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Efficacy of portable ultrasound to detect pneumothorax post-lung resection

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Abstract

Background: The role of bedside Ultrasonography (US) 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 US and Chest Radiography (CXR) after an intraoperatively placed chest tube for lung resection was removed. CXR was the standard in diagnosis of pneumothorax post-chest tube removal.

Results: A total of 78 patients were included in the study. CXR 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 US was 84% and 100%, respectively. The positive and negative predictive values were 100% and 87%, respectively. Only 6 patients were "false negative", i.e. negative US but ultimately positive CXR, none of whom required further intervention.

Conclusion: Our study demonstrates that portable US is efficacious in the detection of pneumothorax after chest tube removal post-lung resection. This suggests that US may be used to detect clinically significant pneumothorax and, with CXR serving as an adjunct this could lead to the reduction of overall costs and radiation exposure to patients. Further studies are required to further define the role of portable US post lung resection.

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 Radiograph (CXR) is obtained daily to monitor for occurrence of pneumothorax as one major indication. 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, because 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 cost and radiation risks to the patient [2]. Transthoracic Ultrasound (US) 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 US 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 US 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 US may be equivalent to standard CXR for the detection of pneumothorax post-lung resection.

Lung US is a useful modality in detecting or ruling out pneumothorax. It depends on many artifacts and signs to achieve this. When starting a lung US exam, one should try to obtain a view with the "Bat sign" by using the B mode on the US machine (Figure 1) [3]. This is a sign formed by two rib shadows and the pleural line in between, resembling a flying bat. Examining the pleural line movement created by the visceral pleura against the parietal pleura and its presence rules out the presence of pneumothorax. This is called the "Lung sliding sign" [3]. Lung sliding can be confirmed 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 an artifact different from the movement of the chest wall. 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 lines and the chest wall, and this can signify the "Stratosphere sign" [3]. The "Lung point sign" is created when a localized transition from the intra-pleural air to the intra-parenchymal air occurs [7]. This can be seen on the B mode as well as on the M mode as a transition point. This has a 100% specificity for pneumothorax [7].

Patients and methods

The study was approved by the institutional review board. 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, lung nodules of in determinant significance, 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 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 was routinely obtained in our practice.

Transthoracic ultrasonography

All enrolled patients underwent bedside thoracic US performed by a Physician's Assistant (PA), resident, or attending surgeon. Patients were positioned either supine or with the head of the bed at 30 degrees, depending on the patient's comfort. The bedside US machine used in this study was the GE Logiq (Wauwatosa, WI, USA). The US 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 allowed 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 US 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, negative predictive values, and accuracy of transthoracic ultrasound in the diagnosis of pneumothorax were calculated, with CXR used as the accepted \ standard. Data was analyzed with the assistance of 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%). All of these identified pneumothoraces were small, apical, and <2 cm in size.US detected pneumothorax in 32 of these 78 patients (41%). Only six patients were "false negative", i.e. negative US but ultimately positive CXR. CXR identified a small apical pneumothorax in each of six these patients, none of whom developed any clinical signs of distress, or required further intervention (Table 2). With CXR as our standard, our sensitivity and specificity for ultrasound was 84% and 100%, respectively. The positive and negative predictive values were 100% and 87%respectively (Table 3). The accuracy was found to be 92% (Table 3). Of the 78 patients who underwent US, 74 of them were performed by a PA, three of them by a resident, and one of them by an attending thoracic surgeon. Of the six patients with missed pneumothoraces on US, each of them were performed by a PA.

Discussion

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 hem thorax. 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. However, in those patients with limited respiratory reserve, a delay in diagnosis can lead to respiratory compromise, and become life threatening. The gold standard for the detection of pneumothorax is Computed tomography. However, given the ease of access, convenience, and portability, CXR is often used a substitute. 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 US has raised the interest and popularity of transthoracic US in the past decade. Wernecke et al. in 1987 reported the first use of us to detect pneumothorax [18]. The use of transthoracic US 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 US machines can be used for thoracic applications. Portable machines allow the performing medical professional 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 intercostal 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 these two ribs forming the lung sliding sign [18]. 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%-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, atelectasis 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 can be due to pneumothorax [24,25]. The Lung Point sign has a 100% sensitivity and specificity in the detection of pneumothorax when present [7].

Compared with CXR, transthoracic ultrasound offers some major advantages. In the vast majority of cases, it can be performed in 2-15 minutes [6,18]. 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 health care provider with basic ultrasound skills can perform it [29,30].

With regards to the six false negative patients, given that the majority of patients were analyzed by PA's, we do not feel that they were missed because of operator variability. More likely, it was because of the underlying disease process along with the post-surgical inflammation that may have made detection more complicated. Nonetheless, none of these patients developed any clinical signs of respiratory compromise, and no further interventions were required.

Our study has several limitations. Transthoracic ultrasound, while expeditious and cost effective, cannot quantify pneumothorax. However, as suggested by our results, quantification may not be a clinically relevant issue. Ultrasound is also operator dependent, and detection of pneumothorax can be variable from user to user. Though 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 make sliding sign not reliable as an indicator in ruling out pneumothorax. Again, this did not appear to greatly hinder our ability to obtain reliable results. Finally, the gold standard for the detection of pneumothoraces is Computed Tomography (CT). Neither US or CXR can be compared to CT. However, given its ease, portability, and availability, CXR has been considered the ostensible standard. Further studies are required to determine if US can serve as a replacement to CXR.

In conclusion, our study suggests that ultrasound may be an effective imaging modality to rule out clinically relevant pneumothorax post lung resection. Advantages include the potential to reduce cost and radiation exposure compared to the standard CXR. Ultrasonography is also a point of care testing tool, with no adverse effects to the patient. It is simple, immediately available, and can provide valuable information. Further studies are required to refine the role of portable ultrasound post-lung resection.

Figures

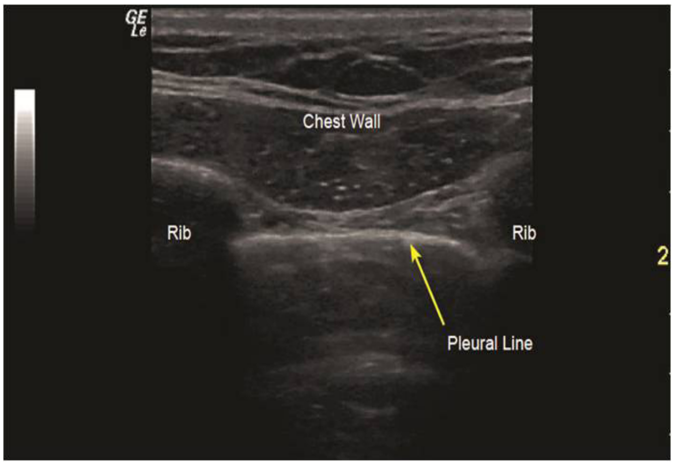

Figure 1: The "Bat Sign".

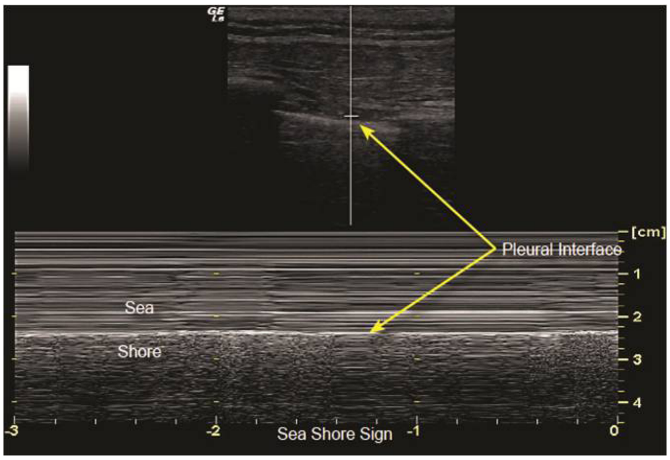

Figure 2: *The "Seashore Sign".*

Tables

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 US	41%(32)
Pneumothorax on CXR	49%(38)

Values are recorded in percentages unless noted otherwise.
Acronyms: US: Ultrasound; CXR: Chest Radiograph

Table 2: 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

Table 3: Sensitivity, specificity, NPV, PPV, and Accuracy of U/S on diagnosis of pneumothorax after chest tube removal*

Sensitivity	84%
Specificity	100%
PPV	100%
NPV	87%
Accuracy	92%

*When compared to the gold standard (CXR)

Acronyms: NPV: Negative Predictive Value; PPV: Positive Predictive Value; U/S: Ultrasound; CXR: Chest Radiograph

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