Lung Ultrasonography for the Diagnosis of Pleural Effusion in Children

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ABSTRACT

Background: Chest radiograph was currently the standard imaging for diagnosing pleural effusion. However, there were many limitations, namely radiation, varying interpretation, and long time to get results. Lung ultrasonography is an alternative procedure that is easy to learn and offers many benefits, including noninvasive, radiation free, fast, valid, and reliable. The objective of this study was to determine sensitivity, specificity, and positive likelihood ratio (LR+)of lung ultrasonography performed by pediatric resident for diagnosing pleural effusion

Subjects and Method: This was a cross sectional study at pediatric intensive care unit (PICU) Dr. Moewardi Hospital, Surakarta, Indonesia. We included pediatric patients aged 1 month-18 years from November 2018 to December 2019. A sample of 44 patients with suspected pleural effusion was selected by consecutive sampling. The independents variable was lung ulrasonography. The dependent variable were pleural effusion. All subjects underwent lung ultrasonography and chest radiograph. Sensitivity, specificity, and positive likelihood ratio were calculated.

Results: There were 44 samples with 59.1% under 1 year old and 54.5% were female. All patients came to the emergency room with complaints of shortness of breath, accompanied by fever (77.3%) or cough (63.6%). Eleven (25.0%) patients had pleural effusion based on the results of lung ultrasonography. Based on chest radiograph, seven (15.9%) patients had pleural effusion. Lung ultrasonography has sensitivity of 14.3%, specificity of 73%, and LR+ of 0.5 for diagnosing pleural effusion.

Conclusion: Lung ultrasonography can be used as a tool to diagnose pleural effusion with good specificity.

Keywords: lung ultrasonography; pleural effusion

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BACKGROUND

Pleural effusion, which in majority pediatric patients was caused by infection, was a collection of abnormal fluid in the pleural space. This disease arise due to excessive filtration or disturbed absorption of accumulated fluid. Pleural effusion can be a primary manifestation or secondary complication of many diseases. Possible complications of this condition include respiratory failure due to massive fluid accumulation, septicemia, bronchopleural fistula, pneumothorax, and thickening of the pleura (Assefa et al., 2018)

Chest radiographs were the most commonly used examination to assess for the presence of a pleural effusion (Sharma et al., 2020) However, the American Academy of Pediatrics (AAP) recommends careful use of chest radiograph for various reason. Unnecessary radiation exposure in young children

has the potential to increase risk of developing cancer later in life. Any abnormal chest radiograph can be interpreted as normal. In addition, there was a time gap between when a chest radiograph is ordered and the availability of the final reading (Pereda et al., 2015; Samson et al., 2018).

Physical examination is usually rarely able to detect pleural effusion if the volume was less than 300 ml. On a standard postero-anterior chest radiograph, the costofrenic angle will only appear blunt when the fluid is quite a lot. Anteroposterior chest radiographs can overlooked quite a number of pleural effusion cases and often misinterpreted as parenchymal opacity (Soni et al., 2015).

The things that have been explained above become the basis of the search for alternative procedures for chest radiograph. Point-of-care lung ultrasonography is a developing method for diagnosing pleural effusion. This examination offers many advantages over chest radiograph and CT scans, which were noninvasive, valid, reliable, inexpensive, free of radiation, and guaranteed availability (Samson et al., 2018).

Lung ultrasonography has proven to be extremely useful for detecting pleural effusion. This method was a great tool for diagnosing even minimal effusion in the pleural space (about < 25 ml) and more effective than chest radiograph. Chest radiograph can not detect an obliteration of the costophrenic sinus below 150–200 ml. One of the most relevant advantages of lung ultrasonography guidance is its real-time needle visualization during the procedure. The support of ultrasonography during the draining of the effusion also helps in terms of safety, amazingly reducing the risk of complications (Rea et al., 2019).

A metanalysis calculated the high accuracy of ultrasonography for detecting pleural effusion, which is 93% for sensitivity and 96% for specificity (Iorio et al., 2018; Samson et al., 2018). The quad sign is the main statistical sign of pleural effusion. Basic 2D mode imagingwith four borders that form a quadrilateral (pleural layer asupper line, lung lining as the lower line, and the shadow of the ribs) (Figure 1) (Medina et al., 2018).
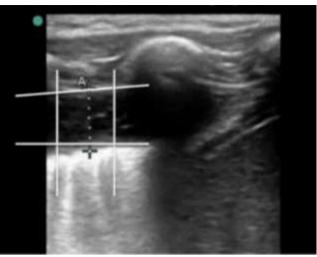

Figure 1. Quad sign

One study reported an increase in examination accuracy related to examiner experience although it did not show a statistically significant difference (Samson et al., 2018).

In a study by Esposito et al, pediatric residents who get only 7 hours of lung ultrasonography training could have high sensitivity and specificity (98% and 95%). Also, Bedetti

et al. (2003) showed that beginners could detect interstitial lung syndrome after 30 minutes of training. And the International Liaison Committee on Lung Ultrasound categorizes lung ultrasound as a basic sonographic technique that is easy to learn (Pereda et al., 2015)

As such, we aimed to determine whether lung ultrasonography can be used to diagnose pleural effusion in PICU Dr. Moewardi Hospital, Surakarta, especially if done by pediatric resident.

SUBJECTS AND METHOD

1. Study Design
This was a cross sectional study conducted in Dr. Moewardi Hospital, Surakarta, Central Java, Indonesia, from November 2018 until December 2019.

2. Population and Sample
The study population were PICU patients aged 1 month-18 years suspected with pleural effusion. The exclusion criteria were patients who have conditions that prevent ultrasonography examination, such as chest trauma, surgical scars, or tumors. A sample of 44 patients was selected by consecutive sampling.

3. Study Variables
The independents variable was lung ultrasonography. The dependent variable were pleural effusion.

4. OperationalDefinition of Variables
Pleural effusion was an abnormal collection of fluid in the pleural space, as a result of excessive filtration or impaired absorption of accumulated fluid. It was measured by history taking and physical examination. Patients were suspected if fever, coughing, and rapid breathing are found. From physical examination obtained nasal flaring, subcostal or intercostal retraction, and a dull sound from the chest percussion at the site if the effusion.
Lung ultrasonography was an imaging device that uses X-rays and can penetrate any part of the body. It was measured by direct examination, early in the patient's admission to the PICU.

5. Study Instruments
All patients underwent chest radiograph, as a gold standard, and lung ultrasonography. Ultrasonography was performed by pediatric resident who has been trained for 15 hours, using GE Healthcare LOGIQ® E9 with a high-frequency linear transducer. The examination is carried out by static imaging (B mode), with the transducer placed longitudinally, perpendicular to the chest wall and a marker pointing at the patient's head then scanning vertically until the entire chest area is examined. Ultrasonography results categorized as pneumonia if air bronchograms, pleural irregularities, confluence, focal, or multiple B line images were found. If a quad sign is found, it was categorized as pleural effusion. Lung ultrasonography was carried out by the examiner without knowing the radiological results and vice versa.

Chest radiograph was performed from the anteroposterior and lateral sides using Sirius Star Mobile X-ray. If a blunt costophrenic angle is found, it is categorized as a pleural effusion. The chest radiograph interpretation was carried out by one radiologist appointed for this study.

6. Data Analysis
All data was processed after the data collection completed. If chest radiograph is done more than once, the data used for the study was the first radiograph taken. Data were analyzed using Software Package for Social Science (SPSS) version 21 software. Sensitivity, specificity, PPV, and NPV were calculated.

7. Research Ethic
Ethical clearance in this study was obtained from the Health Research Ethics Committee of Dr. Moewardi Hospital, Surakarta with the number 787 / XI / HREC / 2018 published on November 28, 2018.

RESULTS

1. Sample Characteristics

There were 44 patients who met the inclusion criteria within the study period. All underwent lung ultrasonography and chest radiograph to be used as study samples. The majority of patients were female (54.5%) and aged <1 year (59.1%). All patients came to the emergency room with complaints of shortness of breath, accompanied by fever (77.3%) or cough (63.6%). Patients came to the emergency room with increased respiratory rate (Mean= 50 times/ min; SD= 15.55), temperature (Mean= 37.58° C; SD= 0.81), and decreased oxygen saturation (Mean= 86.84 SD= 14.2%). The majority of patients were assisted by breathing aids in the form of endotracheal tubes (27 patients, 61.4%). The demographic characteristics of the subjects are shown in **Table 1**.

Table 1. Characteristics of subjects

Characteristics	N= 44
Gender, n (%)	
Male	20 (45.5)
Female	24 (54.5)
Age, n (%)	
< 1 year old	26 (59.1)
>1 − 5 years old	11 (25)
>5 − 10 years old	3 (6.8)
>10 − 15 years old	3 (6.8)
>15 years old	1 (2.3)
Symptoms and signs, n (%)	
Fever	34 (77.3)
Fussy	18 (40.9)
Decreased appetite	13 (29.5)
Cough	28 (63.6)
Shortness of breath	44 (100)
Cyanosis	4 (9.1)
Physical examination	
Heart rate, median (IQR)	150 (34)
Respiration rate (mean, SD)	Mean= 50; SD= 15.55
Temperature (mean, SD)	Mean= 37.58; SD= 0.81
Oxygen saturation (mean, SD)	Mean= 86.84; SD= 14.2
Retraction, n (%)	38 (86.4)
Additional breath sound, n (%)	40 (90.9)
Laboratory examination, median (IQR)	
Hemoglobin	10.5 (2.7)
Leucocyte	12,900 (10,900)
Thrombocyte	342,000 (247,000)
pH	7.38 (0.23)
pCO_2	53 (25.1)
pO_2	66 (84.9)
HCO_3	28.3 (8.1)
Breathing assist device, n (%)	
Endotracheal tube	27 (61.4)
Oronasal mask	12 (27.3)
Nasal cannula	5 (11.4)

Based on chest radiograph, all patients had pneumonia (100%), seven (15.9%) patients had pleural effusion and 1 (2.3%) patient had pulmonary edema. Chest radiograph also

detected other abnormalities in 7 (15.9%) patients, which consisted of subcutaneous emphysema, pulmonary edema, pulmonary hypertension, tuberculosis, infected bullae, suspicion of diaphragmatic hernias, and the prominent thymus.

Forty-one (93.2%) patients had pneumonia based on the results of lung ultrasonography. There were 11 (25%) patients had pleural effusion and 3 (6.8%) patients had pulmonary edema. Eleven (25%) patients had other abnormalities, namely pulmonary edema, subcutaneous emphysema, pericardial effusion, pulmonary atelectasis, pneumothorax, and suspected mass. The results of lung ultrasonography and chest radiographs are shown in **Table 2**.

Table 2. Results of lung ultrasonography and chest radiograph

Result	N= 44
Chest radiograph, n (%)	
Pneumonia	44 (100)
Pleural effusion	7 (15.9)
Lung edema	1 (2.3)
Cardiomegaly	12 (27.3)
Others	7 (15.9)
Lung ultrasonography, n (%)	
Pneumonia	41 (93.2)
Pleural effusion	11 (25)
Lung edema	3 (6.8)
Cardiomegaly	11 (25)
Others	11 (25)

2. The result of bivariate analysis

There was one patient who was diagnosed with pleural effusion and 27 patients who did not have pleural effusion from both chest radiograph and lung ultrasonography. Lung ultrasonography has 14.3% sensitivity, 73% specificity, and 0.5 LR+ to detect pleural effusion (**Table 3**).

Table 3. Diagnostic value of lung ultrasound in pleural effusion

Lung ultrasound	Chest radiograph		Sensitivity (%)	Specificity (%)	LR+
	Pleural effusion	Not pleural effusion			
Pleural effusion	1	10	14.3	73	0.5
Not pleural effusion	6	27			

DISCUSSION

In our study, pleural effusion was diagnosed in seven patients based on radiograph examination, while ultrasonography diagnosed 11 patients. These results were consistent with several studies which state that lung ultrasonography is better than chest radiograph to detect pleural effusion(Lichtenstein et al., 2004; Soni et al., 2015; Svigals et al., 2017; Heuvelings et al., 2019). Ultrasonography also has a better interreader agreement for diagnosing pleural effusion(Heuvelings et al., 2019)

Physical examination is usually rarely able to detect pleural effusion if the volume <300 ml. On a standard posteroanterior chest radiograph, the costofrenic angle will only appear blunt when the fluid reaches 200 ml. Anteroposterior chest radiographs can overlooked quite a number of effusion cases that can be detected by CT scan and ultrasonography. Pleural effusion is often misinterpreted as parenchymal opacity(Soni et al., 2015) Although CT scan is the gold standard for the diagnosis of pleural effusion, ultrasonography shows similar accuracy of sensiti-

vity and specificity(Kurian et al., 2009; Hopkins et al., 2019) The ability of lung ultrasonography to identify complex effusions in pediatric patients correlates with chest radiograph and CT scan (k= 1,0)(Hopkins et al., 2019).

Lung ultrasonography can detect pleural fluid at least 50 ml, even 20 ml. Ultrasonography is also 100% sensitive to pleural effusions with volumes of more than 100 ml. A meta-analysis calculates the high accuracy of ultrasonography to detect pleural effusion, which is 93% for sensitivity and 96% for specificity(Soni et al., 2015; Iorio et al., 2018) However, due to limited facilities and costs, this study uses radiograph as a gold standard so that ultrasonography has a sensitivity of 14.3% and specificity 73% for diagnosing pleural effusion.

Lung ultrasonography examination in this study was carried out by pediatric resident who had undergone training for fifteen hours. The level of accuracy of the examination will increase according to the examiner's experience(Heuvelings et al., 2019) Thus, sensitivity and specificity will also increase if the resident undergo additional training or more often exposed and use ultrasonography.

Our study had several limitations. The gold standard used in this study was chest radiograph, while the gold standard that should have been used was a CT scan. Chest CT scan is not used as a standard service at Dr. Moewardi hospital due to ethical considerations related to radiation doses and also high costs. The majority of research subjects use mechanical ventilator with endotracheal tube, or experience mobility limitations, so ultrasound examination can only be done in the anterior and lateral area of the chest. Examination should also be done in the posterior area to be able to examine all parts of the lung optimally. Ultrasound equipment is only available at PICU so research is carried out in that room. The examinations should be carried out in the emergency room, where all patients with suspected lung disease can be examined, not only those with severe clinical conditions. This can affect the results of research.

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