq N=178	% (95%CI)	Clinically diagnosed ACS n (%)	Not Clinically diagnosed ACS n (%)	Chi p-value
Age (years) [Mean], SD	178	7.6 (4.6)	7.87 (4.79)	7.04 (4.11)	0.2794
Age (years)					
<1					
1-5	2	1.1 (0.27-4.42)	2 (100)	0 (0.0)	
6-10	65	36.5 (30.8-45.0)	41 (63.1)	24 (36.9)	
>10	58	32.6 (25.5-39.3)	42 (72.4)	16 (27.6)	
	53	29.8 (22.9-36.4)	24 (45.3)	29 (54.7)	
Sex					
Male	88	49.4 (42.1-56.8)	57 (64.8)	31 (35.2)	0.055
Female	90	50.6 (43.2-57.9)	70 (77.8)	20 (22.2)	
Full /up to date immunization					
Yes	174	97.8 (94.1-99.2)	123 (70.7)	51 (29.3)	0.200
No	4	2.2 (0.84-5.9)	4 (100)	0	
Chronic Illness					
Absent	168	94.4 (89.8-96.9)	121 (72.0)	47 (28.0)	0.414
Present	10	5.6 (3.03-10.2)	6 (60.0)	4 (40.0)	

Table 1: *Bivariate analysis of the social demographics of the study participants clinically diagnosed with ACS.*

Variables	Freq N=178	% (95%CI)	Clinically diagnosed severe pneumonia n (%)	Not Clinically diagnosed severe pneumonia n (%)	Chi p-value
Age (years) [Mean], SD	178	7.6 (4.6)	7.04 (4.11)	7.87 (4.79)	0.2794
Age (years)					
<1					
1-5	2	1.1 (0.27-4.42)	0 (0.0)	2 (100)	
6-10	65	36.5 (30.8-45.0)	24 (36.9)	41 (63.1)	
>10	58	32.6 (25.5-39.3)	16 (27.6)	42 (72.4)	
	53	29.8 (22.9-36.4)	29 (54.7)	24 (45.3)	
Sex					
Male	88	49.4 (42.1-56.8)	31 (35.2)	57 (64.8)	0.055
Female	90	50.6 (43.2-57.9)	20 (22.2)	70 (77.8)	
Full/up to date immunization					
Yes					
No	174	97.8 (94.1-99.2)	51 (29.3)	123 (70.7)	0.200
	4	2.2 (0.84-5.9)	0	4 (100)	
Chronic Illness					
Absent	168	94.4 (89.8-96.9)	47 (28.0)	121 (72.0)	0.414
Present	10	5.6 (3.03-10.2)	4 (40.0)	6 (60.0)	

Table 2: *Bivariate analysis of the social demographics of the study participants clinically diagnosed with severe pneumonia.*

The mean respiratory rate of all enrolled patients clinically diagnosed with severe pneumonia was 27.6 (SD ± 6.5) breaths per minute. All the variables of patients had statistical significance (P value <0.05) as shown in table 3.

Variable	Freq N= 178	% (95%CI)	Clinically diagnosed severe pneumonia n (%)	Not clinically diagnosed severe pneumonia n (%)	Chi p-value
Fever	124	69.7 (62.4-76.0)	49 (39.5)	75 (60.5)	0.001
Respiratory rate, Mean (SD)	178	27.6 (6.5)	29.3 (6.2)	26.9 (6.6)	0.027
Cough	79	44.4 (37.2-51.8)	51 (64.6)	28 (35.4)	0.001
SPO_2 (<95%)	107	60.1 (52.6-67.1)	38 (35.5)	69 (64.5)	0.013
Intercostal-recession	41	23.0 (17.4-29.9)	37 (90.2)	4 (09.8)	0.001
Chest Wall drawing	38	21.4 (15.9-28.0)	34 (89.5)	4 (10.5)	0.001
Altered mentation	4	2.2 (1.0-05.9)	3 (75.0)	1 (25.0)	0.038
Inability to feed	15	08.4 (5.1-13.6)	14 (93.3)	1 (06.7)	0.001
Chest pain	142	79.9 (73.2-85.1)	18 (12.7)	124 (87.3)	0.001

Table 3: *Bivariate analysis of the clinical features of the study participants clinically diagnosed with severe pneumonia.*

The mean respiratory rate of all enrolled patients clinically diagnosed with ACS was 27.6 (SD ± 6.5) breaths per minute. All the variables had statistical significance (P value < 0.05) as shown in table 4.

Variable	Freq N= 178	% (95%CI)	Clinically diagnosed ACS n (%)	Not clinically diagnosed ACS n (%)	Chi p-value
Fever	124	69.7 (62.4-76.0)	75 (60.5)	49 (39.5)	0.001
Respiratory rate, Mean (SD)	178	27.6 (6.5)	26.9 (6.6)	29.3 (6.2)	0.027
Cough	79	44.4 (37.2-51.8)	28 (35.4)	51 (64.6)	0.001
SPO_2 (<95%)	107	60.1 (52.6-67.1)	69 (64.5)	38 (35.5)	0.013
Intercostal-recession	41	23.0 (17.4-29.9)	4 (09.8)	37 (90.2)	0.001
Chest Wall drawing	38	21.4 (15.9-28.0)	4 (10.5)	34 (89.5)	0.001
Altered mentation	4	2.2 (1.0-05.9)	1 (25.0)	3 (75.0)	0.038
Inability to feed	15	08.4 (5.1-13.6)	1 (06.7)	14 (93.3)	0.001
Chest pain	142	79.9 (73.2-85.1)	124 (87.3)	18 (12.7)	0.001

Table 4: *Bivariate analysis of the clinical features of the study participants clinically diagnosed with ACS.*

In multivariate analysis, the odds of having a diagnosis of severe pneumonia on LUS were 2.76 times higher among children with intercostal recession as compared to those without and this had statistical significance with a P-value of < 0.001; The odds of having a diagnosis of severe pneumonia on LUS were 0.42 times lower among children with chest pain as compared to those without and this had statistical significance with a P-value of < 0.001; The odds of having a diagnosis of ACS on LUS were 0.28 times lower among children with intercostal recession as compared to those without and this had statistical significance with a P-value of < 0.01; The odds of having a diagnosis of ACS on lung ultrasound were 4.78 times higher among children with chest pain as compared to those without and this had statistical significance with a P-value of < 0.01 as shown in table 5.

Variable	Severe Pneumonia		Acute chest syndrome	
	Crude PR (95% CI)	Adjusted PR (95% CI)	Crude PR (95% CI)	Adjusted PR (95% CI)
Fever	10.7 (2.68-12.5) **	3.22 (0.95-10.9)	0.62 (0.54-0.73) ***	
SPO_2 (<95)	1.94 (1.11-3.38) *		0.79 (0.66-0.94) *	
Intercostal recession	8.83 (5.31-14.7) ***	2.76 (1.59-4.75) ***	0.11 (0.04-0.28) ***	0.28 (0.11-0.70) **
Chest Wall drawing	7.37 (4.65-11.7) ***		0.12 (0.05-0.30) ***	
Altered mentation	2.72 (1.47-5.04) ***		0.35 (0.06-1.89)	
Inability to feed	4.11 (3.00-5.63) ***		0.09 (0.01-0.58) *	
Chest pain	0.14 (0.09-0.22) **	0.42 (0.27-0.66) ***	10.5 (3.52-31.1) ***	4.78 (1.67-9.70) **
NOTE: PR, Prevalence Ratio * p<0.05 ** p<0.01 *** p<0.001				

Table 5: *Multivariate analysis of the clinical features of the study participants clinically diagnosed with ACS and severe pneumonia.*

Abnormal lung ultrasound features were noted among 51 children clinically diagnosed with severe pneumonia as shown in table 6.

Radiological finding	Freq (n)	% (95%CI)	Severe pneumonia n (%)	Not Severe pneumonia n (%)	Chi p-value
Consolidation	67	38.5 (31.5-46.0)	39 (58.2)	28 (41.8)	0.001
B-lines	148	85.1 (78.9-89.7)	46 (31.1)	102 (68.9)	0.221
Mixed	62	35.6 (28.8-43.1)	36 (58.1)	26 (41.9)	0.001
Pleural effusion	21	12.1 (7.96-17.9)	19 (90.5)	2 (9.52)	0.001
Pleural irregularity	159	91.4 (86.1-94.8)	47 (29.6)	112 (70.4)	0.814
Pleural thickening	66	37.9 (31.0-45.4)	16 (24.2)	50 (75.8)	0.251

Table 6: *Bivariate analysis of the lung ultrasound findings of the study participants clinically diagnosed with severe pneumonia.*

Abnormal LUS features were noted among 123 children with clinically diagnosed ACS as shown in table 7.

Radiological finding	Freq (n)	% (95%CI)	ACS n (%)	No ACS n (%)	Chi p-value
Consolidation	67	38.5 (31.5-46.0)	28 (41.8)	39 (58.2)	0.001
B-lines	148	85.1 (78.9-89.7)	102 (68.9)	46 (31.1)	0.221
Mixed	62	35.6 (28.8-43.1)	26 (41.9)	36 (58.1)	0.001
Pleural effusion	21	12.1 (7.96-17.9)	2 (9.52)	19 (90.5)	0.001
Pleural irregularity	159	91.4 (86.1-94.8)	112 (70.4)	47 (29.6)	0.814
Pleural thickening	66	37.9 (31.0-45.4)	50 (75.8)	16 (24.2)	0.251

Table 7: *Bivariate analysis of the lung ultrasound findings of the study participants with clinically diagnosed ACS.*

In multivariate analysis, the odds of diagnosing severe pneumonia with LUS were 1.5 times higher among patients with pleural effusion as compared to those without. PR = 1.50 (95% CI; 1.04 - 2.15, P = <0.05) as shown in table 8.

Variable	Severe Pneumonia		Acute chest syndrome	
	Crude PR (95% CI)	Adjusted PR (95% CI)	Crude PR (95% CI)	Adjusted PR (95% CI)
LUS				
Consolidation	5.19 (2.92-9.19) ***	1.14 (0.59-2.22)	0.47 (0.35-0.62) ***	1.38 (0.91-2.10)
Pleural effusion	2.87 (2.00-4.10) ***	1.50 (1.04-2.15) *	0.12 (0.03-0.45) **	0.50 (0.18-1.36)
Mixed	4.34 (2.58-7.28) ***	1.24 (0.85-1.81)	0.48 (0.36-0.66) ***	0.75 (0.50-1.12)
NOTE: PR, Prevalence Ratio * p<0.05 ** p<0.01 *** p<0.001				

Table 8: *Multivariate analysis of the lung ultrasound findings of the study participants.*

Discussion

A total of 178 study participants were enrolled and the majority were aged between 1 to 5 years with a mean age of 7.6 (SD ± 4.6) years and a slight female predilection 90 (50.6%). This could be due to the underdeveloped childhood host immune defense mechanism with increased susceptibility to infections among children in this age bracket (WHO, 2014). However, Platt., *et al*. [12], documented that more males are affected by ACS compared to females possibly due to slightly higher fetal hemoglobin (Hb F) levels among female patients compared to males. Hb F and estrogen both have a partially protective effect against recurrent episodes of ACS due to associated increased nitric oxide bioavailability (a potent vasodilator) from chemical oxidation of hydroxyurea [13]. However, in this study we were unable to test this hypothesis as the use of hydroxyurea therapy was not assessed. In this study, the majority of patients 174 (97.8%), were fully immunized or had immunization up to date which is protective against frequent childhood severe infections such as Streptococcus pneumoniae. However, since no patient immunization card was reviewed, we are not certain if pneumococcal conjugate vaccine was among the vaccines the participants had received. The minority of patients 10 (5.6%), had chronic illnesses which included; HIV infection (2), asthma (3) and malnutrition (5). Comorbidities usually further suppress the host immune system with fatal outcome [14]. All the baseline demographic characteristics of the patients did not differ much as all the variables had no statistical significance with p-values >0.05.

In this study, patients clinically diagnosed with ACS were 127 (71.4%), and the majority had fever (59.1%), hypoxemia (54.3%), and acute chest pain (97.6%), as similarly noted by Vichinsky., *et al* [3]. However, some of the patients initially presented with vaso-occlusive crisis in the limbs and later progressed to develop clinical features of ACS as was similarly noted by Styles., *et al* [15]. In this study, patients clinically diagnosed with severe pneumonia were 51 (28.6%), all had cough and most also had features of difficulty in breathing. This was in agreement with (WHO, 2014), diagnostic criteria for clinically diagnose severe pneumonia in resource constrained areas where CXR and laboratory services are not readily available. However, in both categories of patients, only intercostal recession and chest pain had statistical significance at both bivariate and multivariate analysis. However, intercostal recession strongly favored a diagnosis of severe pneumonia over ACS while chest pain strongly favored a diagnosis of ACS over severe pneumonia.

Lung ultrasound patterns among pediatric SCA patients clinically diagnosed with ACS

Normal LUS findings were noted among 4 (3.1%), patients. This could be secondary to lesions with no pleural surface contact such as in the perihilar area as similarly noted by Iuri., *et al* [16]. Furthermore, lesions located in regions hard to reach with LUS such as retro -scapular, supraclavicular or axillary regions could have also contributed to normal LUS findings [11].

In this study, pleural abnormalities included; diffuse pleural irregularity (88.2%), was the most common pattern, diffuse pleural thickening (39.4%), third common pattern while mild basal anechoic bilateral pleural effusion (1.6%) was the least common pattern. Pleural abnormalities could be attributed to chronic pleural inflammation following pleural irritation due to recurrent pulmonary infections [17], and subpleural microinfarcts [12]. Hence post inflammatory fibrotic changes can lead to pleural scarring and focal thickening. Pleural irregularities and thickening had no statistical significance with P- value = 0.814 and 0.251 respectively. However, pleural effusion only had statistical significance at bivariate analysis with P value = 0.001 hence favoring a diagnosis of ACS.

In this study, diffusely distributed subpleural subcentimeter consolidation (22%), was the fourth most common pattern and only had statistical significance at bivariate analysis with P value = 0.001 hence favoring a diagnosis of ACS. Similar findings at (6.5%), and (,14.6%) were noted by Shah., *et al*. [18], and Pardue., *et al.* [19], respectively. Furthermore, the two studies noted that only a minority of these patients required hospitalization hence concluding that the clinical relevance and management of subcentimeter consolidations was still unclear. This necessitates more study on whether the presence of subcentimeter consolidations warrants antibiotic therapy or a "watchful waiting approach" [20]. However, Razazi., *et al*. [21], noted bilateral basal large consolidations as the most common pattern.

In this study, symmetrically distributed B lines (80.3%), was the second most common pattern with no statistical significance (P- value = 0.221). This could be attributed to the non-specific nature of B line as they are noted in cases with transudative and exudative interstitial edema as well as among those with infective and non-infective inflammatory processes [22]. B lines are an indicator of interstitial pattern of lung disease secondary to peribronchial inflammation [23]. However, Céline., *et al.* [24], noted B lines as the most common pattern and an early indicator of ACS.

In this study, a mixed pattern (alveolar and interstitial pattern) of lung disease (20.5%), was less common and denoted by the concurrent presence of both consolidations and B lines on LUS. However, this only had statistical significance at bivariate analysis with P- value = 0.001. Hence favoring a diagnosis of ACS.

Lung ultrasound patterns among pediatric SCA patients clinically diagnosed with severe pneumonia

In this study, all 51 patients clinically diagnosed with severe pneumonia had abnormal LUS findings. Pleural abnormalities included; diffuse pleural irregularities (92.2%), the most common pattern; echo complex bilateral basal pleural effusion (37.3%), the fifth most common pattern and diffuse pleural thickening (31.4%), the least common pattern. Pleural irregularities and thickening had no statistical significance with P- value = 0.814 and 0.251 respectively. However, pleural effusion had statistical significance at both bivariate (P- value

= 0.001), and multivariate analysis (P-value = 0.05). Hence strongly favoring a diagnosis of severe pneumonia over ACS. Similar etiological factors of pleural abnormalities are shared between severe pneumonia and ACS as was noted by Platt., *et al* [12]. In this study, pleural effusion was mild to moderate ranging from hypoechoic to hyperechoic fluid with septations, loculations or fibrin stranding as similarly noted by Calder., *et al* [25], and Heuvelings., *et al* [26].

In this study, bilateral basal consolidation (76.5%), was the third most common pattern. This yield had statistical significance only on bivariate analysis with P- value = 0.001 hence favoring a diagnosis of severe pneumonia. The consolidations had varying characteristics i.e. subpleural consolidations, focal consolidations with air bronchograms, subcentimeter consolidations and lobar consolidations with hepatization as similarly noted by Milner., *et al* [20]. However, Claes., *et al.* [27], noted bilateral consolidations as the most common finding among 44/45 pediatric severe pneumonia patients.

In this study, diffuse B lines (90.1%), were the second pattern as similarly noted by Kyomuhangi., *et al* [14]. However, this yield had no statistical significance with P- value = 0.221.

In this study, a mixed pattern of lung disease (70.6%), was the fourth common finding. This yield was only statistically significant at bivariate analysis with a P value = 0.001 hence favoring the diagnosis of severe pneumonia.

Similarities between lung ultrasound patterns of clinically diagnosed severe pneumonia and ACS among pediatric SCA patients

Similar lung abnormalities were noted in both conditions and could be attributed to the shared etiology (i.e. bacterial infections) implicated in both disease processes [18].

In both conditions, subcentimeter subpleural consolidations were recorded.

Diffuse pleural irregularities, thickening and B lines were noted in both.

Bilateral basal pleural effusions were noted in both categories of patients.

Mixed pattern was noted in both categories of patients.

Differences between lung ultrasound patterns of clinically diagnosed severe pneumonia and ACS among pediatric SCA patients

Normal LUS findings 4 (3.1%), were only recorded among cases clinically diagnosed with ACS.

Bilateral basal mild to moderate echo complex pleural effusion was noted among cases clinically diagnosed with severe pneumonia predominantly while among cases clinically diagnosed with ACS mild bilateral mild anechoic pleural effusion was noted.

Bilateral basal consolidations with varying characteristics i.e. (large subpleural consolidations, focal consolidations with air bronchograms, subcentimeter consolidations and lobar consolidations with hepatization) were noted among patients clinically diagnosed with severe pneumonia. While diffusely distributed subpleural subcentimeter consolidations were among cases clinically diagnosed with ACS. Mixed pattern of lung disease was more common among cases clinically diagnosed with severe pneumonia compared to those with ACS (70.6% vs 20.5%), respectively.

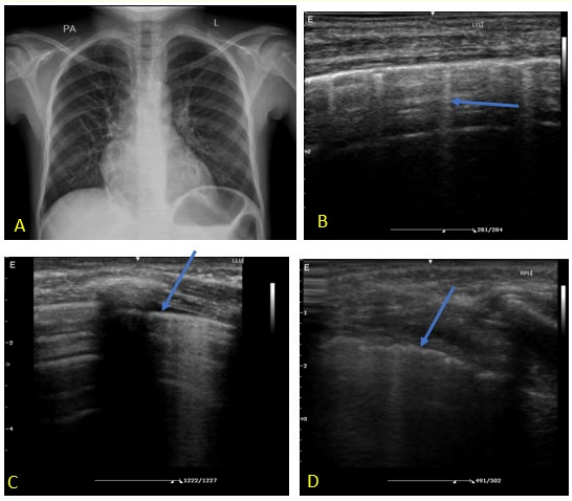

Figure 3: *(A case with normal CXR and abnormal LUS): A 14-year-old female clinically diagnosed with ACS. A: Shows normal PA chest x-ray findings. B: Lung sonogram in transverse plane demonstrating multiple B lines (arrow) in the left lateral lower region. C: Lung sonogram in longitudinal plane demonstrating a small anechoic pleural effusion (arrow) and B lines in the left lateral lower region. D: Lung sonogram in transverse plane demonstrating an irregular pleural (arrow) in the right posterior upper region.*

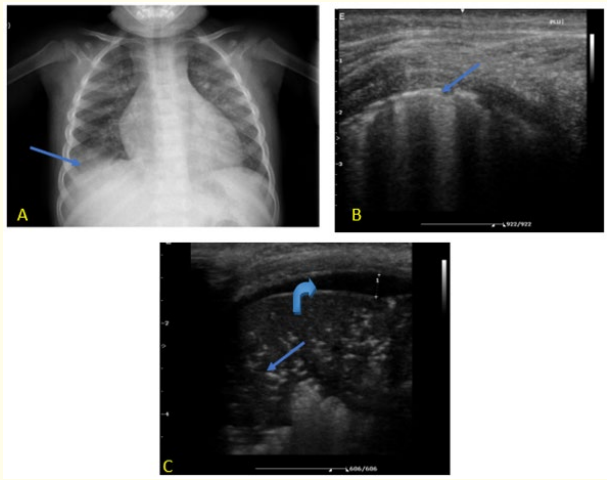

Figure 4: *(A case of mixed pattern of lung diseases): A 3-year-old male clinically diagnosed with severe pneumonia. A: AP chest x-ray demonstrating reticulonodular opacities in the left upper lung zone and a consolidation with air bronchograms in the right lower lung zone (arrow) with cardiomegaly. B: Lung sonogram in transverse plane demonstrating multiple B lines with pleural irregularity (arrow) in the left posterior upper region. C: Lung sonogram in transverse plane demonstrating a consolidation with multiple echogenic foci representing air bronchograms (arrow) and pleural effusion (bent arrow) with low grade internal echoes in the right lower anterior region.*

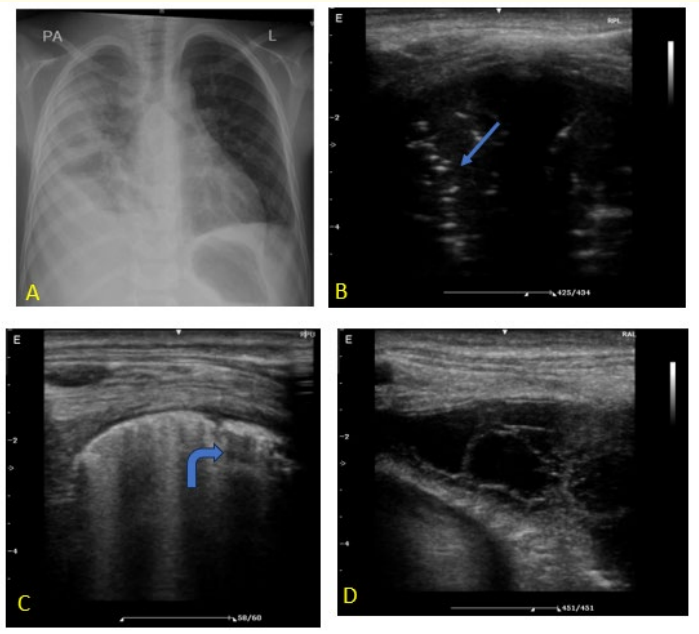

Figure 5: *(A case of right lung consolidation and empyema). An 8- year – old male clinically diagnosed with severe pneumonia. A; PA CXR demonstrating a homogenous opacity with air bronchograms in the right lung field silhouetting the ipsilateral cardiac border. There are associated bilateral homogenous opacities (R>>L) devoid of air bronchograms obscuring the costal phrenic recesses and right hemidiaphragm. B; Lung sonogram in transverse plane demonstrating a large consolidation with multiple echogenic (arrow) branching foci (air bronchograms) in the right posterior lower region. C: Lung sonogram in transverse demonstrating B lines with subcentimeter consolidation (bent arrow) with a shred sign in the right posterior upper region. D: Lung sonogram in transverse demonstrating multiseptated plueral fluid collection with low grade internal echoes in the right anterior lower region zone.*

Conclusion

In conclusion, LUS patterns of ACS include; subcentimeter consolidations, mixed pattern and mild anechoic pleural effusion. LUS patterns of severe pneumonia included; large consolidations, mild to moderate echo complex pleural effusion and mixed pattern. Mild to moderate echo complex pleural effusion strongly favored a diagnosis of severe pneumonia over ACS.

Secondly, LUS can also be used as an add on tool, to physical examination in evaluation of pediatric SCA patients with a normal chest radiograph who are clinically diagnosed with severe pneumonia or ACS.

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