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Original Article

Evaluation of Bedside Lung Ultrasonography in Diagnosis of Acute Pulmonary Oedema

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Abstract:

Background: *Pulmonary oedema is one of the major causes of mortality and morbidity. Acute heart failure is the major cause of pulmonary oedema. NT-pro B-type natriuretic peptide has been found to be effective in distinguishing acute pulmonary oedema from other causes of dyspnea in the emergency care setting. But it is costly and time consuming. Bedside lung ultrasonography (LUS) is being considered as noninvasive, radiation-free and easy to perform tool to diagnosis pulmonary oedema.*

Objective: *To determine the role of bedside LUS in diagnosis of patients with acute pulmonary oedema.*

Methods: *This observational cross-sectional study was carried out in ICU, Department of Anaesthesia, Analgesia, Palliative & Intensive Care Medicine, Dhaka Medical College Hospital, Dhaka from August 2018 to October 2019. Ethical approval was sought before conduction of the study. One hundred critically-ill patients with pulmonary oedema, detected by clinical examination & chest X-ray, due to heart failure were included in the study. Routine labs including NT-pro B-type natriuretic peptide level were sent. Bedside LUS was done with a portable ultrasound machine. Data was collected by using a semi-structured data sheet.*

Observation and Results: *The median age was 42 years (IQR 18-66). Among them, 67.71% were male. 90.0% of patients diagnosed as acute pulmonary oedema by NT-pro B-type natriuretic peptide levels findings and 88.5% of patients were diagnosed as acute pulmonary oedema by bedside lung ultrasonography. The sensitivity, specificity, positive predictive value, negative predictive value and accuracy of lung ultrasonography findings alone statistically significant as 94.2%, 66.7%, 96.4% & 54.5% and 91.66% respectively in detection of pulmonary oedema.*

Conclusions: *Bed side lung ultrasonography can be an effective adjunct tool for rapid and high diagnostic accuracy for diagnosis of acute pulmonary oedema along with NT pro BNP level in ICU.*

Keywords: *Acute pulmonary edema, NT-pro B-type natriuretic peptide, lung ultrasound.*

Introduction:

Pulmonary oedema is defined as accumulation of fluid in the lungs, resulting in impaired gas exchange and arterial hypoxemia. It develops sequentially first in hilar region of the lungs, followed by filling of the interstitial space and lastly, in its most severe form, by alveolar flooding[1]. The most severe manifestation of acute heart failure is pulmonary edema[2].

Two main types of pulmonary edema are recognized: first, cardiogenic and second, noncardiogenic. Owing to their fundamental differences, each occurs in distinct clinical conditions, requires separate therapy, and has a different prognosis[3].

Despite the considerable variation of clinical profiles and the substantial heterogeneity of underlying causes, the vast majority of patients with acute heart failure present with symptoms and signs of pulmonary and systemic congestion rather than low cardiac output. Pulmonary congestion is an important clinical finding in patients with heart failure. Physical examination and chest X-ray have limited accuracy in detecting congestion[4]. Lung ultrasonography (LUS) has been incorporated into clinical practice in the evaluation of pulmonary congestion[4].

Acute pulmonary edema is associated with cardiovascular, renal, cerebral, and pulmonary diseases, trauma to the skull or chest, infections, and shock[5].

Pulmonary artery catheter reliably measures left atrial pressure, but placement can be time-consuming and requires an experienced operator. B-type natriuretic peptide (BNP) is a hormone. NT-pro BNP is a non-active prohormone that is released from the same molecule that produces BNP. Both BNP and NT-pro BNP are released in response to changes in pressure inside the heart.

NT-pro BNP, a rapidly-assayed, serum biomarker, has been found to be effective in distinguishing congestive heart failure (CHF) from other causes of dyspnea in the emergency or urgent care setting[6]. BNP can effectively identify congestive heart failure in the emergency room setting but, despite increasing use, its diagnostic utility has not been validated in the intensive care unit (ICU).

LUS has become widely used to assess alveolar-interstitial syndrome, which encompasses pulmonary congestion of cardiac origin, in intensive care and emergency settings, for hospitalized patients before hospital discharge, and for

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patients with heart failure undergoing outpatient follow-up[4,7].

Point of care ultrasonogram is very effective for rapid diagnosis and prompt treatment of pulmonary oedema patients & can reduce the mortality & morbidity. Therefore, this study was conducted to evaluate the usefulness of bedside LUS in diagnosis of cardiogenic pulmonary oedema and correlation with NT-pro BNP.

Methodology and materials:

This observational, prospective, cross-sectional study was carried out at the department of Anesthesia, Pain, Palliative and Intensive care, Dhaka Medical College Hospital, Dhaka for the period of twelve months from August 2018 to October 2019.

All patients aged ≥18 years with pulmonary edema detected clinically & by Chest X-ray due to heart failure after obtaining informed written consent were included in the study. Patients having acute respiratory distress syndrome (ARDS), end stage renal disease (ERSD), severe pneumonia, fluid over load and massive transfusion were excluded from the study. The study was not randomized & sampling was purposive

Operational Definition:

NT-pro BNP: NT-pro BNP levels higher than 500 pg/ml means pulmonary edema

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Lung ultrasound diagnosis of acute pulmonary oedema: B-Lines are vertical pleural-based discrete, laser-like, hyper-echoic reverberation artifacts. They move with respiration simultaneously and extend to the bottom of the screen without fading. Presence of B- lines in any 8 fields (zones) considered as acute pulmonary edema [8].

Procedure of data collection:

This prospective, observational and cross sectional study was conducted in ICU, Department of Anaesthesia, Analgesia, Palliative & Intensive Care Medicine, DMCH. Ethical approval was obtained from the DMCH ethical review board prior of this study. After matching of the inclusion & exclusion criteria patients were enrolled. Informed written consents were obtained from the attendants of patients.

Heart failure was diagnosed by history, clinical examination and chest X-ray. A blood sample was drawn for Plasma NT pro BNP levels within 6-12 hours of admission from each patient. Bedside lung ultrasonography was done by the investigator with a portable ultrasound machine (Model: Sono-site M-Turbo,USA) using curved array (3.5-5 MHz) and linear array transducer (5.0 to 13.0 MHz). For performing ultrasonography, each hemi thorax was divided into 2 anterior (upper and lower) and 2 lateral zones. Anterior zone marked as the area between sternum and anterior axillary line while lateral zone was between anterior and posterior axillary lines. These zones are further divided by a line passing below/at the level of the nipple – areola complex. And in each segment at least 3 intercostal spaces are scanned. In lateral zone 3rd intercostal space is in axilla

Lungs were scanned for presence of pleural sliding and B-Lines. Pleural sliding is the back and forth movement of visceral and parietal pleura. B-Lines are vertical pleural-based discrete, laser-like, hyper-echoic reverberation artifacts. They move with respiration simultaneously and extend to the bottom of the screen without fading. Ultrasonography performance took 6 minutes for each patient. Final diagnosis of patients was decided based on clinical, laboratory, imaging and response to treatment findings. Then finally correlation was done between lung USG with NT-pro BNP level.

Data was collected by using a semi-structured data sheet. After enrollment & documentation , the coded data was cleaned, validated and analyzed using SPSS. Data presented as table, graph and charts.

Table I : Scoring of B-lines[7]

Score	Number of B-lines	EVLW
0	≤5	Absent
1	6–15	Mild degree
2	16–30	Moderate degree
3	>30	Severe degree

The number of B-lines in the antero-lateral chest scan is usually summed to generate a quantitative or semi-quantitative B-line score *(*Table I*)*. Up to 2 B-lines per single intercostal space, or up to 5 in the comprehensive antero-lateral chest scan can be a normal finding.

Laboratory tests

All participants were advised for routine laboratory investigations for acute heart failure such as Echocardiography, ECG, serum creatinine, blood glucose and serum electrolytes.

Ethical measures

The research protocol was approved by the Dhaka Medical College Ethical Review committee.

Methods of data processing and statistical analysis

Following collection of the data, all data were edited and encoded into SPSS version 22.0. In this study, continuous data was displayed as mean ± standard deviation. A p-value less than 0.05 was considered to be significant. Diagnostic accuracy measures of sensitivity and specificity and calculated with 95% exact binomial confidence intervals (CIs). All collected questionnaire checked very carefully to identify the error in the data. To make out the relation between binary diagnostic test and the presence or absence of disease, a 2/2 contingency table was constructed.

Results:

This cross sectional observational study was conducted in the Department of Anaesthesia, Pain, Palliative & Intensive Care Medicine, Dhaka Medical College Hospital, Dhaka to evaluate the effectiveness of bedside lung ultrasonography in diagnosis of acute pulmonary oedema and correlation with NT Pro-BNP. A total 100 patients were selected for study according to inclusion and exclusion criteria. The number of patients who lost to follow-up (drop out/ missing data) were 4 patients, therefore 96 sample study subject were finally selected.

The median age was 42 years (IQR 18-66). Sixty five patients (67.71%) were male. Male: Female ratio was 2:1.46. 47.92% study patients were smokers (Table II).

Table II: Study patients characteristics (N=96)

Characteristics	Frequency, (%)
Age in years, median [IQR]	42 [18-66]
Gender	
Male	65 (67.71)
Female	31 (32.29)
History of smoking	
Smoker	46 (47.92)
Non-smoker	50 (52.08)

Most common co-existing disease was hypertension among the study population. There is no significant difference between male and female in co-morbidities (Table III). Table IV shows the distribution of the patients according to indication for ICU admission. The difference between male and female groups was statistically non significant ($p \geq 0.05$). Table V showed the NT-pro BNP levels among the study subject. NT-pro BNP levels <500 was detected in 9 (9.3%) of patients with 235.3±46.2 (Mean±SD). NT-pro BNP levels >500 was detected in 87 (90.6%) of patients with 716.1±82.5 (Mean±SD).

Table-III: Distribution of the patients according to co-morbidity (n=96)

Coexisting disease	Male (n_1=65)		Female (n_2=31)		P value
	No.	%	No.	%	
Hypertension	26	40.0	15	48.3	0.208^{ns}
Diabetes	18	27.6	8	25.8	0.382^{ns}
HTN & DM	15	23.0	12	38.7	0.542^{ns}
CAD	12	18.4	8	25.8	0.124^{ns}
COPD	17	26.1	4	12.9	0.075^{ns}

Table-IV: Distribution of the patients according to ICU diagnosis (n=96)

Diagnosis	Male (n_1=65)		Female (n_2=31)		P value
	No.	%	No.	%	
Respiratory disease					
Pneumonia	4	6.1	5	16.1	0.072^{ns}
Acute exacerbation of COPD/BA	4	6.1	1	3.2	0.187^{ns}
Neurological disease					
Head injury & polytrauma	*9*	*13.8*	1	3.2	0.068^{s}
Stroke	5	7.6	1	3.2	0.098^{ns}
Meningo-encephalitis	4	6.1	1	3.2	0.187^{ns}
Seizure disorder	2	3.0	0	0	0.065^{ns}
Neurosurgical status	3	4.6	2	6.4	0.952^{ns}
Post-surgical status	9	13.8	3	9.6	0.085^{ns}
Pre eclampsia, Eclampsia	0	0	5	16.1	0.026^{s}
Sepsis	7	10.7	1	3.2	0.084^{ns}
Metabolic encephalopathy	5	7.6	1	3.2	0.098^{ns}
Poisoning	2	3.0	2	6.4	0.257^{ns}
Liver failure	3	4.6	0	0	0.078^{ns}
Acute pancreatitis	1	1.5	1	3.2	0.086^{ns}

Table-V: Evaluation of NT-Pro BNP levels among the study subject (n=96)

NT-pro BNP levels	Number of patients	Percentage (%)	Mean±SD
< 500 pg/ml	9	9.3	235.3±46.2 pg/ml
> 500 pg/ml	87	90.6	716.1±82.5 pg/ml

Figure 1 showed the 87 (90.0%) patients diagnosed as acute pulmonary oedema. Out of 85 study patients, who were diagnosed acute pulmonary oedema by bedside lung

ultrasound, 82 study patients were diagnosed by NT-pro BNP level. Nine study patients were excluded by BNP level. Bedside lung ultrasonogram could exclude acute pulmonary oedema in 6 patients correctly (Table VI).

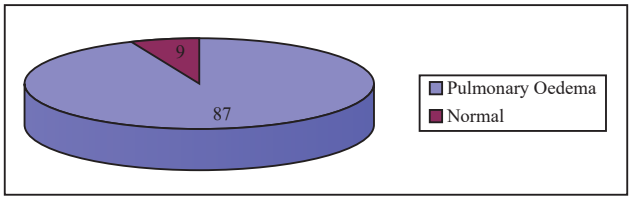

Figure-1: Diagnosis of Acute Pulmonary Oedema according to NT-proBNP levels findings (n=96)

Table VI: Cross tabulation showing the diagnosis of acute pulmonary oedema by Lung Ultrasonogram & BNP level (N=96)

Lung USG finding	NT-pro BNP level (pg/ml)		Total	Test statistic	P-value
	> 500	< 500		X^2	
Disease positive	82	03	85	0.50	0.479
Disease negative	05	06	11		
Total	87	09	96		

True positive (TP) =82, False positive (FP) = 3, False negative (FN) = 5, True negative (TN) = 6

Comparison of diagnosis of acute pulmonary edema by lung USG and NT-Pro BNP level done by Mc-Nemar test. Here p-value is more than 0.05, therefore difference between two test procedure is not significant. The Sensitivity and Specificity of lung USG in diagnosing pulmonary edema was 94.2% and 66.7% respectively. Similarly the positive predicative value and negative predicative value for the same was 96.4% and 54.5% respectively. (Figure 2).

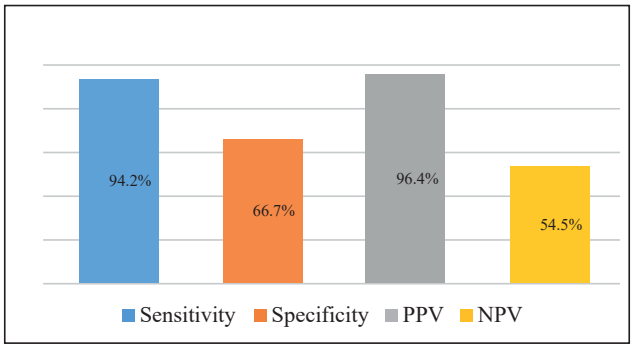

Figure-2: USG findings in diagnosis of acute pulmonary oedema (n=96)

Discussion:

The main objective of this study was to determine the accuracy of bedside lung ultrasonography in diagnosis of acute pulmonary oedema and correlation with NT-Pro BNP in the ICU.

This study was conducted on patients with the median age was 42 years (IQR 18-66). 67.71% were male. The majority of study patients had hypertension (36.46%), followed by DM (20.04%). Many patients had more than one co-morbidities. 47.92% study patients were smokers. In a study by Pirompanich, P. et al, 34 patients were enrolled, the mean age was 66.5 (± 13.5) years; and 16 (47.1%) patients were male[9].

Acute pulmonary edema may be associated with the most varied clinical conditions including cardiovascular, renal, cerebral, and pulmonary diseases, trauma to the skull or chest, infections, and shock[5]. Therefore proper evaluation and appropriate management is pivotal for prevention of mortality and morbidity due to pulmonary congestion.

NT Pro-BNP a rapidly-assayed, serum biomarker, has been found to be effective in distinguishing congestive heart failure (CHF) from other causes of dyspnea in the emergency or urgent care setting. NT Pro-BNP levels greater than 450 pg/mL have specificity greater than 95% and sensitivity greater than 98% when comparing patients without heart failure to all patients with heart failure. High cost, and objectivity have reduced the widespread incorporation of NT Pro-BNP into the clinical evaluation of pulmonary oedema[6]. In this study 87 (90.0%) of patients diagnosed as acute pulmonary oedema by increasing NT Pro-BNP level.

Cepkova et al showed that NT-Pro BNP levels correlate with ventricular filling pressures and predict adverse outcome in patients with acute pulmonary oedema[10]. In this study NT-pro BNP levels <450 pg/ml was detected in 9 (9.3%) of patients with Mean±SD 235.3±46.2pg/ml. NT-pro BNP levels >450 pg/ml was detected in 87(90.6%) of patients with Mean±SD 716.1±82.5pg/ml.

In this study 85 (88.5%) of patients were diagnosed as acute pulmonary oedema. The sensitivity and specificity was 94.2% and 66.7% respectively. Similarly the positive predicative value and negative predicative value for the same was 96.4% and 54.5% respectively& accuracy was 91.66%.

Pulmonary ultrasound increased accuracy by 90%, in thisstudy the accuracy was 91.66%.

The presence of B-lines ≥15 correlated with high BNP values (≥ 500) having prognostic impact in ICU patients at hospital discharge and those followed up on an outpatient basis[4]. The B-lines had a sensitivity of 100% and a specificity of 92% in indicating pulmonary oedema. Lichtenstein and Mezière suggested that LUS might be used in differentiating pulmonary oedema from COPD[11]. An increased number of B-lines is typical for sonographic imaging of pulmonary oedema. Another review study by Muniz et al showed patients with acute heart failure followed up on an outpatient basis has concluded that pulmonary ultrasound has great diagnostic potential for identifying pulmonary congestion signs at the bedside, can become a state-of-the-art marker of interstitial fluid, and that the B-line pattern usually disappears after proper treatment of acute heart failure, revealing itself as an alternative diagnostic tool of easy use and therapeutic applicability [4]. A recent study by Platz et al has shown that the pulmonary ultrasound findings can rapidly change with therapy for heart failure, and that the identification of residual congestion in patients with acute heart failure at hospital

discharge or in patients with chronic Heart failure followed up on an outpatient basis can indicate those at higher risk for adverse events [12]. There is the excellent correlation between two observers with different specific expertise regarding pulmonary ultrasound for the analysis of B-lines at the bedside of patients with known or presumed heart failure[13].

Studies investigating the use of LUS in the diagnosis of pulmonary oedema first emerged with the introduction of defining peripheral lesions by ultrasound images in the late 1960s. The wedge and round-shaped pleural-based peripheral lesions, and they found that the sensitivity of these lesions for the diagnosis of pulmonary oedema was 74%, the specificity was 95%, the positive predictive value was 95%, and the negative predictive value was 75%. They reported that these findings were valuable in the diagnosis of pulmonary oedema, but negative results did not exclude such a diagnosis[14]. Pooled estimates for lung ultrasound were 0.88 (95% Cl, 0.75-0.95) for sensitivity and 0.90 (95% Cl, 0.88-0.92) for specificity. lung ultrasound should be considered as an adjunct imaging modality in the evaluation of patients with dyspnea at risk of pulmonary oedema[15]. Bedside chest ultrasonography can be used for immediate understanding for lung status that also influences to take the early therapeutic decision.

Limitations of the study: The limitation of this prospective observational study was small sample size and bed side lung ultrasonoghrahy is an operator dependent procedure, so skilled person is needed.

Conclusion and Recommendations:

Bed side Lung ultrasound can be an effective adjunct tool for rapid and high diagnostic accuracy for diagnosis of acute pulmonary oedema along with NT pro BNP level in intensive care unit. Along with other investigations sonographic facility should be available in all critical care setting.

Funding:

The study was self-funded.

Conflict of interest:

There is no conflict of interest to any of the authors of the article.

References:

1. Pappas, L. and Filippatos, G. 2011. Pulmonary Congestion in Acute Heart Failure: From Hemodynamics to Lung Injury and Barrier Dysfunction. *Sociedad Española de Cardiología*,vol. 64,no. 9, pp. 735-738.
2. Hall. J. 2016.Guyton & Hall Physiology review.Elsevier,pp. 765-796
3. Murray, J. 2011. Pulmonary edema: pathophysiology and diagnosis. *The International Journal of Tuberculosis and Lung Disease*, vol. 15,no. 2, pp. 155-160. (3)
4. Muniz, R., Mesquita, E., Junior, C., Martins, W. 2018. Pulmonary Ultrasound in Patients with Heart Failure - Systematic Review. *Arq Bras Cardiol*, vol. 110,no. 6, pp. 577-584.
5. Luisada, A. &Cardi, L. 1956. Acute Pulmonary Edema- Pathology, Physiology and Clinical Management. *Circulation*, vol. 13, pp. 113-117.
6. Levitt, J., Vinayak, A., Gehlbach, B., Pohlman, A., Van Cleve, W., Hall, J. & Kress, J. 2008. Diagnostic utility of B-type natriuretic peptide in critically ill patients with pulmonary edema: a prospective cohort study. *Critical Care*, vol. 12,no. 3, pp. 1-5.
7. Lichtenstein, D., Mézière, G., Biderman, P., Gepner, A., Barré, O. 1997. The comet-tail artifact, an ultrasound sign of alveolar-interstitial syndrome. *Am J RespirCrit Care Med*, vol. 156,no. 5, pp. 1640–1646.
8. Lichtenstein, D.A., 2015. BLUE-Protocol and FALLS-Protocol: two applications of lung ultrasound in the critically ill. *Chest*, vol. 147, no. 6, pp. 1659–1670.
9. Pirompanich, P., Romsaiyut, S. 2018. Use of diaphragm thickening fraction combined with rapid shallow breathing index for predicting success of weaning from mechanical ventilator in medical patients. *Journal of Intensive Care*, vol. 6,no. 1,pp. 1-7.
10. Cepkova, M., Kapur, V., Ren, X., Quinn, T., Zhuo, H., Foster., E, et al. 2011. Clinical significance of elevated B-type natriuretic peptide in patients with acute lung injury with or without right ventricular dilatation: an observational cohort study. *Annals of Intensive Care*, vol. 1,no. 18,pp. 132-39. (12)
11. Lichtenstein, D., Mezière, G. 1998. A lung ultrasound sign allowing bedside distinction between pulmonary edema and COPD: the comet-tail artifact. *Intensive Care Med*, vol. 24,no. 4, pp. 1331–4.
12. Platz, E., Merz, A.A., Jhund, P.S., Vazir, A., Campbell, R., McMurray, J.J. (2017). Dynamic changes and prognosis value of pulmonary congestion by ultrasound in acute and chronic heart failure: systematic review. *Eur J Heart Fail*, vol. 19,no. 9,pp. 1154–1163.
13. Gullett, J., Donnelly, J.P., Sinert, R., Hosek, B., Fuller, D., Hill, H. (2015). Interobserver agreement in the evaluation of B lines using bedside ultrasound. *J Crit Care,* vol. 30,no. 6,pp. 1395–1399.
14. Mathis, G., Blank, W., Reissig, A., Lechleitner, P., Reuss, J., Schuler, A. (2005). Thoracic ultrasound for diagnosing pulmonary embolism: *a prospective multicenter study of 352 patients. Chest*, vol. 128, pp. 1531–8.
15. Maw, A., Hassanin, A., Ho, M., McInnes, M., Moss, A., Juarez-Colunga. E. et al. 2019. Diagnostic Accuracy of Point-of-Care Lung Ultrasonography and Chest Radiography in Adults With Symptoms Suggestive of Acute Decompensated Heart Failure- A Systematic Review and Meta-analysis. *JAMA Network Open*, vol. 2, no. 3, pp. 190.