



# Efficacy of Portable Ultrasound to Detect Pneumothorax Post-Lung Resection

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## Abstract

**Background:** The role of bedside ultrasonography in detection of Pneumothorax in the acute care setting is well established. However, its role in the diagnosis of Pneumothorax following chest tube removal post-lung resection has yet to be elucidated. Our aim was to assess the efficacy of portable ultrasound in the detection of Pneumothorax following chest tube removal post-lung resection.

**Methods:** The study was approved by the institutional review board and all patients gave informed consent prior to enrollment. Patients underwent bedside transthoracic ultrasonography and chest radiography after an intraoperatively placed chest tube for lung resection was removed. Chest radiography was the standard in diagnosis of Pneumothorax post-chest tube removal.

**Results:** A total of 78 patients were included in the study. Chest radiography detected Pneumothorax in 38 patients (49%). Of the 78 patients, Ultrasonography (US) detected Pneumothorax in 32 of these patients. With CXR as our standard, our sensitivity and specificity for ultrasound was 84% and 60%, respectively. The positive and negative predictive values were 67% and 80% respectively. Only 6 patients were “false negative”, i.e. negative ultrasound but ultimately positive CXR, none of whom required further intervention.

**Conclusion:** Our study demonstrates that portable sonography is efficacious in the detection of Pneumothorax after chest tube removal post-lung resection. This suggests that sonography may replace routine Chest X-Ray (CXR), thus leading to reduced overall costs and radiation exposure. Further studies are required to further refine the role of portable ultrasound post lung resection.

**Keywords:** Pneumothorax; Ultrasound; Perioperative care

## Introduction

Lung resection is the most commonly performed procedure in thoracic surgery. After lung resection, air in the pleural space, i.e. pneumothorax may occur as a result of the introduction of air from the atmosphere or from lung parenchyma, e.g. staple line. In order to evacuate the post lung resection pneumothorax, chest tubes are routinely placed intraoperatively [1]. In standard practice, a Chest X-Ray (CXR) is obtained daily to monitor for occurrence of pneumothorax as one major indication. Furthermore, once it is deemed that there is no further need for the chest tube, it is removed. A CXR is then routinely performed, again to rule out the occurrence of pneumothorax as a major indication, for it is feared that an undetected pneumothorax, even if clinically silent, may lead to major morbidity and possibly mortality in patients who may at baseline have limited pulmonary reserve. Routine CXRs add to stand radiation risks to the patient [2]. Transthoracic ultrasound plays a significant role in the diagnosis and evaluation of a wide range of thoracic pathologies, including peripheral parenchymal, pleural and chest wall diseases [3]. Multiple studies have shown ultrasonography to be more sensitive and specific in the diagnosis of pneumothorax compared to CXR in the setting of emergency medicine and critical care [4-6]. However, its role in thoracic surgery has yet to be elucidated. We hypothesized that transthoracic ultrasound may be an alternative to CXR for detection of a pneumothorax post lung resection. We sought to compare the two modalities in order to determine whether ultrasound may be equivalent to standard CXR for the detection of pneumothorax post-lung resection. Lung ultrasound is a useful modality in detecting or ruling out pneumothorax. It depends on many artifacts and signs to achieve this. When starting a lung ultrasound exam, one should try to obtain a view with the “Bat sign” by using the B mode on the ultrasound machine (Figure 1) [3]. This is a sign formed by two rib shadows and the pleural line in between, resembling a bat flying towards you. Examining the pleural line movement

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**Table 1:** Patients' Demographics and Clinical Characteristics.

	N=78
Age (mean ± SD)	64 ± 12
Age > 60 years	70.5% (55)
Sex (male)	53.8% (42)
Race	
Caucasian	69.2% (54)
African American	25% (20)
Other	5% (4)
Post Chest Tube Removal Radiologic Findings	
Pneumothorax on U/S	41% (32)
Pneumothorax on CXR	49% (38)

Values are recorded in percentages unless noted otherwise.

Acronyms: NPV: Negative Predictive Value; PPV: Positive Predictive Value; U/S: Ultrasound; CXR: Chest X-Ray

**Table 2:** Sensitivity, specificity, NPV and PPV of U/S on diagnosis of pneumothorax after chest tube removal.

Sensitivity	84%
Specificity	60%
PPV	67%
NPV	80%
Accuracy	71%

\*When compared to the gold standard (CXR)

Acronyms: NPV: Negative Predictive Value; PPV: Positive Predictive Value; U/S: Ultrasound; CXR: Chest X-Ray

**Table 3:** Comparison in the detection of pneumothorax CXR vs. US.

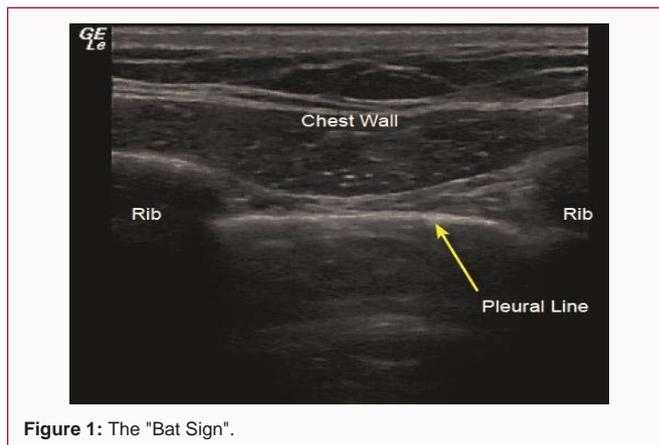
	Pneumothorax	No Pneumothorax
Chest X-ray	38	40
Ultrasound	32	46

\*Reported as number of patients

created by the visceral against the parietal pleura and its presence rules out the presence of pneumothorax. This is called the "Lung sliding sign" [3]. Confirming the lung sliding can be done also by using the M mode on the ultrasound machine. The M mode identifies the structures in motion over time. The movement of the pleural line will create a different artifact compared to the chest wall, and this is called the "Seashore sign", and its presence rules out the presence of pneumothorax (Figure 2) [3]. The absence of pleural movement will create no difference in the artifact between the pleural line and the chest wall, and that can be identified as the "Stratosphere sign" [3]. The "Lung point" sign is created when a localized transition from the intrapleural air to the intra-parenchymal air happens [7]. Can be seen on the B mode as well as on the M mode as a transition point. This has 100% specificity for pneumothorax [7].

## Patients and Methods

The study was approved by the institutional review board of Henry Ford Hospital. Patients were enrolled from May 2010 to March 2014. All patients gave informed consent prior to enrollment. All patients underwent lung resection by either wedge resections or lobectomy. The indications for lung resection included malignancy, undiagnosed lung nodules or bullous disease. Methods of resection varied from conventional thoracotomy, axillary thoracotomy, Video-Assisted Thoracic Surgery (VATS) or robotic assisted procedures. Pleural fluid drainage with one or more chest tubes was performed in all of these patients. Post-operatively, a CXR was performed routinely

**Figure 1:** The "Bat Sign".

to monitor the status of the lung and pleural space. Once there was no need for further drainage based on clinical assessment of the patient and the surgeon's decision, the chest tube was removed. After removal of the chest tube, a 2-view CXR is routinely obtained in our practice.

## Transthoracic ultrasonography

All enrolled patients underwent bedside thoracic ultrasound performed by a resident, fellow, or physician assistant. Patients were positioned either supine or with the head of the bed at 30 degrees, depending on the patient's comfort. The bedside ultrasound machine used in this study was the GE Logic (Wauwatosa, WI, USA). The ultrasound transducer used was a linear transducer (12 MHz) and was placed at multiple points on the patient's chest. After applying gel to the transducer face, the transducer was placed on the anterior chest wall initially with the indicator of the transducer marker pointing cephalad. This position will allow two rib shadows to be identified, and the pleural line between them, identifying the "bat sign". The lung point sign was also used to identify the presence of pneumothorax, if present. A pneumothorax was ruled out in the presence of the "Lung sliding" sign on B mode or the "seashore" sign in M mode in the anterior chest region [8,9]. The performing medical professional was blinded to the results of CXR until the ultrasound was completely interpreted. Routine CXR accompanied with US were done within two hours of one another.

## Statistical analysis

Demographic data collected included gender, age, race as well as the post-removal occurrence of pneumothorax. Data are given as percentages. The sensitivity, specificity, positive and negative predictive values of transthoracic ultrasound in the diagnosis of pneumothorax was calculated, with CXR used as the standard. Data was analyzed in Foundation for Statistical Computing, Vienna, Austria.

## Results

A total of 78 patients (36 females and 42 males) were enrolled. Median age was 64 years (range 43-84 years) as depicted in Table 1. CXR confirmed a pneumothorax in 38 out of 78 patients (49%). Ultrasonography detected pneumothorax in 32 of these 78 patients. Only six patients were "false negative", i.e. negative ultrasound but ultimately positive CXR, none of whom required further intervention, as shown in Table 2. With CXR as our standard, our sensitivity and specificity for ultrasound was 84% and 60% respectively. The positive and negative predictive values were 67% and 80% respectively.

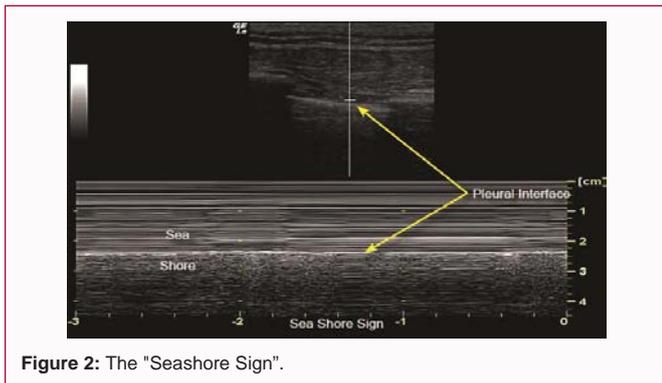


Figure 2: The "Seashore Sign".

## Comment

The routine use of postoperative CXR in cardiothoracic surgical patients has been challenged [10-12]. CXRs are done after chest tube removal to rule out complications such as pneumothorax, pleural effusions or hemothorax. Eisenberg and Khabbaz report the incidence of pneumothorax after chest tube removal in cardiac surgery patients to be 9.3% [13]. They are generally not life threatening if small or moderate in size, but a delay in diagnosis can lead to respiratory compromise, especially in patients with limited lung reserve. When a pneumothorax is detected, CXRs are used serially to monitor the progression or resolution of a pneumothorax in the postoperative care of a patient. The cumulative cost of all the CXRs done can be substantial [14-17]. The associated considerable cost and exposure to radiation has led to investigations of alternative techniques for exclusion of post-interventional pneumothorax.

The availability of portable ultrasound has raised the interest and popularity of transthoracic ultrasound in the past decade. Wernecke et al. [18] in 1987 reported the first use of ultrasound to detect pneumothorax. The use of transthoracic ultrasound has been well studied in the diagnosis of thoracic injury in the setting of trauma [19]. However, there is scant literature in assessing its role in the diagnosis of iatrogenic pneumothorax in the thoracic surgery patient [20]. Several studies report ultrasound to be more sensitive than CXR with a specificity of up to 100% in the diagnosis of pneumothorax after computed tomography guided biopsy [21,22]. Furthermore, CXR can be unreliable leading to a misdiagnosis rate of 30% [23]. Most basic ultrasound machines can be used for thoracic applications. Portable machines allow the performing physician to interpret the results immediately. In the chest, air tends to rise to the least dependent area. In a supine patient, this corresponds to the apical region, i.e. midclavicular region, between the second and fourth intercostals spaces [3]. The majority of significant pneumothoraces have been shown to be identifiable in this position in trauma patients [24,25]. With the probe in the sagittal position, the "Bat Sign" can be identified. The two layers of the pleura can be seen sliding across one another between the setworibs [23] forming the lung sliding sign. Identification of sliding pleural lines effectively rules out the presence of pneumothorax in the majority of patients [9,26]. The negative predicted value of this technique has been reported to be between 99.2% to 100% [4,5,27]. The absence of sliding sign, however, may not be reliable in certain conditions, such as acute respiratory distress syndrome, pulmonary fibrosis, at elect as is and pleural adhesions [5,28]. Another sign to rule out pneumothorax is the Seashore sign on the M Mode. Absence of the seashore sign or the presence of the barcode sign in M mode [8,9] can be due to pneumothorax. The Lung

Point sign has a 100% sensitivity and specificity in the detection of pneumothorax when present. Compared with CXR, transthoracic ultrasound offers some major advantages. In the vast majority of cases, it can be performed in 2 min to 15 min [6,19]. It also allows instant diagnosis, decreases costs, and eliminates the radiation risks and unnecessary transport of the patient [22]. Furthermore, transthoracic ultrasound may obviate the need for serial CXRs to follow possible progression of pneumothorax once detected, further reducing cost and radiation exposure. All operators in this study had only undergone basic ultrasound skill training as part of their curriculum. This highlights the benefit of ultrasound as any healthcare provider with basic ultrasound skills can perform it [29,30]. Our study has several limitations. Transthoracic ultrasound, while expeditious and cost effective, cannot quantify pneumothorax. In the majority of cases however, quantification is not a clinically relevant issue. Ultrasound is also operator dependent, and detection of pneumothorax can be variable from user to user. Our study also had a small number of patients. However, our early experience led us to posit a great deal of confidence in the technique. Our patients also had underlying lung disorders, as well as recent surgery, which may makes liding sign not reliable as an indicator in ruling out pneumothorax. Again, this did not appear to greatly hinder our ability to obtain reliable results.

## Conclusion

Our study suggests that ultrasound may be an effective imaging modality to rule out pneumothorax post lung resection. Advantages include the potential to reduce cost and radiation exposure compared to the standard CXR. Further studies are required to refine the role of portable ultrasound post-lung resection.

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