

## Review Article

# A review of role of lung ultrasound and clinical congestion score in acute left ventricular failure

Praveen M. P., Lokesh Shanmugam\*, P. Arun Prasath

Department of General Medicine, MGMCRI, Pondicherry, India

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### \*Correspondence:

Dr. Lokesh Shanmugam,

E-mail: [lokeshs@mgmcri.ac.in](mailto:lokeshs@mgmcri.ac.in)

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## ABSTRACT

Congestive cardiac failure (CCF) is a worldwide phenomenon and affects millions of people years and is accompanied with high mortality. The present review is undertaken to evaluate the usefulness of Lung Ultrasound Scan in diagnosis and to identify its role as a marker of clinical outcome in patients with Acute LVF. A review of literature was done to find the role of lung ultrasound and clinical congestion score in acute left ventricular failure from search engines such as PubMed, google scholar. Major exclusion criteria were the studies that included patients with Right Ventricular Failure, renal insufficiency, other respiratory causes of breathlessness like pneumonia, pulmonary embolism, pneumothorax and pleural effusion. This review concluded that lung ultrasonography is as a rapid, non-invasive, bedside tool for the diagnosis and risk assessment of pulmonary congestion in Acute LVF.

**Keywords:** Acute heart failure, Clinical Congestion score, Hospital stay, Kerly B lines, Lung ultrasound

## INTRODUCTION

Congestive cardiac failure (CCF) is a worldwide phenomenon and usually affects millions of people years and is accompanied with high mortality. Even with the significant improvement of the medical therapy, CHF remains a major clinical problem. It is a major public health problem with increased morbidity and mortality.<sup>1</sup>

American College of Cardiology Foundation (ACCF)/ American Heart Association (AHA) guidelines defines Heart failure as a complex clinical syndrome which results from structural or functional dysfunction of ventricular filling or ejection of blood, which in turn leads to the characteristic clinical symptoms of dyspnoea and fatigue and signs of HF, namely edema and rales.<sup>2</sup>

The heart failure is a burgeoning problem across the world with more than 20 million of the people usually affected. The prevalence of the heart failure in the adult population in developed countries is 2%. The prevalence

of heart failure follows an increasing pattern, increases with age and affecting 6 - 10% of the people over the age of 65 years.<sup>3</sup>

The causes and demographic pattern of these patients suffering with the heart failure varies from one geographic region to another. Hypertension, rheumatic heart disease (RHD) and idiopathic cardiomyopathies are the major causes of heart failure especially in younger age group patients when compared with the developed countries.<sup>4,5</sup>

The common cause for the systolic dysfunction includes valvular heart disease, idiopathic dilated cardiomyopathy, hypertension and ischemic heart disease. The major causes includes restrictive cardiomyopathy, ischemic heart disease, hypertrophic cardiomyopathy and hypertension.<sup>6</sup>

Clinical diagnosing heart failure is the mainstay as there is no definitive tests available for heart failure and is

mainly based on taking history and physical examination and is supported by tests including chest x-ray, ECG and echo cardiography.<sup>7</sup> Traditionally, the clinical assessment in assessing the pulmonary congestion in admitted patients has lesser sensitivity and specificity.<sup>8</sup> The gold standard test for detection of cardiac congestion is mainly by assessing the right and also left atrial pressure by measuring pulmonary capillary wedge pressure (PCWP) through cardiac catheterisation. However, this test is invasive, expensive, consumes time, and carries risk and hence not routinely performed in patients with acute LVF.<sup>9,10</sup>

Although advances have been in the treatment of heart failure patients yet the post discharge mortality and recurrent admission rates have continued to be high. A predictor for frequent hospitalization and high mortality in patients with heart failure is due to excessive accumulation of fluid in the alveoli and interstitial space of lungs. Early diagnosis of congestion in pulmonary vasculature may prevent re-hospitalization.<sup>11</sup> In heart failure patients B-lines have been considered as a reliable ultrasound technique for the evaluation of pulmonary congestion.

Interstitial pulmonary edema has been reliably found out in multiple studies by chest ultrasound and has been used in the differentiating between CHF exacerbation and Chronic Obstructive Pulmonary Disease (COPD). Lung ultrasonography has emerged as a rapid, non-invasive, bedside tool for the detection and assessing degree of pulmonary congestion in Acute LVF.<sup>12</sup>

In this article, authors have reviewed various articles which discuss the usefulness of Lung Ultrasound Scan in diagnosis and to identify its role as a marker of clinical outcome in Acute LVF.

### Search strategy

This review was conducted through an internet search on public websites such as PubMed, Google Scholar, Proquest until 2019. Keywords utilized included Lung ultrasound, clinical congestion score, acute left ventricular failure.

The major exclusion criteria were the studies that included patients with right ventricular failure, renal insufficiency, other causes of breathlessness like pneumonia, pulmonary embolism, pneumothorax and pleural effusion.

## REVIEW OF LITERATURE

Andreas Nerlich from Munich examined in detail the histopathology of lungs and made description regarding presence of pulmonary edema, probably secondary to heart failure, as the histochemical staining of lung parenchymal tissue ruled out other disease due to 'fluid

within the air spaces of the lung' including microbacterial infections, granulomas or tuberculosis.<sup>13</sup>

Kitab al – Advuyt – al book by Avicenna discusses about the management strategies available for syncope, dyspnea, and palpitation.<sup>14</sup> A vasodilator heart failure trial performed by J Cohn discovered the drugs to reduce the after load of the heart.<sup>15</sup>

The piezoelectric effect of various crystals was discovered by Pierre Curie and Jaques Curie in 19th century (e.g., Quartz) which were later by Langevin.<sup>16</sup> In the midst of 20th century Dussik brothers explained the diagnostic utility of ultrasound and Joyner et al, studied the usefulness of thoracic ultrasound of diagnosing pleural effusion.<sup>17</sup> Lagrange et al, made use of ultrasound for placement of needle in nerve blocks.<sup>18</sup> Axler and Lichtenstein the pioneers of lung ultrasound in the early 90s assessed the scientific principle behind LUS.<sup>19</sup>

## HEART FAILURE

Dyspnoea and fatigue are the cardinal manifestations of the Heart failure which may often limit exercise tolerance and fluid retention leading to pulmonary congestions and peripheral edema. The pulmonary congestion and edema impairs the functioning capacity and quality of life of affected individuals, but they do not necessarily dominate the clinical picture at the same times.<sup>20</sup>

### Epidemiology

The evidence available shows that, the heart failure is a major and growing public health problem in the world. Almost 5 million patients in this country have HF and over 550,000 patients are often diagnosed as with heart failure for the first time each year.<sup>21</sup> Heart failure is a primary reason for the 12 to 15 million office visits and 6.5 million hospital days each year in United states.<sup>22</sup> The annual number of hospitalizations has increased from approximately 810,000 to over 1 million for HF as a primary diagnosis and from 2.4 and 3.6 million for heart failure as a primary or secondary diagnosis from 1990 to 1999.<sup>23</sup> The estimates of 2001 shows that almost 53,000 patients died of HF as primary cause. The number of heart failure deaths have increased steadily despite of advances in treatment, in part because of increase in the number of patients with HF due to better treatment, in part because of increasing percentage of patients with HF due to better treatment and "Salvage" of patients diagnosed with acute myocardial infarctions (MIs) earlier in life.<sup>20</sup>

The prevalence of heart failure in India secondary to coronary heart disease ranges from 1.3 to 4.6 million, with an yearly incidence of 491,600 - 1.8 million. The dual burden due to rise in cardiovascular risk factors and persistent presence of 'pre transition' disease like rheumatic heart disease, limited health care facilities and

social disparities contributes to the disease.<sup>23</sup> Heart failure being predominant disease in the elderly, hence the lifetime risk for the HF increases with ageing and also the burden of HF is likely to increase with ageing of population. The epidemiological transformation reflects changes in the occurrence of disease patterns as society's develop.<sup>24</sup> LV remodelling is sufficient to result in disease progression in patients with heart failure independent of neurohormonal state of the patient.<sup>25</sup>

### Aetiology

Heart failure is a characteristic clinical syndrome which is often diagnosed by the cluster of symptoms and signs of decreased effort tolerance and retention of fluid due to neurohormonal responses to the cardiac dysfunction.<sup>26</sup> Hypertension, Rheumatic heart disease and Cardiomyopathy are often considered as important causes of heart failure which accounts for 75.5% of the cases in USA.<sup>27,28</sup> In developed nations IHD alone or in concurrence with diabetes mellitus, hypertension and atrial fibrillation and constitutes the commonest cause of HF, with dilated cardiomyopathy (DCM) being the minor cause.<sup>29</sup>

The reports available show that, cardiomyopathy accounts for about 30% of the cases of heart failure in African adults.<sup>30</sup> Endomyocardial fibrosis (EMF), Dilated cardiomyopathy and peripartum cardiomyopathy (PPCM) and are endemic in South Africa. The four year mortality of dilated cardiomyopathy is 34%.<sup>31</sup>

RHD is the most common cause of the acquired valvular heart disease in young adults adolescents and children in developing countries. A study from South Africa had shown a prevalence of 31 cases per 1000 and 20.2 cases per 1000 respectively among scholars in range of 4 - 24 years in Ethiopia and South Africa. A high mortality study had shown that, the initial within the hospital mortality of 17.5% and 2 months mortality of 24.8% and a 6 months day mortality of 35.4%.<sup>32</sup>

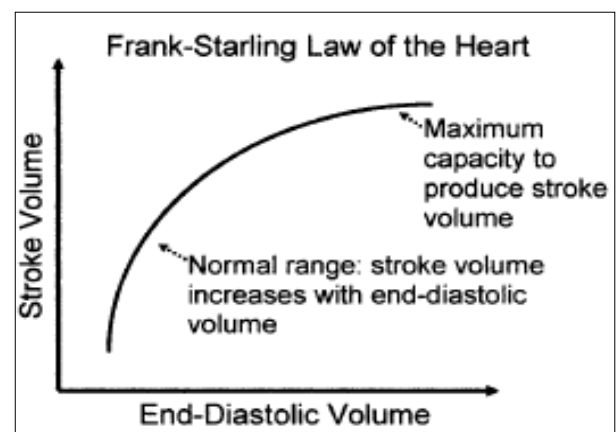
TB pericarditis accounts for the most common form of pericardial disease worldwide. In South Africa, greater than 90% of pericardial effusions are due to TB in HIV infected population. In a patient cohort from Cape Town, the prevalence of myopericarditis in TB pericarditis has been described to be 53%. Constrictive pericarditis is a serious and common complication secondary to TB pericarditis.<sup>33</sup>

### Pathophysiology

An abnormality in conduction, rhythm, cardiac structure or function results in the syndrome of CHF. The ventricular dysfunction is the etiology for the majority of cases and results mainly predominantly from hypertension, myocardial infarction or both. The major causes of heart failure are due to alcoholic cardiomyopathy, idiopathic cardiomyopathy and degenerative valve disease. Some common co morbidities

including renal dysfunction have multiple etiologies (volume depletion from over diuresis or reduced perfusion), whereas others (e.g. cachexia, depressive disorders, Anemia, and breathing disorders) are understood poorly.<sup>34</sup>

The end diastolic pressure/ volume of the left ventricle determine the preload and is clinically assessed by measuring the right atrial pressure. The preload is characterized by the amount of volume of blood that needs to be pumped by the heart and it is mainly dependent on contractility of heart. The end diastolic volume is assessed through measurement of the right atrial pressure. Preload is dependent on both intravascular volume and restriction of filling of ventricles.



**Figure 1: As per Frank-Starling law it states that if ventricular volume is increased, it results in stretching of myocardial muscle fibers which results in increase in stroke volume, till its maximum capacity.**

The diastolic function is mainly dependent on two factors - the ability of left ventricle to distend, a passive process and myocardial relaxation, an active phenomenon that causes suctioning effect that helps in filling of left ventricle. Loss of either of the above two mentioned factors causes diastolic dysfunction which results in elevation of left atrial pressure thus leading to pulmonary congestion.<sup>35</sup>

Afterload is the load which myocardial pump works against force and is determined by mean arterial pressure.<sup>36</sup> The elevated end diastolic pressure leads to the pulmonary edema and dyspnea and hence the respiratory care provider should be cautious with the CHF patients. The patient presentation can greatly differ, depending on the chronicity of the disease. Most patients experience dyspnoea when pulmonary artery occlusion pressure exceeds 25 mm Hg. The patient with longstanding CHF can tolerate filling pressure up to 40 mm of Hg.<sup>37</sup> The lung provides multiple mechanisms to avoid the consequences of pulmonary edema. Initially, as pressure increases, pulmonary capillaries are recruited and increase capacitance to deal with the added volume.<sup>38</sup> The volume can be diverted from the alveoli to the interstitium as the pressure continues to increase. The peripheral edema develops due to continued sodium

retention and ultimately results in development of pleural effusion.<sup>39</sup>

With acute decompensation, the pulmonary capillary membrane may succumb to the increased pressure, with sharing of the capillary and release of fluid, protein and occasionally red blood cells into the alveoli.<sup>40</sup> The lungs response will include cough, to expel the fluid in the alveoli. Thus, severe chronic heart failure can result in interstitial fibrosis and a restrictive lung disease.

### **Diagnosis of heart failure**

Diagnosis of heart failure is made by usage of various findings that includes physical examination of the patient, symptoms and signs of heart failure assessment. 2D Echocardiography for LV function assessment, NT ProBNP measurement has sensitivity of 99% with 85% specificity for diagnosing heart failure and these measurements have been recommended in both admitted and outpatients.<sup>41</sup>

### **Lung ultrasound**

B-line assessment through LUS has been currently proposed as it is not invasive, easily accessible, no radiation exposure for quantifying EVLW.<sup>42</sup> In one of the studies conducted by Lichstein and his team concluded that B-lines are significant indicator of accumulation EVLW and also emphasized that it is 99% feasible for doing this investigation in their study.

A-line and B-line are the two types of artifacts being produced in lung as assessed by lung ultrasound scan. A normal aerated lung shows repeated horizontal lines termed as A-lines, that are being replaced with B-line or comet tail due to edema in interstitium of lung. B-line historically was first identified by ziskin in a patient who had sustained gun shot wound in abdomen.<sup>43,44</sup>

Higher sensitivity and specificity of the B-lines for the detection of interstitial edema has been demonstrated by Lichenstein since then several studies have identified the usefulness of B-lines and its direct correlation to excessive extravascular lung water. The evidence available shows that B-lines correlate with N-terminal ProBNP levels in patients with acute breathlessness and after a stress test.

Lung ultrasound scan could aid in optimizing treatment in heart failure patients by detecting pulmonary edema that cannot be diagnosed by clinical examination.<sup>45,46</sup> The value of the lung ultrasound follows from the inadequacy of the physical findings, chest X-ray, free from radiation exposure and can be easily performed by clinicians and radiologists at bedside.<sup>45</sup>

### **Clinical congestion score**

The gold standard for determining cardiac congestion is cardiac catheterization with determination of right and left

atrial pressures, as estimated by pulmonary capillary wedge pressure. These tests are invasive, time consuming and carry risk, and are not typically performed in all patients. As a result, physicians rely on clinical assessments to diagnose and management of heart failure.<sup>9</sup>

Clinical assessment is traditionally done using Killip and certain components of Clinical Congestion Score (CCS). The Killip score (0-4) is used to grade severity of heart failure, with 0 indicating no heart failure and 4 indicating cardiogenic shock. Killip score has been designed specifically in the setting of Acute Myocardial Infarction, hence limiting its use in all cases of Acute LVF.<sup>47</sup>

The Clinical Congestion Score (CCS) is a validated tool in clinical evaluation of stable heart failure and has been shown to correlate with echocardiographic findings of increased filling pressure. The CCS includes scoring based on pulmonary rales (0-4), Central Venous Pressure (0-4), S3(Presence 1, absence 0) and orthopnoea scoring (0-4). The CCS has a maximum score of 13, where a score of '0' has a good prognosis and a score of more than 3 is considered to have decompensated heart failure.<sup>48</sup>

It is also known that clearance of symptoms during the hospital stay of patients admitted for Acute LVF is not always linked to a stable real improvement of fluid accumulation. This could lead to incorrect titration of therapy and inappropriate early discharge.<sup>11</sup>

### **Management of heart failure<sup>47</sup>**

The main aims in treatment of HF includes:

- To decrease mortality and improving prognosis
- Symptomatic relief and decrease morbidity by altering cardiac dysfunction progression.

For patients admitted in hospital along with the above goals:

- Decreasing duration of stay in hospital
- Decreasing subsequent admissions to hospital.
- Adequately treat the comorbid conditions that may interfere with prognosis

The 2013 ACC/AHA updated guidelines, 2010 HFSA guidelines and the 2008 ESC guidelines recommend the following management strategies in various group of HF patients:

For admitted patients:

Its advised to admit in ICU:

- If PaO<sub>2</sub> is <60% or SaO<sub>2</sub> is <90% then to provide oxygen
- To start on NIPPV for those cases having respiratory distress

- Using pharmacological agents based on precipitating event and signs /symptoms of congestion:
  - ARBs or ACEIs for peripheral vasodilation; increasing left ventricular ejection fraction and neurohormonal regulation
  - Betablockers for preventing arrhythmia, control of heart rate, neurohormonal regulation and symptomatic improvement
  - Reduction of salt intake and use of diuretics
  - Digoxin usage can result in minor improvement in cardiac output, reduces the rate of frequent hospitalizations
  - Aldosterone receptor antagonists to be used as adjunctive agent for diuresis, decreasing risk of arrhythmias, reducing workload to heart, improving left ventricular ejection fraction and improving survival
  - Inotropic medications to improve tissue perfusion, decrease congestive symptoms by improving cardiac output
  - In patients refractory to medical line of management, those with refractory heart failure ultrafiltration is being used for reducing fluid

#### *Outpatient management of heart failure patients<sup>47</sup>*

- Based on patients educational level, detailed counselling and educating about the illness
- Detection of early symptoms and signs of volume overload
- Behavioural modifications and emphasizing on increase adherence to treatment
- Careful followup post discharge
- Optimizing medical line of management strategies
- Addressing financial and social issues
- Easy accessibility to health care providers.

## **REVIEW OF RELATED LITERATURE**

In a cohort study done by Miglioranza et al, in patients having moderate to severe heart failure, ROC analysis was undertaken to make comparison of lung ultrasound scan with a priorly used CCS, Chest radiograph, six minutes walk test, E/e0 ratio and NT-proBNP levels. Study was done in ninety seven patients. 57.7% patients had decompensation as estimated by clinical congestion score, 53.6% as by N-terminal ProBNP, 68% by lung ultrasound and 65.3% through E/e  $\geq 15$ . The B-lines number was correlated with CCS ( $r = 0.43$ ;  $p < 0.0001$ ), E/e0 ( $r = 0.68$ ;  $p < 0.0001$ ), N-terminal Pro-Brain natriuretic peptide. In receiver operating characteristic analysis, decompensation reference was considered by using combined method (NT-proBNP  $> 1,000$  pg/ml and/or E/e  $\geq 15$ ), C-statistic of 0.89 was yielded by lung ultrasound (95% confidence interval: 0.82 to 0.96), thus giving best accurate result with cutoff  $\geq 15$  B-lines (specificity 83% and sensitivity 85%).

A systemic method using E/e0, Chest radiograph, six minutes walk test and clinical congestion score as reference in various combinations also correlated this cut-off and also identified accuracy with lung ultrasound scan. They came to conclusion that in outpatients clinics for heart failure patients, B-lines were correlated predominantly with previously well established indicators of decompensation. For a reliable and fast assessment in outpatient based patients with heart failure B-line  $\geq 15$  could be taken as a cutoff for HF.<sup>48</sup>

Prosen et al, conducted a prospective study in Maribor of Slovenia in a emergency medicine center, during July 2007 to April 2010. Two patient groups were compared - A respiratory (COPD/asthma) associated acute breathlessness group and acute dyspnoea secondary to heart failure group. Lung ultrasound scan along with various laboratory investigations, chest radiograph, rapid testing of NT-Pro BNP was done in all the patients. The comet sign in ultrasound has PPV of 96%, NPV of 100%, specificity of 95% and sensitivity of 100% for diagnosing heart failure. N-terminal amino Pro Brain natriuretic peptide (1000pg/ml being cutoff) has PPV of 90%, NPV of 86%, 92% sensitivity with a specificity of 89%. Modified version of Boston criteria have 80% of NPV, 85% sensitivity, 90% PPV and specificity of 86%.

On comparison of the above three methods, significant variations were found between N-terminal Pro BNP ( $p < 0.05$ ) and LUS and modified Boston criteria ( $p < 0.05$ ). On combining lung ultrasound scan and NT-Pro BNP has 100% specificity, 100% PPV, 100% sensitivity and 100% NPV. With the usage of lung ultrasound authors could differentiate dyspnoea due to pulmonary conditions and due to heart failure through NT-Pro BNP ( $> 1000$ pg/ml) with heart failure history. Conclusion that comet tail sign in ultrasound alone or along with NT-Pro BNP has better diagnostic accuracy for distinguishing acute heart failure from pulmonary related etiologies for acute breathlessness in patients presenting to hospital.<sup>49</sup>

A study conducted by Jambrik et al, in one twenty patients (fourty three women and seventy eight men; aged  $67 \pm 12$  years) consecutively admitted to combined pulmonary medicine and cardiology department (including cardiac ICU); commercially available portable 2D Echo machines was used for the study. In every patient, multiple left and right intercoastal spaces that were priorly determined locations were scanned. Examiners who were noted aware of clinical diagnosis noted the comet numbers at each site and total scoring was done by adding comet tail numbers in scanned intercoastal spaces. Chest radiograph was done in few minutes after admission and it was assessed for EVLW by two radiologists and two pulmonologists who were blinded to 2D echo and clinical findings. Average time for imaging in each patient was less than three minutes. EVLW score ( $r = 0.78$ ,  $p < 0.01$ ) and comet score in 2D Echo had a linear correlation. Variations within patient ( $n = 15$ ) even showed an more correlation between EVLW



score and changes noted in 2D Echo comet score. Among one twenty one patients who were consecutively hospitalized, authors had found EVLW Score radiologically and comet score in 2D echo had linear correlation. Hence comet tail is less time consuming, accurate indicator of EVLW in lung ultrasound which can be done bedside and is not interfered by acoustic shadow of heart.<sup>50</sup>

Sartnini et al, conducted a study among patients presenting with breathlessness that are not related to trauma. These patients underwent chest radiograph, ultrasound of lung and N-terminal pro-Brain natriuretic peptide levels. Authors made comparison regarding diagnosis of HF through the above investigations with those patients diagnosed by clinicians clinically. A specificity and sensitivity of 87.97% and 57.73%, 86.26% and 74.49% for chest radiograph, 27.56 and 97.59 for N-terminal pro brain natriuretic peptide. Combining LUS and chest radiograph together gave better results with 77.69% specificity, 87.07% NPV and 84.69% sensitivity. Authors were not able to establish best investigation for diagnosing acute HF in emergency department however they made a suggestion that combination of LUS and chest radiograph, N-terminal pro brain natriuretic peptide levels would be favorable for assessing breathlessness patient.<sup>51</sup>

## DISCUSSION

Congestive cardiac failure (CCF) is often a worldwide phenomenon and affects millions of people. The congestive cardiac failure is often a complex syndrome characterized by the shortness of breath, fatigue, congestion and cachexia and symptoms related to inadequate tissue perfusion, fluid retention and neurohormonal activation. CHF remains as a serious problem even after improvement in the therapy.<sup>1</sup>

Heart failure usually affects more than 20 million of the people and overall prevalence in developed countries is 2%. The prevalence of heart failure follows an exponential pattern, rising with age and affecting 6-10% of the people over the age of 65 years.<sup>3</sup>

Clinical diagnosis of heart failure is the mainstay as there is no definitive diagnostic test available for heart failure and is mainly based on careful history and physical examination and supported by ancillary test including chest radiograph, electrocardiogram and echo cardiography.<sup>7</sup> The evidence available shows that, ultrasound of the thorax may show extra vascular lung water present in patients with CHF.<sup>11</sup> Artefacts known as "Lung Rockets," or "B-lines," which represent interstitial fluid seen on the periphery of the pleura have been associated with CHF.<sup>11</sup> This review was done to evaluate the usefulness of Lung Ultrasound Scan in diagnosis and to identify its role as a marker of clinical outcome in patients with Acute LVF. This review concluded that lung ultrasonography is as a rapid, non-invasive, bedside

tool for the diagnosis and risk assessment of pulmonary congestion in Acute LVF.<sup>12</sup>

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