Role of Chest Ultrasonography in the Diagnosis of Acute Pulmonary Edema

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Abstract: In this study we assessed the diagnostic performance of chest ultrasonography in pulmonary edema. Differential diagnosis between acute cardiogenic pulmonary edema (APE) and acute lung injury/acute respiratory distress syndrome (ALI/ARDS) may often be difficult. We evaluated the ability of chest sonography in the identification of characteristic pleuropulmonary signs useful in the diagnosis of ALI/ARDS and APE. ***Material and methods:***97 patients with provisional diagnosis of pulmonary edema were included in this study,portable CXR, bedside U/S and CT chest were done to all cases.we used CT chest findings as a gold standard for diagnosing pulmonary edema and detecting its type(etiology). ***Results:*** *US in CPE*: sensitivity was 93.4%, specificity: 93.3%, PPV: 98.6%, NPV: 73.7%, accuracy:87.6%. *US in NCPE*: sensitivity was 86.7%, specificity: 93.4%%, PPV: 72.2%, NPV: 97.5%, accuracy: 86.6%. *CXR in CPE*: sensitivity was 41.6%,s pecificity: 90.0%, PPV: 97.0%, NPV: 16.7%, accuracy: 42.3%. *CXR in NCPE:* was 60.0%, specificity: 90.0%, PPV 46.2%, NPV: 94.6%, accuracy: 78.4%.
Conclusion: chest U/S is a valuable tool for diagnosis of pulmonary edema and in detecting its etiology,portable CXR is poorly sensitive tool in diagnosis of pulmonary edema and in detection of its etiology.

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Keywords: ALI: acute lung injury, ARDS: adult respiratory distress syndrome, APE: acute cardiogenic pulmonary edema, NCPE: non-cardiogenic pulmonary edema, U/S: ultrasonography, CXR: chest x-ray, CT: computed tomography.

1. Introduction

Pulmonary edema can be defined as an increase in lung fluid caused by extravasation of fluid from the pulmonary vasculature into the interstitium and alveoli of the lungs. The buildup of fluid leads to progressive deterioration of alveolar gas exchange and resulting hypoxia. Pulmonary edema is generally classified as non-cardiogenic and cardiogenic. [1, 2]

CPE results from leakage of fluid from the pulmonary capillaries and venules into the alveolar space as a result of increased hydrostatic pressure. When the pulmonary capillary hydrostatic pressure exceeds pulmonary interstitial pressure, fluid transudates into the pulmonary alveoli and interstitium. [2]

Noncardiogenic pulmonary edema also is called acute respiratory distress syndrome (ARDS). It is characterized by diffuse alveolar damage, marked increased permeability of the alveolar-capillary membrane, and accumulation of protein-rich fluid in the alveolar air sacs. Noncardiogenic pulmonary edema is thought to represent a wide spectrum of lung injury with progressive respiratory distress and increasing hypoxemia refractory to oxygen therapy. This is believed to be secondary to parenchymal cellular damage which is characterized by endothelial cell destruction, deposition of platelet and leukocyte aggregates, destruction of type I pneumocytes, and hyperplasia of type II pneumocytes.

Definitions have been established for the severe form, ARDS, and the milder form, acute lung injury (ALI). [3,4]

In daily practice, examination of the lung can be approached by physical, radiological and CT scan examination. Physical examination is mastered by auscultation, nearly a two- century-old technique. [5] Chest radiography is a century-old technique.[6] CT has been fully available since the 1980s.[7]

It is not usual to proceed to lung ultrasonography, since this organ is reputedly inaccessible to this method.[8,9]

Role of chest ultrasonography in Differential Diagnosis between Lesional and Cardiogenic Pulmonary Edema

Determining the lesional or cardiogenic origin of a white lung is a frequent task. To oversimplify, water in cardiogenic pulmonary edema is submitted to hydrostatic pressure and moves up to the nondependent areas. In lesional edema, water passively descends to the dependent areas. These movements will have a sonographic outcome: the absences of diffuse anterior lung rockets when there are white lungs on the radiograph are highly suggestive of lesional edema. [10]

Sonographic appearance of APE is characterized by AIS homogeneously involving both anterior and posterior lung fields. Superior lung fields might be less affected, but "spared areas" were never observed (Figure1).

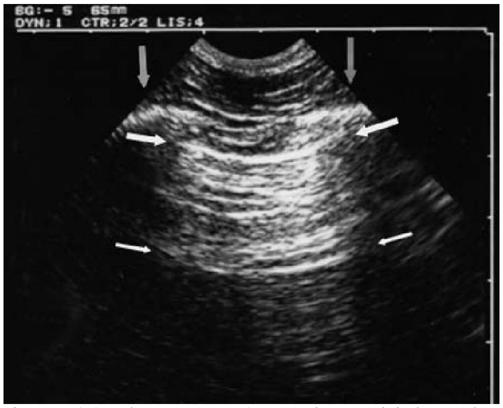
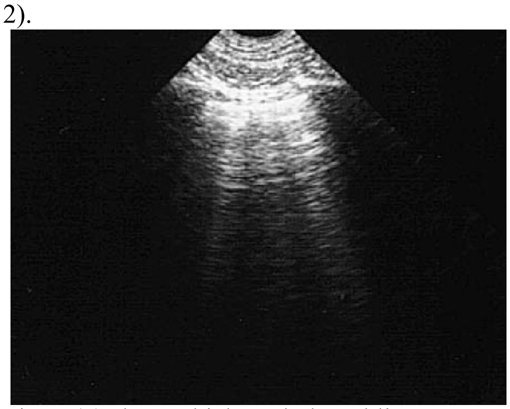


Figure (1): shows AIS (acute interstitial syndrome).

The pleural line was rarely involved, and appeared as a hyperechoic band without sliding impairment (Fig. 2).



Figure(2):shows thickened pleural line.

Small sub pleural consolidations were found in some cases, particularly at the It should be understood that interstitial edema involves all interstitial tissue, the superficial part of it being accessible to ultrasound.[11,12]

Role of CT scanning in the diagnosis of pulmonary edema:

In non cardiogenic pulmonary edema: CT scanning is seldom used in assessing patients with NPE and ARDS, mostly because of problems in transporting and monitoring these severely ill individuals. In addition, cardiogenic edema can give rise to an appearance similar to NPE on CT scans. High-resolution CT (HRCT) scanning demonstrates widespread airspace consolidation, which may have predominant distribution in the dependent lung regions. A reticular pattern with a striking anterior distribution is a frequent finding of follow-up CT scanning in ARDS survivors.[14]

High-Resolution CT Findings in cardiogenic pulmonary edema:

Abnormalities visible on high-resolution CT scans included areas of ground-glass opacity, interlobularseptal thickening peribronchovascular interstitial thickening, increased vascular caliber (four patients), and pleural effusion or thickening of fissures.[14-16]

2. Material and Methods

From 1/10/2013 to 1/4/2014, all cases admitted to department of critical care with preliminary diagnosis of pulmonary edema were included in our study.

All patients included in the study will be subjected on admission to routine examination and investigations.

Plain chest radiographs, chest ultrasonography, CT chest were done to all cases.

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Chest X-ray Signs suggestive of CPE (congestive pattern):[17,18]

- Increased cardiac size.
- Increased width of vascular pedicle.
- Central distribution of edema.
- Presence of thickened septal lines.
- Presence of consolidation with air bronchogram.

Chest X-ray Signs suggestive of NCPE (consolidative pattern):[17,18]

- Normal cardiac size.
- Normal width of vascular pedicle.
- Patchy distribution of edema.
- Normal septal lines.
- Presence of consolidation with air bronchogram.

In this study CT chest was the gold standard for differentiating (CPE) and (NCPE) we will use the CT chest to determine: consolidative pattern or congestive pattern.[13-16]

- Consolidative pattern:(CT findings) as consolidation, pleural abnormalities andspared areas are most specific signs in ALI/ARDS (NCPE).
- Congestive pattern: (CT findings)
- absence of consolidation, diffuse involvement of both lung fields,basal >apical, hilar congestion.

signs in chest ultrasonography are higlysuggestive of (consolidative pattern)NCPE[19,20]

- Pleural lines abnormalities defined as thickenings greater than 2 mm, evidence of small subpleural consolidations or coarse appearance of the pleural line.

- "Spared areas" defined as areas of normal lung patter in at least one intercostal space surrounded by areas of AIS.
- Consolidations defined as areas of hepatisation (tissue pattern) with presence of air bronchograms Lung pulse: defined as absence of lung sliding with the perception of heart activity at the pleural line.
- Areas with absent or reduced "sliding" sign with respect to adjacent or controlateral zones at the same level on the opposite hemithorax.

Sonographic appearance of CPE(congestive pattern):[21]

- AIS homogeneously involving both anterior and posterior lung fields. Superior lung fields might be less affected.

Absence of the above mentioned sonographic signs of NCPE.

Statistical Analysis:

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0.

Qualitative data were described using number and percent. Quantitative data were described using mean and standard deviation, median, minimum and maximum.

Agreement of the different predictives with the outcome was used and was expressed in sensitivity, specificity, positive predictive value, negative predictive value and accuracy. Receiver operating characteristic curve (ROC) was plotted to analyze a recommended cut off, the area under the ROC curve denotes the diagnostic performance of the test. Area more than 50% gives acceptable performance and area about 100% is the best performance for the test.

3. Results

Our study included 97 patients with preliminary diagnosis of pulmonary edema.

The following table demonstrates the distribution of the studied cases according to demographic data:

Table(1): Distribution of studied cases according to demographic data (n=97)

	No.	%
Age		
16 - <30	4	4.1
30-40	4	4.1
40-50	7	7.2
50-60	18	18.6
60-70	54	55.7
≥70	10	10.3
Min. – Max.	18.0-87.0	
Mean ± SD.	59.84±11.56	
Median	62.0	
Sex		
Female	37	38.1
Male	60	61.9

Final diagnosis according to CT chest CPE:82 patients, NCPE:17 patients. Sensitivity and specificity of both CXR and US chest were calculated in agreement with CT chest as follows:

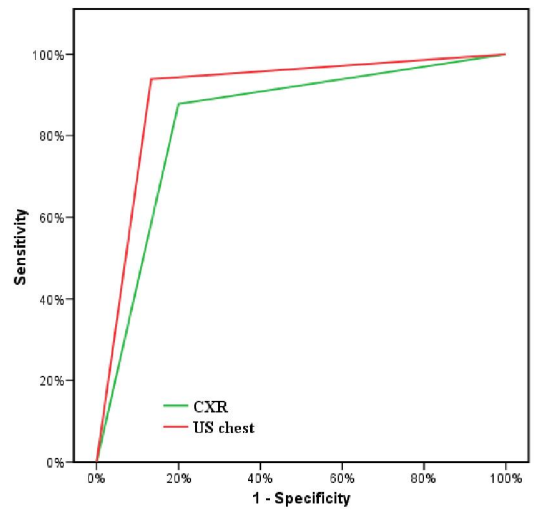

Figure (1): Roc showing sensitivity, specificity of CXR and US chest in congestion

Table (2): Agreement (sensitivity, specificity and accuracy) for X ray and lung ultrasonography with CT chest regarding congestion

		CT Chest No	CT Chest Yes	Sensitivity	Specificity	PPV	NPV	Accuracy
X chest	**No**	9	45	41.6	90.0	97.0	16.7	42.3
	Yes	1	32					
Lung ultrasonography	**No**	14	5	93.4	93.3	98.6	73.7	87.6
	Yes	1	71					

Table (3):Agreement (sensitivity, specificity and accuracy) for X ray and lung ultrasonography with CT chest regarding consolidation

		CT Chest		Sensitivity	Specificity	PPV	NPV	Accuracy
		No	Yes					
X chest	No	70	4	60.0	90.9	46.2	94.6	78.4
	Yes	7	6					
Lung ultrasonography	No	71	2	86.7	93.4	72.2	97.5	86.6
	Yes	5	13					

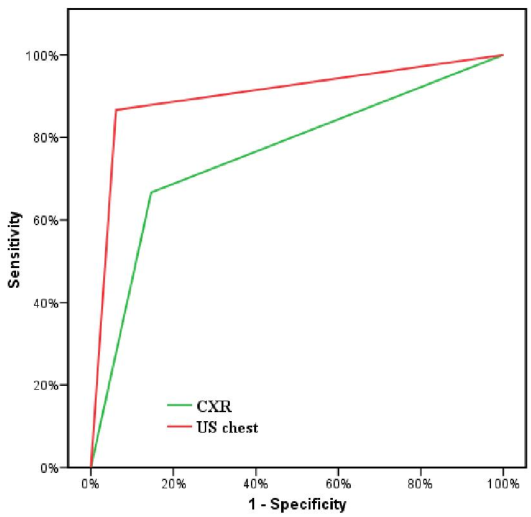

Figure (2): Roc showing sensitivity, specificity of CXR and US chest in consolidation.

According to previous tables and graphs:

US in CPE: sensitivity was 93.4%, specificity was 93.3%, PPV was 98.6%, NPV was 73.7%, accuracy:87.6%.

US in NCPE: sensitivity was 86.7%, specificity: 93.4%%, PPV:72.2%, NPV:97.5%, accuracy: 86.6%.

CXR in CPE: sensitivity was 41.6%, Specificity: 90.0%, PPV was 97.0%, NPV was 16.7%,accuracy was 42.3%.

CXR in NCPE: was 60.0%, specificity: 90.0%, PPV 46.2%, NPV: 94.6%, accuracy:78.4%.

4. Discussion:

Regarding the role of chest radiography in diagnosis of pulmonary edema (cardiogenic and non cardiogenic):

In our study, the sensitivity of chest radiography in detecting cardiogenic pulmonary edema (congestion) was 41.6% in agreement with chest computed tomography. The specificity was 90.0%, with PPV: 97%, NPV:16.7%, accuracy of 42.3%.

In a study performed by Sean P. Collins, Christopher J, sensitivity for detecting signs of cardiogenic pulmonary edema about: 41%, specificity about: 96%.[21]

In a study by Sivak ED, Richmond BJ, O'Donavan PB, Borkowski GP named(Value of extravascular lung water measurement vs portable chest x-ray the sensitivity of CXR in detecting cadriogenic pulmonary edema was 42%.[22]

In our study the sensitivity of chest radiography in detecting consolidation pattern in agreement with chest CT was 60.0%, specificity 90.9% with PPV of 46.2%, NPV:94.6%, and accuracy 78.4%.

In a study by Lichtenstein,, Ivan Goldstein, Comparative Diagnostic Performances of Auscultation, Chest Radiography, and Lung Ultrasonography in Acute Respiratory Distress Syndrome. The sensitivity of chest radiography in detecting consolidation which is the most specific radiologic sign of ARDS was 68%, specificity was 95%, diagnostic accuracy 75%.[23]

Role of lung ultrasonography in diagnosis of pulmonary edema (cardiogenic and non cardiogenic)

In our study we assessed the diagnostic performance of lung ultrasonography in cardiogenic pulmonary edema in agreement with CT chest as: Sensitivity was 93.4%, specificity:93.3%%, PPV:98.6%, NPV:73.7% and accuracy 87.6%.

In a study Lichtenstein A, Meziere GA Relevance of Lung Ultrasound in the Diagnosis of Acute Respiratory Failure The BLUE Protocol.[131] chest ultrasonography in cardiogenic pulmonary edema, the sensitivity:97%, specificity 95%, PPV:87% and NPV: 99%.[24]

In our study, the diagnostic performance of lung ultrasonography in non-cardiogenic pulmonary edema in agreement with CT chest: Sensitivity was 86.7%, specificity 93.4%, PPV:72.2%, NPV:97.5% and accuracy 86.6%.

In a study by Copetti R, Soldati G, Copetti P Chest sonography: a useful tool to differentiate acute cardiogenic pulmonary edema from acute respiratory distress syndrome, the sensitivity of lung ultrasonography in detecting non cardiogenic pulmonary edema was 83.3%, specificity was 100%.[25)]

These results demonstrate that chest sonography represents a useful tool for the diagnosis because it can detect very peculiar findings.[26)]

Conclusion

- Bedside chest ultrasonography is a valuable,easy tool for diagnosing pulmonary edema and detecting its etiology (type),with high specificity, sensitivity and accuracy.
- Portable Plain chest radiographs is simple tool for diagnosing pulmonary edema with high specificity but low sensitivity and accuracy.

But, Lung ultrasonography has some shortcomings.

- For obese patients visualization of lung parenchyma might be difficult.
- Adequate interpretation of lung ultrasonographic findings requires special training and some experience. However, because ultrasound abnormalities are well defined and easy to recognize, operator dependence is minimal.

  These limitations should be balanced against the benefits of lung ultrasonography, which has a direct diagnostic and therapeutic impact for more than two thirds of critically ill patients.

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