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Ultrasound Appearance of Lungs in Patients with Ventilator Associated Pneumonia

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Abstract

Ventilator associated pneumonia is a complication in pediatric intensive care units and increases the morbidity and mortality in mechanically ventilated children. Ultrasound examination of lungs can be easily performed by the intensivist on duty quickly and is also radiation free as compared to routine chest X rays. Data are scant on role of lung ultrasound in diagnosis of ventilator associated pneumonia. In this study we describe the ultrasound lung appearances in children with ventilator associated pneumonia.

Keywords: Lung ultrasound; Ventilator associated pneumonia (VAP); Point of care ultrasound (POCUS);

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Introduction

Ventilator Associated Pneumonia (VAP) is a common and dreaded complication in PICU; increasing the length of hospital stay and medical care cost. Routine investigation for diagnosis of VAP is a chest radiograph along with clinical signs and symptoms[1]. The procedure of getting done a radiograph in a critically ill child is somewhat complicated as proper positioning of the child is to be done. It takes much time when the report is available and involves radiation exposure of pediatric ICU (PICU) healthcare staff. Moreover it involves extra personnel entries for example radiographer in PICU which increases the risk of hospital acquired infections in patients. On the other hand Ultrasound examination is a quick procedure, can be easily performed by the intensivist on duty and is also radiation free. Role of LUS has been defined in diagnosis of community acquired pneumonia in children and in emergency department[2,3]. Evidence suggests that accuracy and reliability of a structured LUS by adequately trained clinicians is good and can detect lung consolidation and other features of pneumonia in children[4,5]. There is paucity of data on role of lung ultrasound (LUS) for diagnosis of VAP. It is inadequately known if the sonographic appearance of lungs in children receiving mechanical ventilation is different from those of who do not receive it i.e community acquired pneumonia. There are only few studies available discussing the role of LUS in VAP. In this prospective study we aimed to document ultrasound appearance of lungs in patients with VAP.

Materials and Methods

This was a prospective observational cohort, single centre study conducted in PICU of a university

affiliated tertiary care hospital. A total of 28 patients of age 1 year to 14 years who were receiving invasive mechanical ventilation for reasons other than pneumonia and other lung diseases were selected by consecutive sampling technique. The LUS was performed whenever there was a suspicion of VAP and these were diagnosed as per CDC criteria.[1]

Technique of LUS: LUS was performed by the four senior residents on duty. The ultrasound machine used was ALOKA SSD-90 with both 7.5 and 3.5 MHz probes. Each lung was divided into six areas (superior and inferior of anterior, lateral and posterior zones). Anterior axillary line divided anterior from lateral and posterior axillary line divided lateral from posterior area.[6] The probe orientation was perpendicular to the ribs. The ultrasound images were taken and stored. The clinical details (chest auscultation, percussion, inspection) and diagnosis were recorded. Separate folders were made for each patient. The ultrasound images were read and interpreted by one radiologist (SJ) and one pediatric intensivist (SC) team and findings were recorded.

Diagnosis of VAP- Pneu1 (CDC criteria)

For child >1 year old or ≤ 12 years old, at least three of the following:

1. Fever (>38.0°C or >100.4°F) or hypothermia (<36.0°C or <96.8°F)
2. Leukopenia (< 4000 WBC/mm^3 or leukocytosis (≤ 4000 WBC/mm^3) or leukocytosis (> 15,000 WBC/mm^3)
3. New onset of purulent sputum or change in character of sputum, or increased respiratory secretions or increased suctioning requirements
4. New onset or worsening cough, or dyspnea, apnea, or tachypnea
5. Rales or bronchial breath sounds
6. Worsening gas exchange

And one chest imaging test results with at least one of the following

1. New and persistent or Progressive and persistent Infiltrate
2. Consolidation
3. Cavitation

Diagnosis of VAP- Pneu2

In addition to above criteria, following lab criteria were considered At least one of the following:

a) Organism identified from blood

b) Organism identified from pleural fluid

c) Positive quantitative culture or corresponding semi-quantitative culture result 9 from minimally-contaminated LRT specimen (specifically, BAL, protected specimen brushing or endotracheal aspirate)

d) ≥5% BAL-obtained cells contain intracellular bacteria on direct microscopic exam (for example: Gram's stain)

e) Positive quantitative culture or corresponding semi-quantitative culture result of lung tissue

f) Histopathologic exam shows at least one of the following evidences of pneumonia:

   1. Abscess formation or foci of consolidation with intense PMN accumulation in bronchioles and alveoli
   2. Evidence of lung parenchyma invasion by fungal hyphae or pseudohyphae

Statistical analysis

Demographic data are reported as frequencies, medians for ordered non-normal data and as means (SDs) for continuous normal data. Discrete and ordinal variables are described as counts and proportions.

Results

A total of 28 patients (18 males) were enrolled over 2 years. Median age was 6.5 years ranging from 1-13 years. The diagnosis of all enrolled patients has been shown in Table 1. These were patients admitted with diagnosis other than lung diseases, received mechanical ventilation and developed VAP. Most of the patients had neurological infections and diseases with meningo-encephalitis being the most frequent. Mean number of days on mechanical ventilation before development of VAP were 5.6 days. The frequency and description of various ultrasonographic findings has been shown in Table 2. Dynamic linear/arborescent air-bronchograms was most common finding (Figs. 3,5). Partial loss of aeration was seen in 68% while total loss of aeration was seen in 32% cases. Pleural effusion was seen in two patients (Figs. 3,5). Etiological diagnosis of VAP has been shown in (Fig. 6). Acinetobacter baumani was the most common organism grown in endotracheal or BAL cultures.

Table 1: Characteristics of enrolled children

S. No	Characteristic	Total 28 n (%)
1	Age [median(range)]	6.5 (1-13)
2	Gender (M:F)	1.8:1
3	*Diagnosis*	
	Guillain Barre Syndrome	4 (14.28)
	Compicated Malaria	1 (3.57)
	Pyogenic meningitis/Enchephalitis	6 (21.4)
	Tubercular Meningitis	4 (14.28)
	Acute Disseminated Encephalomyelitis	2 (7.14)
	Aplastic anemia with shock	2 (7.14)
	Congenital hydrocephalus raised Intra Cranial Pressure	1 (3.57)
	Hepatic encephalopathy	1 (3.57)
	Neurocysticercosis disseminated	1 (3.57)
	Space Ocupying Lesion with raised Intra Cranial Pressure	1 (3.57)
	Autoimmune hepatitis with sepsis	1 (3.57)
	Sepsis with shock	4 (14.28)
4	Day of mechanical ventilation at development of VAP [Mean (sd)]	6.6 ± 3.2
5	PNU1	28 (100)
	PNU2	25 (89.2)

Table 2: Lung Ultrasound Findings

LUS findings	Patients n (%)	Description of findings
Air bronchogram	28 (100)	These represent air in bronchioles and appear as multiple hyper-echoic punctate or lenticular specs or branching tree-like structures within the hypo-echoic consolidated lung. (Figs. 3,5)
Shred sign	4 (14.29)	A hypo-echoic area with ragged margin separating it from the surrounding normal. (Fig. 7).
Pleural abnormalities	15 (53.57)	Thickening and disruption of pleural line.
B lines	17 (60.71)	Hyper-echoic (bright) lines arising from pleura and running perpendicular to it below up to the lower edge of the image. These B-lines erase A-lines such that A-lines are not visible in their presence. (Fig. 1)
Pleural effusion	2 (7.14)	Anechoic or hypo-echoic area (dark/grey) in the pleural space, with or without internal structures like finrin strands (Quad sign). (Figs. 3,5)
Hepatisation	6 (21.43)	Large consolidations tend to have a characteristic liver-like appearance, referred to as hepatisation.(Fig. 4)
Heterogeneous echo texture	3 (10.71)	No distinctive specific pattern seen.
No A lines	28 (100)	Hyperechoic lines running parallel to the pleural line that are parallel lines and equidistant from each, in fact, reverberation artefacts of the pleural lines (Fig. 2). These were not seen in consolidated lungs.

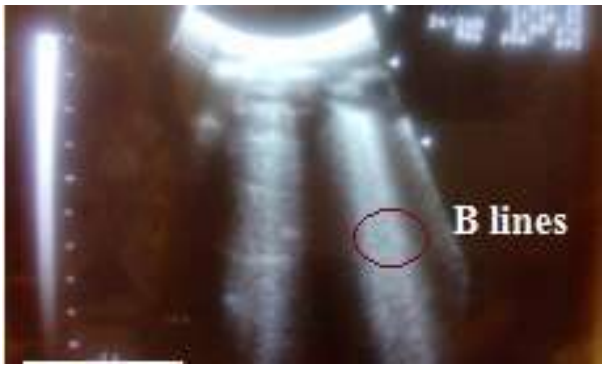

Fig. 1: LUS image showing B-Lines in red circle.

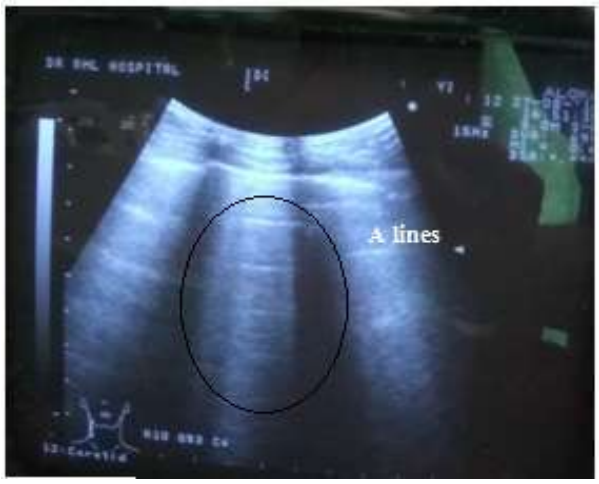

Fig. 2: LUS image from a normal lung. Black circle showing A-Lines.

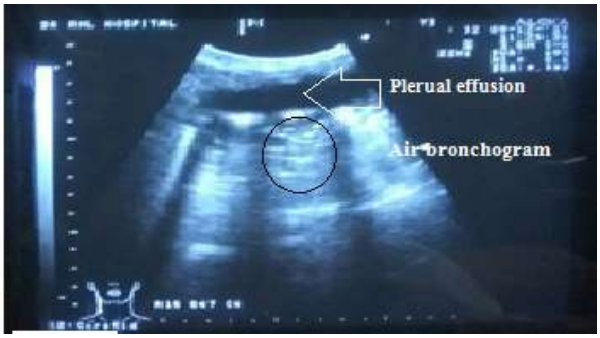

Fig. 3: LUS image from VAP lungs. Hollow arrow showing pleural effusion and black circle showing air bronchogram.

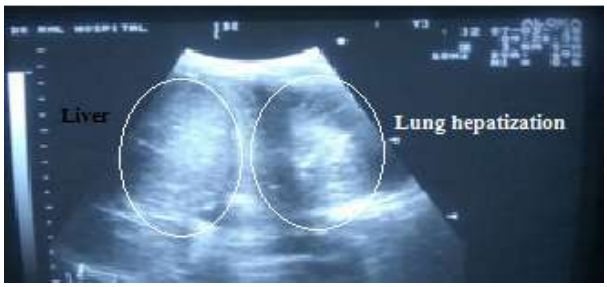

Fig. 4: LUS image showing lung hepatisation in right side circle and liver in left side circle. Lung appears like liver tissue on ultrasound.

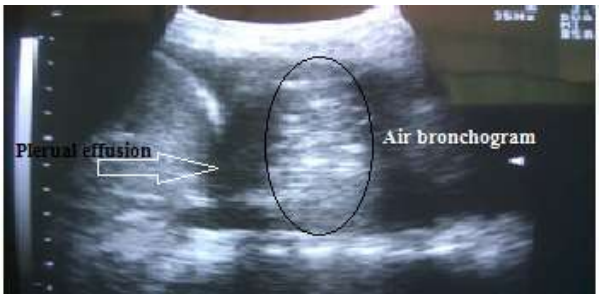

Fig. 5: LUS image showing air brochogram in black circle and pleural effusion shown by arrow.

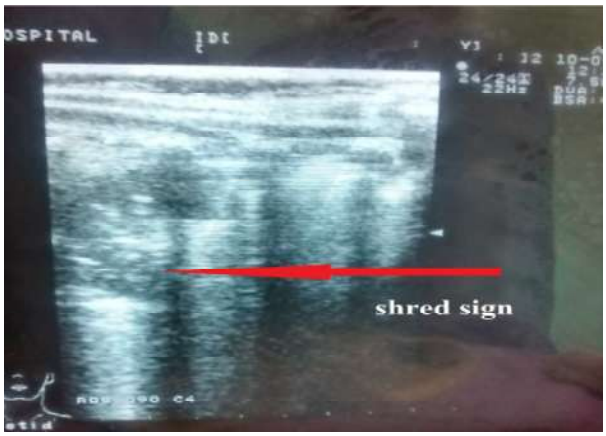

Fig. 7: LUS image showing shred sign.

Discussion

Ventilator associated pneumonia is a pneumonia that occurs in a patient who was intubated and ventilated at the time of or within 48 hours before the onset of the pneumonia[1]. Recent studies show an incidence of VAP ranging from 6% to 22% of ventilated PICU patients in different studies[7]. Studies also have shown a high mortality (16–94%) in patients developing VAP[8]. It is important to define the role of lung ultrasound as a point of care diagnostic tool for VAP. In this cohort of 28 patients diagnosed as VAP according to CDC criteria, all had typical specific sonographic findings in lungs. The fact that these were mechanically ventilated posed no difficulty in conducting the LUS examination. Moreover, the findings we saw in VAP have been similar to what is seen in Community Acquired Pneumonia[2].

Many studies have evaluated the diagnostic performance of LUS compared to chest radiographs for the diagnosis of pneumonia, usually defined as the presence of air-space consolidation on either modality. A meta-analysis published by Pereda et al compared LUS with a reference standard of either chest radiography alone or a combination of (chest radiographs, clinical and laboratory findings); showed high sensitivity of LUS 96% (95% [CI]: 94–97%), and high specificity of 93% (95% CI: 90–96%). The positive and negative likelihood ratios were 15.3 (95% CI: 6.6–35.3) and 0.06 (95% CI: 0.03–0.11). In subgroup analysis, both experts in specialty and and non-experts in specialty such as emergency department physicians, general practitioners, residents, or health care professionals achieved high rates of diagnostic accuracy with sensitivity and specificity above 90% in both groups[9]. Similarly, a more recent meta-analysis, by Xin-H *et al.* showed good performance of LUS in diagnosis of pneumonia (sensitivity: 93.0% (95% CI, 88.0%–96.0%) and specificity: 96.0% (95% CI, 92.0%–98.0%), respectively. The pooled positive likelihood ratio were 25.8 (11.0, 60.4), negative likelihood ratio were 0.07 (0.05, 0.12), and diagnostic odds ratio were 344 (104, 1140). Moreover, the summary receiver operating characteristic area under the curve was calculated to be 0.98 (0.97, 0.99) which

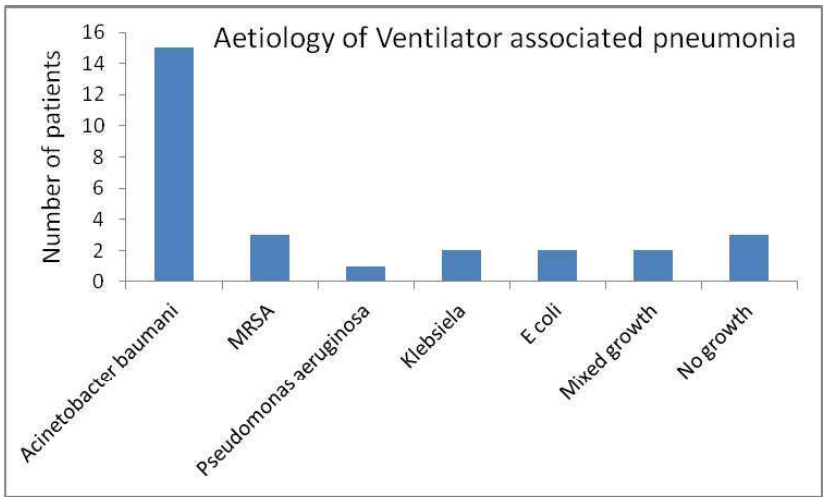

Fig. 6: Aetiological organism causing VAP

shows excellent discriminatory power[10]. But both the meta-analysis used studies which were performed on community acquired pneumonia. Only two studies have discussed role of LUS in VAP. A study by Berlet T *et al.* showed that a wide range of abnormal sonographic patterns were seen in most patients. The study was conducted in a total of 57 patients[11]. The sonographic pattern of lung consolidation with either dynamic or static air bronchograms was 100% sensitive and 60% specific for VAP in those patients who developed clinical signs and symptoms compatible with pneumonia. The pretest and posttest probabilities were 0.38 and 0.6, respectively. In another multicenter study done by Mongodi S *et al.* in 99 patients concluded that LUS is a reliable tool for bedside diagnosis of VAP[12]. Presence of a subpleural consolidation and dynamic arborescent/linear air bronchogram had a positive predictive value of 86% with a positive likelihood ratio of 2.8. Two dynamic linear/arborescent air bronchograms produced a positive predictive value of 94% with a positive likelihood ratio of 7.1. In our study air brochogram and loss of aeration were the main findings. The LUS findings were similar to the findings seen in community acquired pneumonia and thus there was no interference due to mechanical ventilation of the child on image quality was seen. The main strength of the study is that the patients enrolled did not have any lung disease at the time of enrolment thus it avoided any contamination in the ultrasound findings. Although the sample size is small but the selection criteria was such that it permitted lower number of patients as the most common cause for admission in our PICU is pneumonia and other lung diseases. Moreover the incidence of VAP is low in our PICU.

Conclusion

It is feasible to perform LUS in mechanically ventilated patients. Specific LUS findings are seen in patients with VAP which can be used to diagnose it rapidly at bedside.

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