The role of lung ultrasound in differentiating lung congestion and lung infection in pediatric cardiac patients

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Background
Lung sonography in emergency situations has become one of the most appropriate studies. This technique allows us to diagnose the major causes of acute respiratory distress at the bedside without major interventions. It is an easy and costless approach to diagnose many lung diseases.

Patients and methods
This work is a cross-sectional, prospective, and descriptive study that included cardiac patients admitted to the pediatric cardiology ward through a period of 6 months. They had their data completely revised and their treatment recorded and diagnosis traced with a direct question: is it congestion or infection. A lung ultrasound (LUS) was done to assure the diagnosis. Also, chest radiography and echocardiography correlation were assessed.

Results
A total of 60 patients were enrolled over a period of 6 months (58% were males), with a mean age ± SD of 17.33 ± 30.91 months. The B-profile was found in 27 patients; A-profile was found in 35 patients; AB-profile was found in six cases and hypoechoic areas were found in nine cases. LUS appeared to be normal in three cases.

Conclusion
LUS shows high reliability and accuracy in the diagnosis of pneumonia, pulmonary congestion, pulmonary edema, air trapping, and the possibility of a follow-up until complete resolution of many lung diseases, without exposure to harmful radiation.

Keywords:
A-profile, B-profile, congenital heart disease, heart failure, lung ultrasound, pulmonary congestion, pulmonary edema

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Introduction

Lung ultrasound (LUS) is used at the bedside in emergency and critical care settings. It is a rapid and low-cost approach that can direct patient care without the use of harmful radiation. The success of this technique depends on its simplicity to discover the sonographic signs which indicate certain lung pathology [1]. These signs include a hyperechoic and sliding line, moving forward and back with ventilation seen 0.5 cm below the rib line and is called the pleural line. The A-profile associates anterior lung sliding with A lines. A lines are horizontal repetition artifacts of the pleural line. The B-profile associates anterior lung sliding with B lines. B lines appear as shining vertical lines arising from the pleural line and reach the edge of the screen [2].

Aim

The aims were as follows:

(1) To describe how far lung congestion or infection is behind our cardiac patients; thus, LUS will enable us to use antibiotics or antifailure measures when needed
(2) To evaluate the diagnostic accuracy of bedside LUS in pediatric cardiac patients admitted to the pediatric cardiology unit with suspected pneumonia or heart failure or both and final diagnosis at discharge
(3) How much lung sonar could change our decision and help us for an easier costless diagnosis.

Patients and methods

This study was conducted in Assuit University Children Hospital at the Cardiology Unit during the period between the start of November 2016 and end of April 2017. A total of 60 cardiac patients were enrolled from the age of 1 month to the age of 16 years.

The study was approved by the Institutional Ethics Committee of Assuit University.

Inclusion criteria

Cardiac patients from 1 month to 16 years of age admitted to the Pediatric Cardiology Unit with respiratory infection or manifestations of heart failure whatever the cardiac anomaly.

Exclusion criteria

If admission was due to causes other than respiratory infection or heart failure.

Workup scheme

All patients were subjected to careful history taking and full clinical examination. Detailed chest and cardiac examination were performed searching for signs of lung congestion and lung infection. All patients eligible to participate had undergone the following:

(1) Posteroanterior chest radiography (CXR)
(2) Echocardiography
(3) Complete blood count
(4) LUS: transthoracic LUS examinations were performed with available ultrasound machines, equipped with a linear probe with frequencies ranging from 6 to 9 MHz. The probe was placed perpendicular, oblique, and parallel to the ribs in the anterior, lateral, and the posterior thorax to perform a complete scanning of the chest in all children. The sonographer was unaware of the radiographic findings.

Results

The study was conducted on children admitted to the pediatric cardiology ward in Assuit University Children Hospital over 6 months. The study included 60 cases.

Demographic data

The mean age ± SD was 17.33 ± 30.91 months (Table 1). The majority of cases were in the infancy time by 77% followed by the age range 1–5 years, 17%, lastly, 5–10 years and greater than 10 years were 3% each.

History and presenting symptoms in studied patients

The history and presenting symptoms are given in Table 2 and Fig. 1.

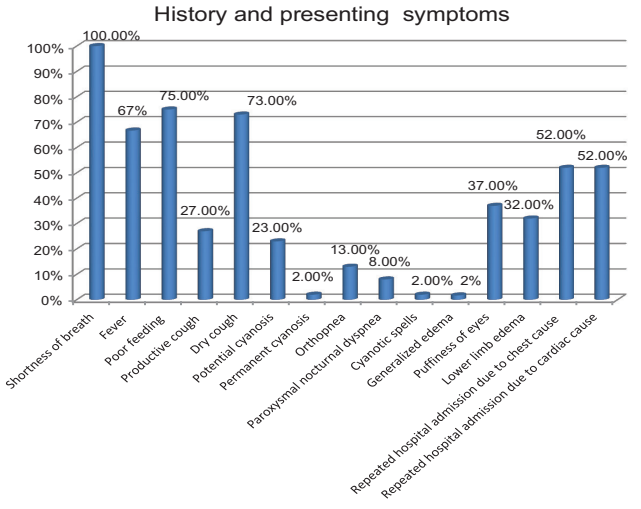
Table 1 The demographic data of studied cases

	n (%)
Age (*n*=60)	
1-12 months	46 (77)
1-5 years	10 (17)
5-10 years	2 (3)
>10 years	2 (3)
Sex (*n*=60)	
Male	35 (58)
Female	25 (42)
Residence (*n*=60)	
Rural	38 (63)
Urban	22 (37)

Table 2 History and presenting symptoms in studied patients

History and presenting symptoms	*n*=60 [*n* (%)]
Shortness of breath	60 (100)
Fever	40 (67)
Poor feeding	45 (75)
Productive cough	16 (27)
Dry cough	44 (73)
Potential cyanosis	14 (23)
Permanent cyanosis	1 (2)
Orthopnea	8 (13)
Paroxysmal nocturnal dyspnea	5 (8)
Cyanotic spells	1 (2)
Generalized edema	1 (2)
Puffiness of eyes	22 (37)
Lower limb edema	19 (32)
Repeated hospital admission due to chest cause	31 (52)
Repeated hospital admission due to cardiac cause	31 (52)

Figure 1

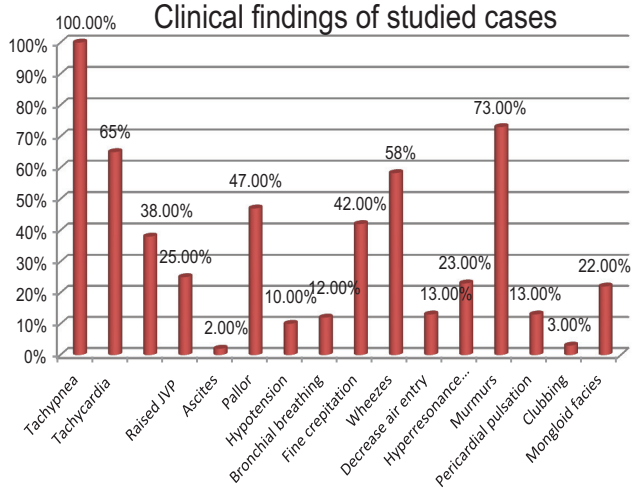


History and presenting symptoms.

Clinical findings of studied cases

Signs of heart failure included tachycardia (65%), enlarged tender liver (38%), and raised jugular venous pressure (JVP) (25%) (Table 3 and Fig. 2).

Figure 2



Clinical findings of the studied cases. JVP, jugular venous pressure.

Laboratory and radiological findings among the studied cases

Laboratory and radiological findings are given in Table 4 and Fig. 3.

Management

Antibiotics were prescribed in all cases which is the usual practice in the unit but unwise. All cases received ampicillin/sulbactam. The decision was taken to upgrade the antibiotics in 30% of cases in the form of ceftazidime in five cases, cefotaxime in 10 cases, and cefepime in three cases. Fifty cases (83%) were on antifailure medication. A total of 36 cases were already on antifailure medication before admission. Antifailure medications were newly prescribed in 14 cases (Table 5 and Fig. 4).

Outcome of the studied cases

As shown in Table 6 and Fig. 5, 55 (92%) cases clinically improved and were discharged, whereas five (8%) cases died as they were suffering from severe respiratory distress. The duration of admission ranged from 3 days up to 11 days (Figs. 6-9).

Table 3 Clinical findings of studied cases

Examinations	*n*=60 [*n* (%)]
Tachypnea	60 (100)
Tachycardia	39 (65)
Enlarged tender liver	23 (38)
Raised JVP	15 (25)
Ascites	1 (2)
Pallor	28 (47)
Hypotension	6 (10)
Vesicular breath sounds	53 (88)
Bronchial breathing	7 (12)
Fine crepitation	25 (42)
Wheezes	35 (58)
Decreased air entry	8 (13)
Hyper-resonance on lung percussion	14 (23)
Murmurs	44 (73)
Pericardial pulsation	8 (13)
Clubbing	2 (3)
Mongoloid facies	13 (22)

JVP, jugular venous pressure.

Table 4 Laboratory and radiological findings among studied cases

Laboratory and radiological findings	*n*=60 [*n* (%)]
A-profile on lung ultrasound	35 (58)
B-profile on lung ultrasound	27 (45)
AB-profile	6 (10)
Hypoechoic areas on lung ultrasound	9 (15)
Right ventricular enlargement on ECHO	37 (62)
Left ventricular enlargement on ECHO	21 (35)
Valvular regurge on ECHO	27 (45)
Pulmonary hypertension on ECHO	9 (15)
Rosaries on CXR	1 (2)
Increase cardiothoracic ratio on CXR	45 (75)
Pneumonic patches on CXR	49 (82)
Lobar consolidation on CXR	6 (10)
Increase bronchovascular markings on CXR	43 (72)
Pulmonary hypertension on ECG	10 (17)
Leukocytosis	21 (35)

CXR, chest radiography.

Table 5 Management results

Management	*n*=60 [*n* (%)]
Antibiotics	60 (100)
Change of antibiotics during admission	18 (30)
Bronchodilators	24 (40)
Antifailure medications	50 (83)
Mucolytics	7 (12)

Table 6 Outcome of studied cases

Prognosis	*n*=60 [*n* (%)]
Clinical improvement and discharge	55 (92)
Death	5 (8)
Duration of admission in days	3–11

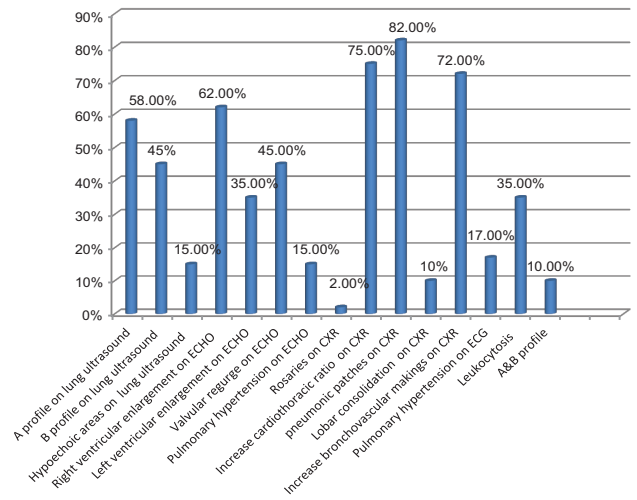
Discussion

This is a descriptive study to discuss the role of LUS in differentiating lung congestion and lung infection in pediatric cardiac patients.

This study was done on cardiac patients admitted to the pediatric cardiology ward at Assiut University Children Hospital from the start of November 2016 to end of April 2017. Inclusion criteria included respiratory infection or heart failure whatever the cardiac anomaly. Exclusion criteria included admission due to cyanotic spells or central nervous system cause.

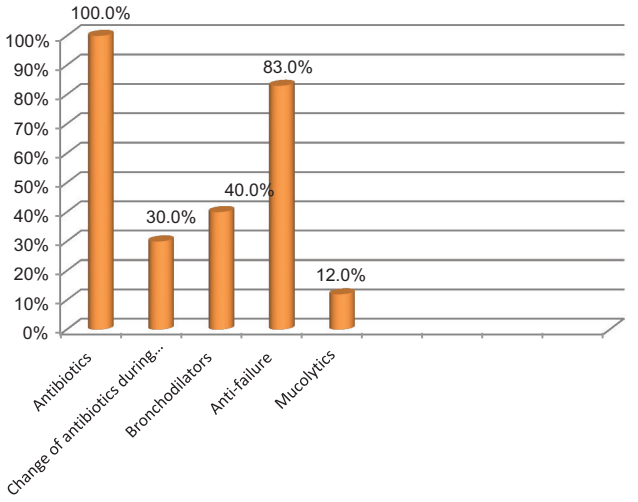
This study included 60 cases, 35 (58%) males and 25 (42%) females. Caiulo *et al.* [3] who started a

Figure 3



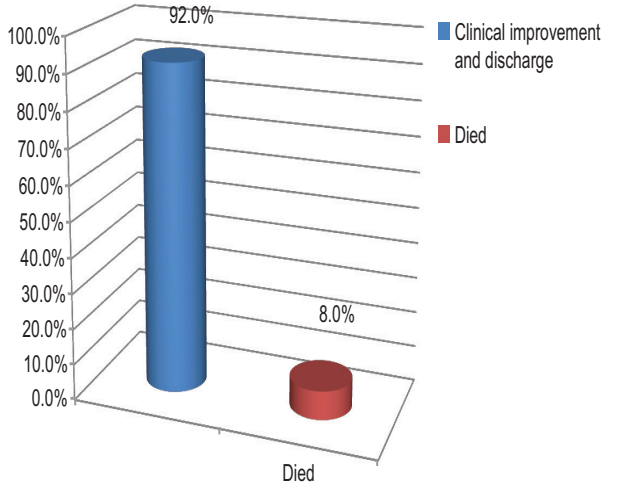
Laboratory and radiological findings. CXR, chest radiography.

Figure 4



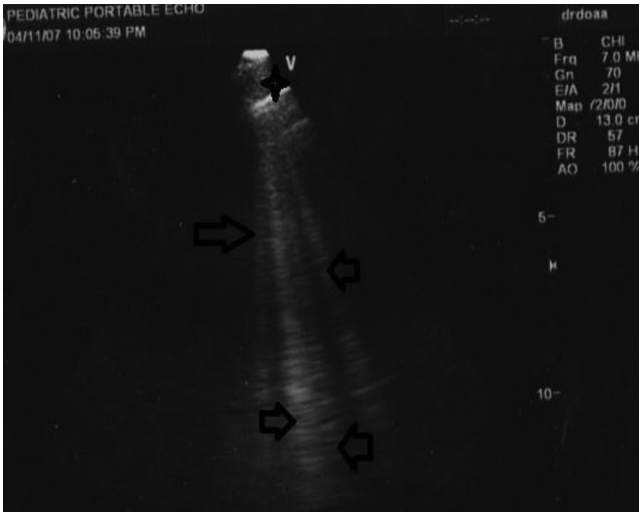
Management results.

Figure 5



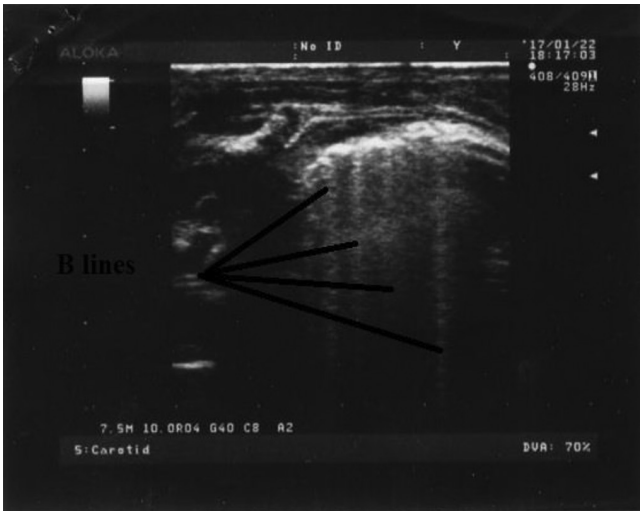
Outcome of the studied cases.

Figure 6



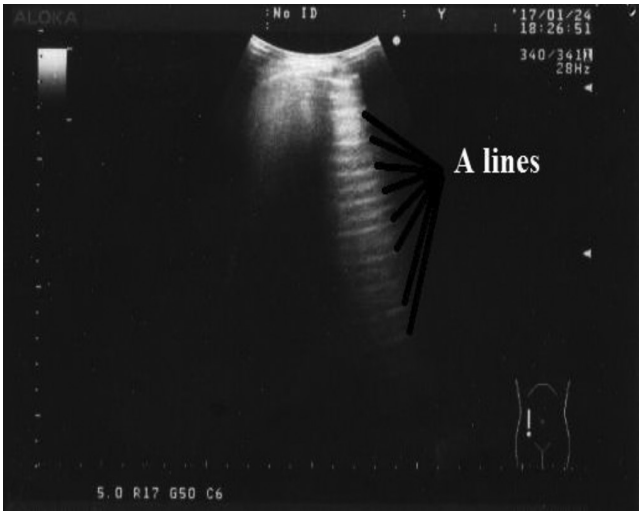
Multiple B lines (black lines) vertical hyperechoic lines that arise from the pleural line to the end of the screen.

Figure 7



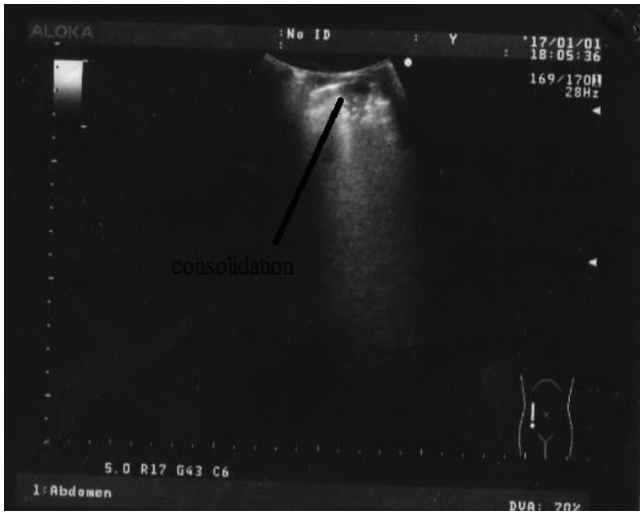
Multiple B lines and pleural line which appeared hyperechoic.

Figure 8



Multiple A lines horizontal artifacts parallel to the pleural line.

Figure 9



Lung consolidation: hypoechoic area with internal hyperechoic elements, representing air bronchograms.

similar study also had 53 (52%) males and 49 (48%) females.

According to the age in this study, the majority of cases were in the infancy time by 77%, followed by the age range 1–5 years 17%, lastly, 5–10 years; and greater than 10 years were 3% (17.33 ± 30.91 months).

However, Iorio *et al.* [4] mentioned that ages ranged from 2 months to 12.5 years (3.5 ± 3.1 years).

According to the history and presenting symptoms in this study, it was found that all cases whatever their diagnosis, their main complaint was shortness of breath. This was followed by two symptoms nearly on the same foot of equality; poor feeding (75%) and dry cough (73%), then comes fever (67%).

According to the general examination in the present study, it was found that the main clinical finding was tachypnea in every case (100%).

Signs of heart failure in this study included tachycardia (65%), enlarged tender liver (38%), puffiness of eyes (37%), lower limb edema (32%), and raised JVP (25%).

The results are in agreement with Jayaprasad [5] who reported that the clinical features suggestive of heart failure in infants include tachypnea, feeding difficulty, and diaphoresis. Irritability with feeding, sweating, and even refusal of feeds were also common.

Also, the Masarone *et al.* [6] study reported that the typical presentation of heart failure in infants and young children is difficulty in feeding, while in older children and adolescence: fatigue, shortness of breath, tachypnea, and exercise intolerance were the main symptoms. Abdominal pain, oliguria, and leg pitting edema could be present.

Signs of chest infection in this study were wheezes (58%), mainly then comes fine crepitation (42%), followed by bronchial breathing (12%), and decreased air entry (13%).

This in coincidence with Qin and Shen [7] as they mentioned that examination findings in suspected cases of pneumonia include crepitations, decreased breath sounds, bronchial breathing (findings indicating consolidated lung parenchyma), and wheezing (more common in pneumonia caused by atypical bacteria and viruses).

Also, two symptoms were found to be equal in our studied cases, repeated hospital admission due to chest cause, and repeated hospital admission due to cardiac cause, 52% each.

The Healy *et al.* [8] study reported that respiratory tract infection in children with coronary heart disease is an important cause of morbidity and mortality including respiratory failure, prolonged mechanical ventilation, and hospitalization. These patients often have many contributing factors that place them at increased risk for respiratory tract infection including malnutrition, aspiration, prolonged duration of tracheal intubation and/or mechanical ventilation and previous use of extended spectrum antibiotics that inhibit intestinal flora. This confirms that the main focus of the present study is to differentiate between heart failure and chest infection.

Pallor was found in 47% of our studied cases which agree with Masarone *et al.* [6] as they reported that complete blood count is used to assess anemia, which may cause or aggravate heart failure.

LUS findings in this study showed that the A-profile was found in 35 (58%) cases; however, in Bitar *et al.* [9] A-profile was found in 14 patients of the total 61 (23%) patients.

B-profile was found in 27 (45%) cases, this agrees with Caiulo *et al.* [3] which showed B lines in 59 (55%) patients.

However in Bitar *et al.* [9], B-profile was found in 47 patients of the total 61 (77%) patients.

Platz *et al.* [10] reported that B lines were found in 32% of the studied cases.

Hypoechoic areas were found in nine (15%) cases in this study; however, Caiulo *et al.* [3] showed lung consolidations in 65 (78%) cases.

AB-profile was found in six (10%) cases.

LUS appeared to be normal in three (5%) cases, this agrees with Caiulo *et al.* [3] who showed that LUS appeared to be normal in 1/89 children with pneumonia.

CXR findings in the current study showed that pneumonic patches were found in 49 (82%) cases, increased cardiothoracic ratio in 45 (75%) cases, increased bronchovascular markings in 43 (72%) cases, and lobar consolidation in six (10%) cases.

In this study, three patients with negative consolidation on CXR were positive with hypoechoic areas in LUS.

However, Iorio *et al.* [4] showed that CXR detected pneumonia in 25 (86.2%) patients.

According to the radiological findings of echocardiography in this study; decreased fractional shortening below 28% was found in 29 cases. By examination of these cases, it was found that all of them had tachypnea and tachycardia, 19 cases had enlarged tender liver, 15 cases had raised JVP and when LUS was done to these patients, B lines were found in 27 cases. Left ventricular enlargement in 21 (35%) cases, valvular regurge in 27 (45%) cases, and pulmonary hypertension in nine (15%) cases.

The study results are in agreement with Kirkpatrick *et al.* [11] who reported that heart failure is classically described as left ventricular dysfunction leading to congestion and reduced systemic perfusion, most often manifesting symptomatically as dyspnea and fatigue.

Leukocytosis was found in 21 (35%) cases in this study, which agree with Masarone *et al.* [6] who mentioned that leukocytosis may result from stress or signal to an underlying infection.

According to the management in this study, baseline antibiotics were prescribed in all cases which is the usual practice in the unit. It is a pity to do this, but it was a must because the bacterial infection is endemic in the locality and to protect against hospital-acquired infection. All cases received ampicillin/sulbactam. The decision was taken to upgrade the antibiotics in 30% of cases in the form of ceftazidime in five cases, cefotaxime in 10 cases, and cefepime in three cases. Fifty (83%) cases were on antifailure medication. A total of 36 cases were already on antifailure medication before admission. Antifailure medications were newly prescribed in 14 cases. In this study, 55 (92%) cases clinically improved and were discharged, whereas five (8%) cases died as they were suffering from severe respiratory distress. Three cases died due to fulminant chest infection and two cases died due to heart failure and cardiogenic shock. The duration of admission ranged from 3 days up to 11 days.

This is in congruence with Engelings *et al.* [12] study which reported that the leading causes of death in congenital heart diseases were heart failure and sudden cardiac death.

To our knowledge, this is a unique study to use combination between history, physical examination, and investigations such as LUS, echocardiography, complete blood count, and CXR. This study has several strengths and a unique work. Also in this work, there were two experts; one in echocardiography and the other in LUS. It is believed that LUS could diagnose by itself pulmonary edema, pneumonia, air trapping even pleural effusion and pneumothorax without use of other modalities such as CXR and computed tomography chest. The main limitation of radiography is the risk of damage from ionizing radiation.

Blind use of antibiotics should be avoided as it could cause drug resistance and repeated chest infections in cardiac patients as it was mentioned before.

Conclusion and recommendations

The use of LUS to diagnose or to confirm the diagnosis of chest infection, air trapping, lung congestion up to pulmonary edema differentiates which line of treatment is better for the patients, antibiotics or bronchodilators or antifailure medication. We hope to apply LUS as day and night approach for progress on antifailure medication and help changing the line of treatment together with other tools as biomarkers and inferior vena cava index.

Limitations

This study has several limitations. First, computed tomography chest was not applied in the study for financial issues and to protect the patients from harmful radiations. Second, the LUS has been done by a single expert sonographer.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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