PLUS
PHYSIOTHERAPY LUNG ULTRASOUND

Blackpool Teaching Hospitals NHS
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Lung Ultrasound & Atelectasis

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Atelectasis is a loss of lung aeration in part or all of a lung and occurs when there is an airway blockage (sputum plug or foreign body), when pressure outside the lung keeps it from expanding (pleural effusion or abdominal pressure), hypoventilation (anaesthesia or pain) or when there is not enough surfactant for the lung to expand normally.

Atelectasis may not cause any signs or symptoms when only a small area of lung is affected however, if a larger area, such as a lobe or whole lung is affected, it can cause signs of respiratory distress. The most common test used to diagnose atelectasis is a chest radiograph (CXR) but lung ultrasound (LUS) is now becoming an alternate option for physiotherapists.

In LUS terminology atelectasis is a differential diagnosis under the overarching term of “consolidation”, along with pneumonia or lung contusion, but the suspicion of atelectasis should correlate with the patients clinical picture. Based on a small selection of studies, LUS has shown to be more accurate than CXR at identifying consolidation (sensitivity: 91-100% *versus* 38-68%, specificity: 78-100% *versus* 89-95%) when compared to computed tomography (CT) in patients with acute respiratory failure [1]. However, where opacity is seen on CXR, for example, atelectasis can be to difficult to differentiate from other types of consolidation, such as pneumonia.

Atelectasis is potentially a component of numerous lung disorders but to differentiate atelectasis from other types of consolidation Lichtenstein et al propose a number of characteristic signs [2,3]. In the early phase of atelectasis lung sliding is abolished and replaced with a “lung pulse”. The “lung pulse” is where the motion from the cardiac contraction is transmitted through the slightly denser atelectic lung parenchyma. Normal aerated lung parenchyma would typically cushion this cardiac motion but this movement now becomes visible and indicates impaired lung inflation. A CXR will only show an opacity in the more advanced stages of atelectasis whereas the lung pulse can be seen almost immediately.

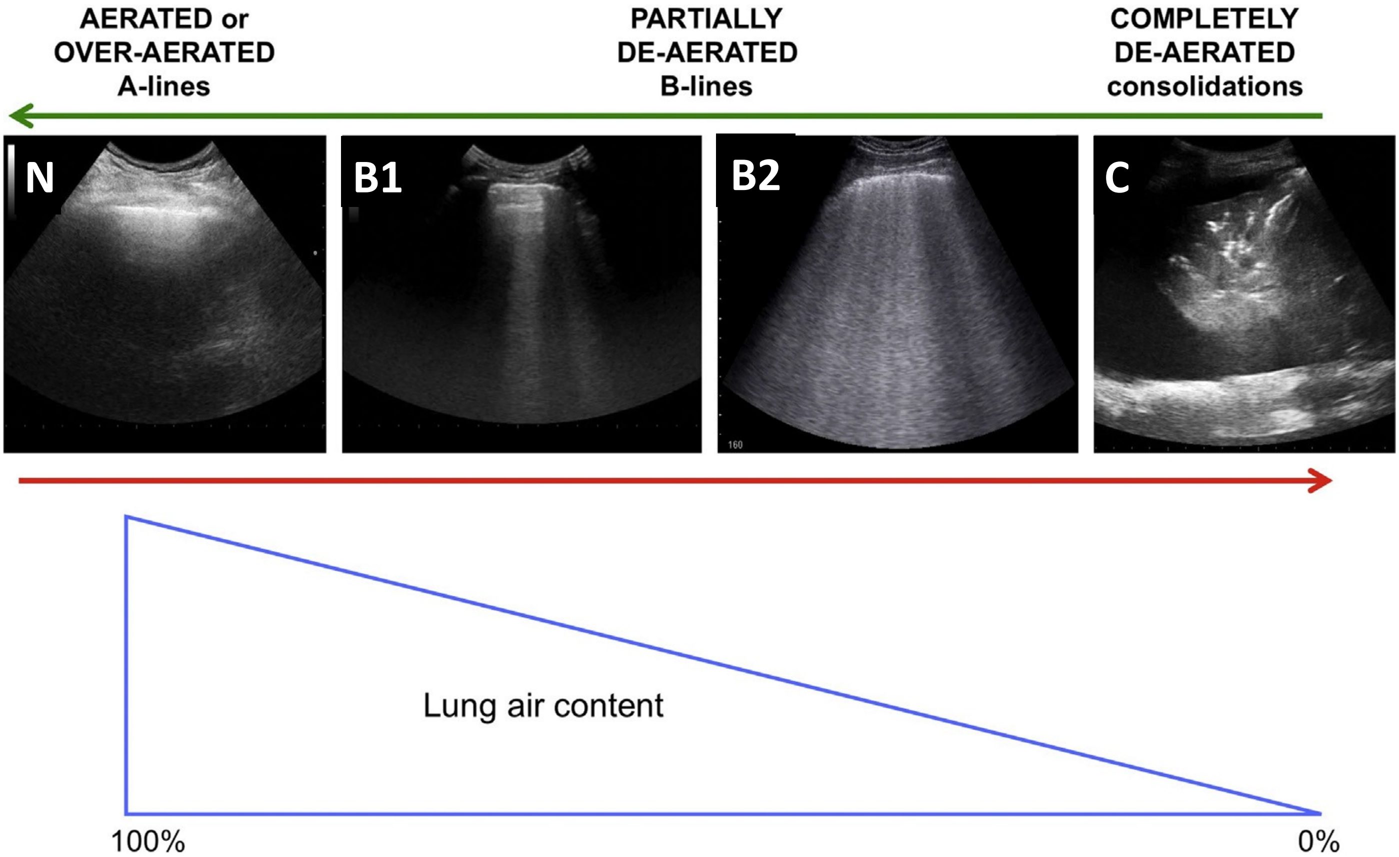

Fig. 1. The concept of lung ultrasound as a densitometer: different ultrasound patterns for different levels of lung aeration. (Adapted from Gargani 2019) [6]

During the later phases of atelectasis as gas is absorbed from a significant proportion of alveoli, the presentation on LUS resembles that of consolidation or a "tissue-like" pattern with air bronchograms. Both atelectasis and pneumonia can present with air bronchograms however the presence of dynamic air bronchograms implies a patent airway and would indicate pneumonia, whereas atelectasis will result from impeded air flow resulting in static air bronchograms. Caution must be noted, as pneumonia can also have static air bronchograms. So, according to Lichtenstein et al, dynamic air bronchograms rule out atelectasis [3].

As the loss of lung aeration in atelectasis progresses the normal A-line presentation with lung sliding changes to a lung pulse with absent lung sliding. Air loss results in denser lung parenchyma, B-lines begin to appear which increase in numbers per rib space until complete aeration loss occurs, and the lung parenchyma appears as a tissue-like consolidation (Figure. 1 & 3). This progression of LUS signs has been interpreted by some researches as a way to monitor the progression of worsening atelectasis from Normal aeration (N) to multiple B-lines (B1) to confluent B-lines (B2) through to consolidation (C). The reverse of this process can also be used to monitor atelectasis (Figure. 3) as is resolves following medical or physiotherapy interventions such as pleural effusion drainage followed by lung re-expansion [4,5].

One extreme presentation of atelectasis is the complete collapse of a whole lung often termed an opaque hemithorax or "whiteout" when identified by CXR (Figure. 2). There are however, multiple potential causes of a "whiteout" other than complete lung collapse and LUS can assist in differentiating between them [7]. The use of LUS to confirm a "whiteout" is due to atelectasis can indicate the need for a bronchoscopy and can subsequently track the lung re-expansion with or without the need for positive pressure [8,9].

One case report presents that as the main bronchus was cleared, the LUS study showed the appearance of an air bronchograms near the hilar pulmonary structures which gradually advanced towards the peripheral parenchyma in real-time until the tissue-like appearance of atelectasis resolved and lung sliding returned [10].

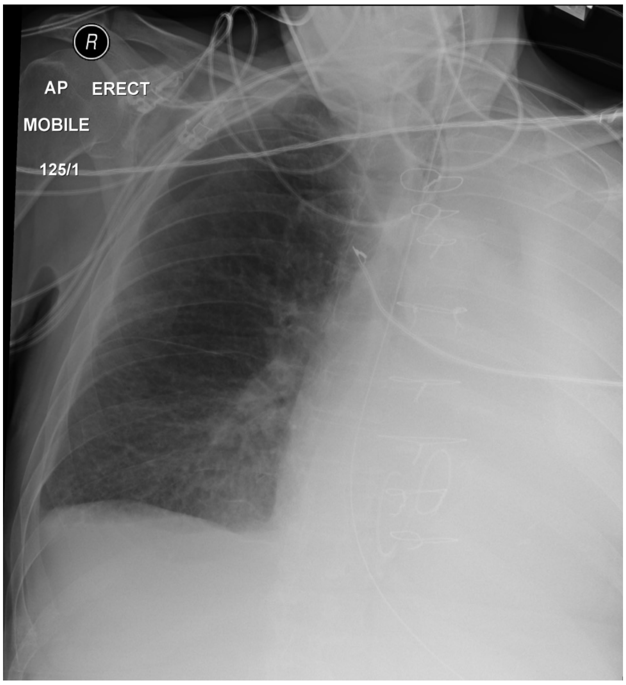

Fig. 2. Chest radiograph presentation of a left sided opaque hemithorax or "whiteout"
(From Hayward and Hayward, 2019) [5]

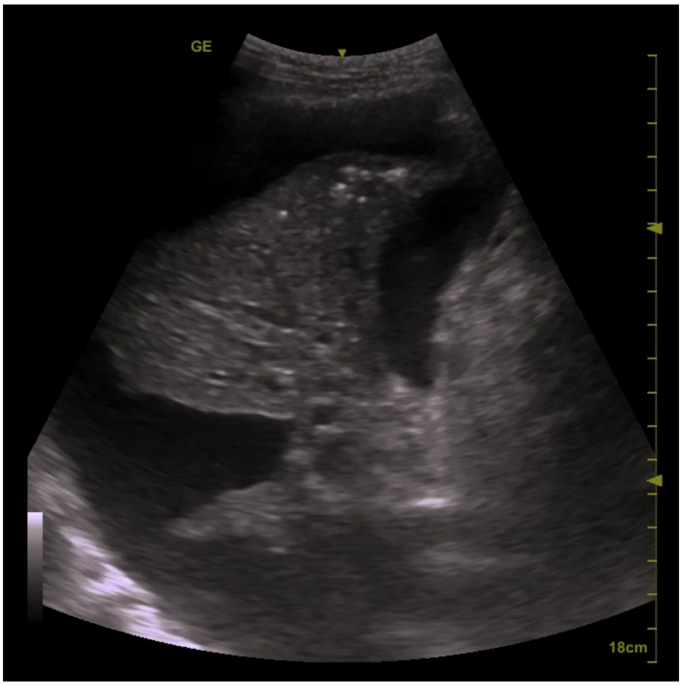

Fig. 3. Lung ultrasound of left upper anterior chest showing complete atelectasis secondary to a large pleural effusion.
(From Hayward and Hayward, 2019) [5]

Another well-established cause of atelectasis in both adults and children is due to the administration of a general anaesthetic [11]. Studies are showing that LUS can be a useful method to accurately detect anaesthesia-induced atelectasis in children (sensitivity: 88%, specificity 89%, accuracy 88%) when compared to magnetic resonance imaging (MRI) [11] and in adults (sensitivity: 87%, specificity 92%, accuracy 91%) following laparotomy [12]. One mechanism of this process is thought to be due to the general anaesthesia inducing diaphragm dysfunction which allows unresisted abdominal pressure to compress basal lung aeration [13]. Post-operative pulmonary complications such as atelectasis can be monitored in the immediate post-operative period using LUS as mild to moderate atelectasis is frequently missed by clinical examination and CXR combined [14]. In a cardiac surgery population LUS detected more postoperative pulmonary complications, such as atelectasis, and more clinically-relevant postoperative pulmonary complications than CXR, and at an earlier time-point [15].

Lung ultrasound can monitor the alveolar derecruitment and atelectasis formation at the bedside when patients are disconnected from ventilation during processes such as suctioning [16] or a spontaneous breathing trial (SBT). Pre-extubation LUS can help to detect lung derecruitment during a SBT as a means to predict post-extubation distress by using a scale of 0-36 point LUS scoring system [17]. Lung derecruitment during a "T-piece" SBT was mainly seen in anterior, lateral and upper-posterior lung regions by identifying either normal lung (N) developing B-lines (B1) or B-lines (B1) becoming confluent B-lines (B2) [17]. The exact cut-off score for low, medium or high risk patient extubation following a SBT is still under investigation but the LUS score could contribute to the decision making process.

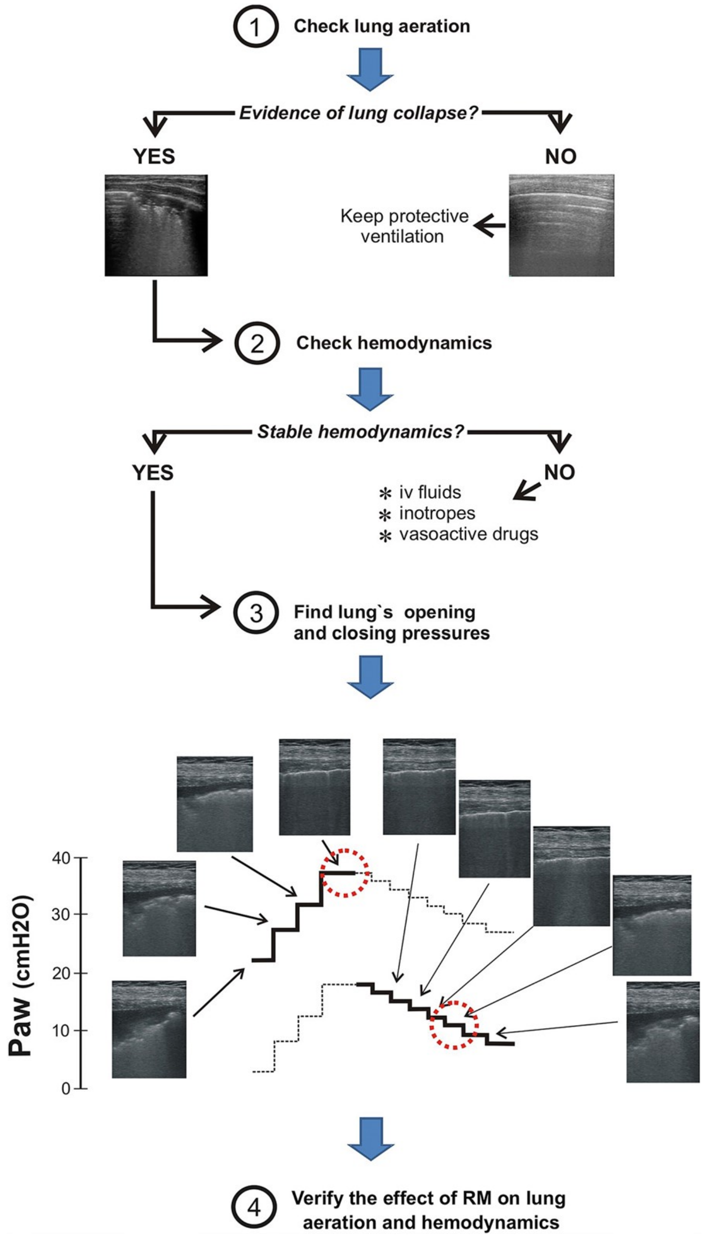

Fig. 4 Algorithm to assess recruitment manoeuver by ultrasound. Ultrasound diagnoses lung collapse (step 1) and assesses hemodynamics (step 2) before the lung recruitment manoeuvre is done (step3). During the step-wise increment in airways pressure (Paw) of the recruitment manoeuver, ultrasound can detect the plateau pressure at which dependent lungs collapse disappear (opening pressure—*upper circle*). Then, ultrasound defines the start of lung re-collapse in the most dependent pulmonary areas during the PEEP trial (closing pressure—*lower circle*).

(From Tusman, 2016) [18]

Lung ultrasound is being used to monitor the resolution of atelectasis through the administration of positive pressure ventilation techniques such as recruitment manoeuvers, positive end expiratory pressure (PEEP) or the combination of both (Figure. 4) [18]. Assessment of atelectic lung recruitment is necessary during mechanical ventilation and is easily repeated at the bedside with LUS allowing recruitment of atelectic lung at lower levels of PEEP [19] as well as regional analysis of both dependent and non-dependent lung regions [20]. Regardless of the patients position (i.e. supine, side lying or prone lying) it is possible to monitor the progression of atelectasis from consolidated (C) towards normal (N) [20]. It must be noted however that LUS cannot assess for hyperinflation during these procedures [20,21].

The effects of positional changes to reverse the affects of atelectasis have also used LUS as the outcome measure. Repositioning a critically unwell patient into a prone position allows the use of LUS to monitor the previously dependent dorsal lower lobes as they begin to re-expand [19]. Other positional changes such as alternate side lying in combination with increased PEEP had greater effect on lung re-expansion than PEEP alone when in a supine position [22].

Lung ultrasound can be used to detect the resolution of distal atelectasis and the endpoint of lung recruitment thus allowing improved lung compliance and/or oxygenation. The advantages of LUS include its use in real-time while other treatments are being implemented and it can be used to assess the effect of lung recruitment in dependent and non-dependent areas.

To date there have been no full studies looking at the lung recruitment techniques employed by Physiotherapists with LUS as the outcome measure. This area of research warrants further investigation for those Physiotherapists, Physical Therapists and Respiratory Therapists working with respiratory compromised patients.

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