Monitoring whole-lung lavage using lung ultrasound: The changing phases of the lung

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ABSTRACT

Lung ultrasound (LUS) has been proven to yield valuable information for lung and pleural pathology. It is well validated for assessing extravascular lung water. It can also be used to monitor stages of controlled lung de-aeration in whole lung lavage (WLL) which is the treatment for Pulmonary Alveolar Protienosis (PAP),characterized by abnormal surfactant in the alveoli affecting gas exchange .LUS can help decide the point of termination of lung flooding. A 55 year old lady with biopsy proven pulmonary alveolar proteinosis presented with respiratory failure. WLL was planned. LUS was used to study the stages of lung flooding as previously described for ARDS model.6 areas screened based on six areas that are normally examined like upper zone, mid zone and lower zone showed alveolar interstitial pattern. One lung ventilation (OLV) was done and isolation of lavage lung was confirmed which was seen as lung collapse (lung pulse) on LUS. Saline infusion resulted in increase in B lines followed by tissue like pattern with fluid bronchogram on LUS(alveolar flooding) in all the areas. During the lavage of the second lung, appearance of alveolar flooding pattern resulted in termination of saline infusion. The use of LUS in monitoring WLL reduced amount of saline used for lavage, pick up complications like pleural effusion and spillage.

KEY WORDS: Alveolar proteinosis, lung ultrasound, whole-lung lavage

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INTRODUCTION

Pulmonary alveolar proteinosis (PAP) is a condition characterized by the accumulation of abnormal surfactant in the alveoli which hampers gas exchange and leads to hypoxia. Whole-lung lavage (WLL) is the treatment of choice. The procedure includes isolation and ventilation of dependent lung, lavage of nondependent lung with multiple aliquots of saline, and then drainage by lung clearance maneuvers till the milky appearance of the fluid clears. Success is confirmed by radiological clearance of shadows and improvement in gas exchange.

Lung ultrasound (LUS) has proved to be of great help in evaluating lung and pleural pathology. Its use in assessing extravascular lung water (EVLW) in fluid overload conditions such as chronic renal failure and congestive cardiac failure is already known. LUS use in WLL in cases of PAP has not been studied, where theoretically alveoli are flooded with lavage fluid instead of extravascular fluid.

We hypothesized that LUS could be used to guide the extent of alveolar flooding in WLL and study the different stages of lung aeration in WLL with the help of LUS. This would reduce complications such as spillover to opposite lung, overdistension of alveoli, and systemic absorption of saline, thus making the procedure safer.

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CASE REPORT

A WLL was planned in a 55-year-old-lady with biopsy-proven PAP presented with type I respiratory failure (PAO_2 = 56 mmHg, SpO_2 = 76% in room air). WLL was performed under monitored anesthetic care.

After intubation with a double-lumen endotracheal tube, the right lung was intubated, and the patient was connected to a ventilator. One-lung ventilation of the right lung was done, and isolation of the left lung (which was to be lavaged) was confirmed clinically and by fiber-optic bronchoscopy. The patient was then placed in the right lateral decubitus position so that the to-be lavaged left lung was nondependent. The left lung was then lavaged. Each lavage cycle was terminated when the endotracheal tube was filled with saline. This was followed by vigorous chest physiotherapy and drainage of the fluid by gravity.

LUS was performed using Sonosite S-ICU ultrasound system, P-07577-05, using a sector probe (5–11 MHz). The scan was performed in the lateral decubitus position by a single operator; both static images and videos were recorded. Six areas were identified on the left hemithorax, by dividing the latter into anterior, lateral, and posterior regions: Each region was further divided into upper and lower quadrants. LUS was used to study the stages of lung flooding as previously described for Acute respiratory Distress Syndrome (ARDS) model. Six areas were screened based on six areas that are normally examined such as upper zone, mid zone, and lower zone. The probe was insinuated as lateral as possible under the chest wall to look at the lateral areas.

All six areas screened which showed the following patterns from baseline till the termination of WLL:

- Stage 1: Alveolar interstitial pattern in supine position (basic pattern of PAP) [Figure 1]
- Stage 2: Postintubation, the isolated lung for lavage underwent collapse revealing the presence of lung pulse [Figure 2]
- Stage 3: Saline infusion resulted in increase in the appearance of B lines [Figure 3]
- Stage 4: B lines increased in number [Figure 4a] and became confluent till the appearance of fluid bronchograms with tissue pattern [Figure 4b].

The procedure was terminated only after there was progressive clearing of fluid from very turbid and milky to clear transparent. A total volume of 6.2 L of normal saline was instilled and 5.2 L of fluid was retrieved from the left lung. Serial arterial blood gasses were monitored for acidosis, hypoxia, and electrolyte imbalance.

Five days later, the patient was posted for WLL of the right lung and the above-mentioned procedure was repeated.

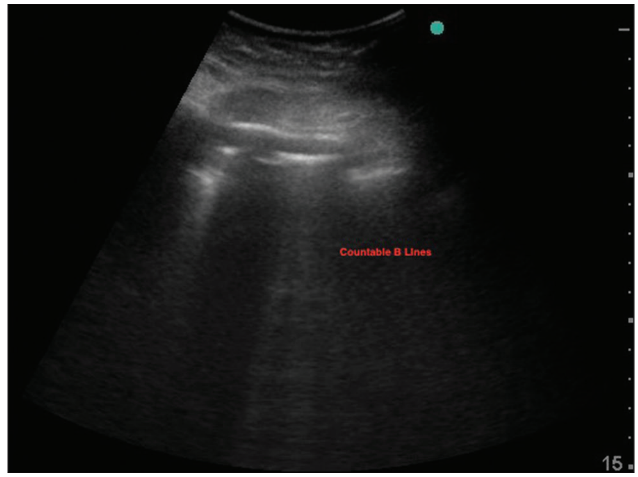

Figure 1: Alveolar interstitial pattern in supine position Countable B lines (basic pattern of pulmonary alveolar proteinosis)

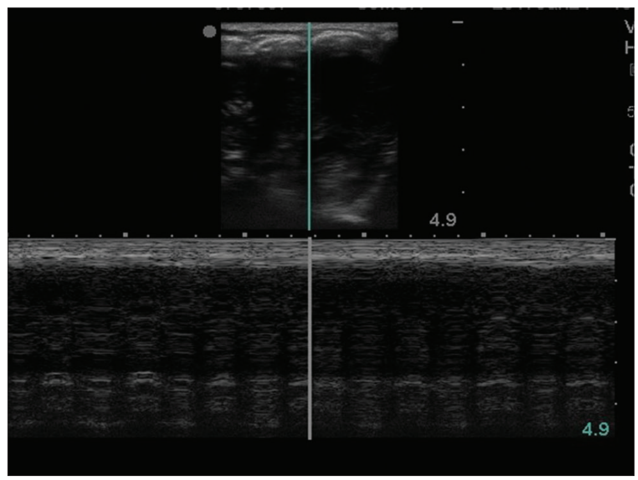

Figure 2: Stage 2 – Postintubation, the isolated lung for lavage underwent collapse showing lung pulse on M Mode

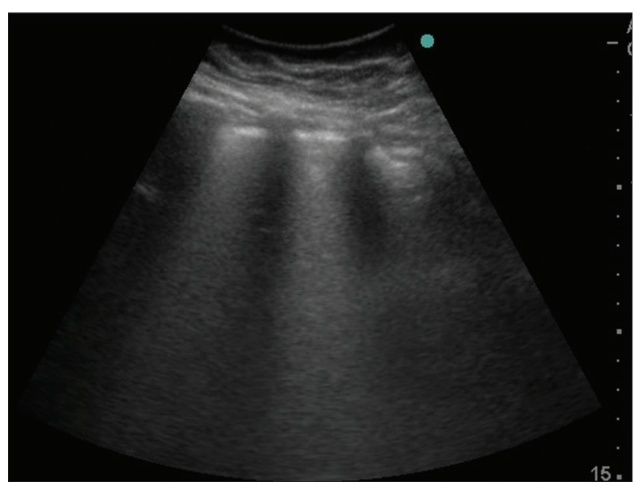

Figure 3: Stage 3 – Saline infusion resulted in increase in appearance of B lines

But this time, we used LUS to titrate the quantity of normal saline to be used for lavage. Verbal consent was taken for this. The instillation of saline was terminated with the appearance of fluid bronchograms (Stage 4) in all lung fields

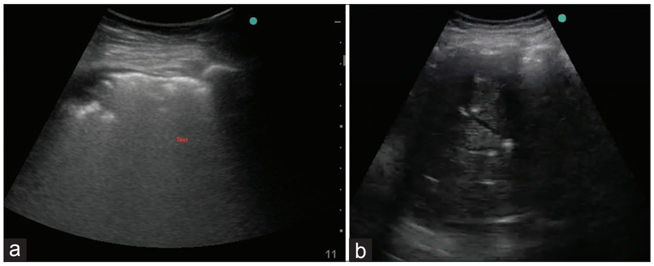

Figure 4: (a) Stage 4: B lines increased in number. (b) Confluent B lines till the appearance of fluid bronchograms with tissue pattern

rather than wait till fluid flooded into the endotracheal tube. The total amount of normal saline instilled was 5.2 L and 4.9 L was retrieved from the right lung.

The patient improved symptomatically with room air saturation up to 91% postprocedure. She was followed up 20 days later during which she reported no respiratory symptoms and had a room air saturation of 94%. Chest radiograph showed clearing of the parenchymal shadows and LUS pattern of normal A profile (Stage 5) in all the lung fields.

DISCUSSION

LUS is a novel extension of a well-established diagnostic procedure very commonly used in respiratory, critical, and cardiac care units. It is often referred to as the "third eye" of the health-care provider.[1] This imaging modality gained a lot of popularity owing to its immediate availability at the bedside and freedom from radiation exposure. The use of LUS to monitor therapeutic procedures such as WLL is still in its nascent stage.

LUS can be used to assess aeration changes in the lungs as in ventilator-associated pneumonia[2] and assessment of EVLW in patients with renal failure undergoing dialysis[3] and pulmonary edema.[4]

Although WLL is a widely used procedure for PAP, LUS visualization of the procedure and stages is not well described.

In the present case report with the help of LUS, we initially have attempted to monitor and record all the different stages of WLL in a patient with PAP. The LUS findings in WLL are similar to what is seen with other diseases with increased EVLW such as pulmonary edema and ARDS.[3-6] As the lung was flooded with saline, the B lines progressively increased from countable B lines to the white lung. This stage corresponds to ARDS-like lung which was similar to findings in another study by Via *et al*.,[5] who studied changes in LUS during WLL, but further use of LUS to terminate lung flooding was not studied.

The procedure of WLL is associated with many complications such as pneumothorax, pleural effusions and hydropneumothorax,[7,8] mediastinal shift, increased intrathoracic pressure, and increased central venous pressure due to excess of fluid used for lavage leading to hypotension.[9] Hence, meticulous charting of the infused saline solution and the output has to be done to limit the difference to a few 100 mL in consecutive lavages.

This is the first report of the use of LUS guiding the flooding of lung effectively resulted in lesser fluid being used without any compromise in outcome. This might limit the known complications of WLL.[7-9] This may by far be one of the most important advantages of LUS-guided WLL. This aspect has not been addressed in any previous study.

Another important application of LUS was to identify spillage to the ventilated lung during the lavage. This can cause respiratory insufficiency and hypoxia.[10] When spillage is suspected, LUS can guide us in early detection with the presence of increase in B lines as compared to the baseline. This was also being checked by us with LUS throughout the procedure.

To the best of our knowledge, this is the first time LUS was used for this indication.

CONCLUSION

LUS, a noninvasive surface imaging technique, can quantitate lung water content.

We report a case where we utilized this principle of LUS to guide the extent of alveolar flooding and evaluate the different stages of lung aeration during the WLL with an aim to reduce the complications such as spillover to opposite lung, overdistension of alveoli, and systemic absorption of saline.

Limitation

Further prospective studies are required to validate this tool and set guidelines for its use in WLL in patients with PAP.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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