Surgical Science, 2015, 6, 352-357
Published Online August 2015 in SciRes. http://www.scirp.org/journal/ss
http://dx.doi.org/10.4236/ss.2015.68052

Scientific Research Publishing

The Role of Ultrasound and Air Leak Measurement in Assessing Lung Expansion after Thoracic Surgery

Abraham Chavarín[1], Laureano Molins[1,2*], Jose M. Mier[3], Juan J. Fibla[1], Cristina Izquierdo-Vidal[2], Cristina Simon[4], Angela Guirao[1], Jorge Hernandez[1]

[1]Department of Thoracic Surgery, Hospital Universitari Sagrat Cor, Barcelona, Spain
[2]Department of Thoracic Surgery, Hospital Clinic, Barcelona, Spain
[3]Department of Thoracic Surgery, Instituto Nacional de Enfermedades Respiratorias, México D.F., México
[4]Department of Radiology, Hospital Universitari Sagrat Cor, Barcelona, Spain
Email: *lmolins@clinic.ub.es

Received 18 June 2015; accepted 27 July 2015; published 30 July 2015

Abstract

Objective: To determine if lung ultrasound semiology is applicable to the post-surgical hemithorax, and its value in the evaluation of lung expansion in the postoperative period when paired with the use of digital chest drain systems. Methods: Prospective observational study including all patients undergoing thoracic surgery from June 2012 to March 2013. Patients undergoing pleurodesis or hemodynamically unstable were not considered candidates. Final inclusion in the study was based on the availability of digital chest drain system. A transthoracic lung ultrasound evaluation of the anterior and anterolateral windows was performed 20 minutes after chest drain placement. Presence or not of lung sliding and air leak values taken from the digital chest drain system were recorded. Data were submitted to a binomial classification test for analysis. Results: Forty-nine patients were included, yielding a total of 64 hemithoraces. Lung sliding was seen in 53 cases (82.8%), and an air leak value of 20 ml/min or less in 56 cases (87.5%). Sensitivity was 92.8% (95% CI: 82.6% to 97.9%) and specificity 87.5% (95% CI: 47.3% to 97.9%). Positive predictive value was 98.1%, and negative predictive value was 63.6%. Conclusions: Transthoracic lung ultrasound is a useful technique that can complement the use of digital chest drain systems in the evaluation of post-surgical lung expansion. The incorporation of lung ultrasound can greatly reduce the need for chest radiographs in thoracic surgery departments.

Keywords

Thoracic Surgery, Pneumothorax, Ultrasonography, Lung Expansion, Chest Radiograph

*Corresponding author.

How to cite this paper: Chavarín, A., Molins, L., Mier, J.M., Fibla, J.J., Izquierdo-Vidal, C., Simon, C., Guirao, A. and Hernandez, J. (2015) The Role of Ultrasound and Air Leak Measurement in Assessing Lung Expansion after Thoracic Surgery. *Surgical Science*, **6**, 352-357. http://dx.doi.org/10.4236/ss.2015.68052

1. Introduction

With the publication of the BLUE protocol [1]—Bedside Lung Ultrasound Evaluation—a lung ultrasound semiology has been consolidated. Concepts like the "seashore sign" (lung sliding) shown in **Figure 1**, or the "stratosphere sign" shown in **Figure 2** (pneumothorax) are becoming mainstream in many emergency medicine and intensive care units that use lung ultrasound in patient evaluation. The visualization of lung sliding is the basic principle in lung ultrasound. The pleural line is the image formed by the two pleurae in contact with each other. Lung sliding is the sparkling movement of the pleural line with ventilatory movements. In 1995, Lichtenstein *et al.* [2], demonstrated that lung sliding was absent in 100% of pneumothoraces. Galbois *et al.* [3] proved in their series that lung ultrasound was more effective than conventional chest X-rays in the diagnosis of residual pneumothorax. When compared with a computer aided tomography scan, lung ultrasound identified 100% of residual pneumothorax while chest X-ray only detected 61%. Our aim is to determine if lung ultrasound is applicable in post-surgical thorax and its value in the evaluation of lung expansion in a post-operative care setting.

2. Patients and Methods

This is a prospective observational study including patients undergoing thoracic surgery in the period from June 2012 to March 2013. In all the patients a digital chest drain system was employed. The work was conducted in compliance with our Institutional Review Board and Human Subjects Research Committee requirements. Informed written consent was obtained in pre-surgical evaluation in all cases that were considered to meet inclusion criteria. In order to obtain 95% confidence intervals with a range of ±3, and 80% power calculations a minimum sample size of 60 hemithoraces was required.

Patients with hemodynamic instability were excluded as well as patients that underwent pleurodesis. A transthoracic lung ultrasound evaluation of the anterior (second intercostal space at the midclavicular line) and the anterolateral (fourth or fifth intercostal space at the anterior axillary line) wall was performed 20 minutes after chest drain placement. These particular windows were preferred due to the presence of surgical wound dressings in most cases. The presence ("seashore sign" **Figure 1**) or absence ("stratosphere sign" **Figure 2**) of

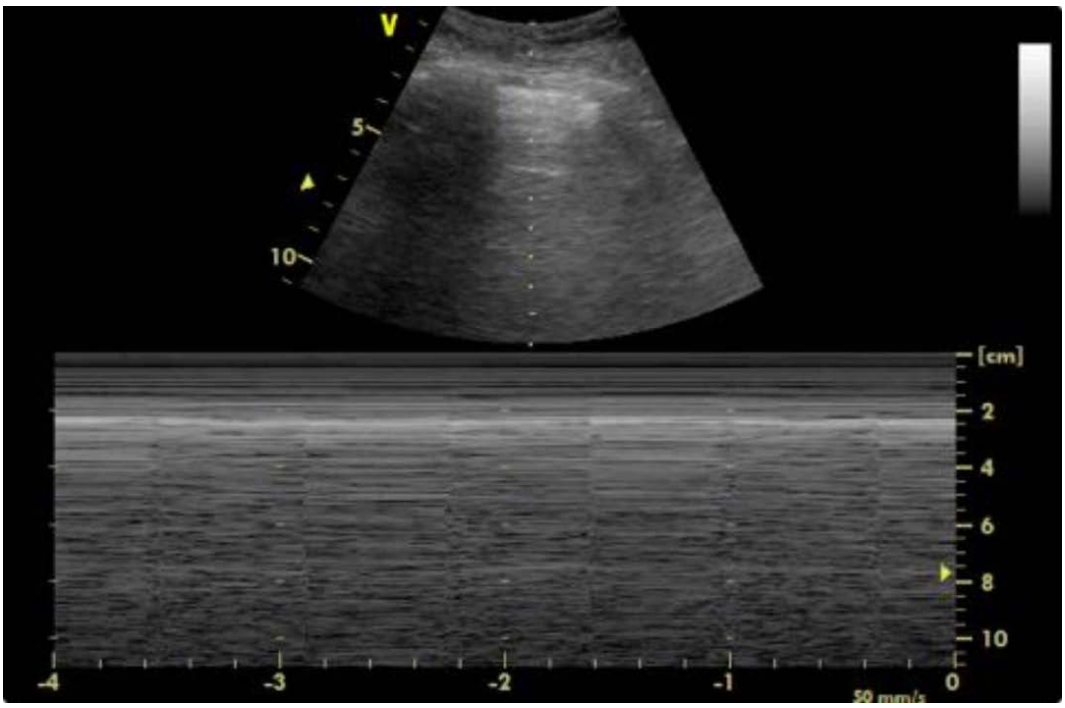

Figure 1. Seashore sign. The pleural line is the image formed by the two pleurae in contact with each other. This sign is a normal finding of lung sliding. In absence of a seashore sign or presence of a stratosphere sign, pneumothorax is likely.

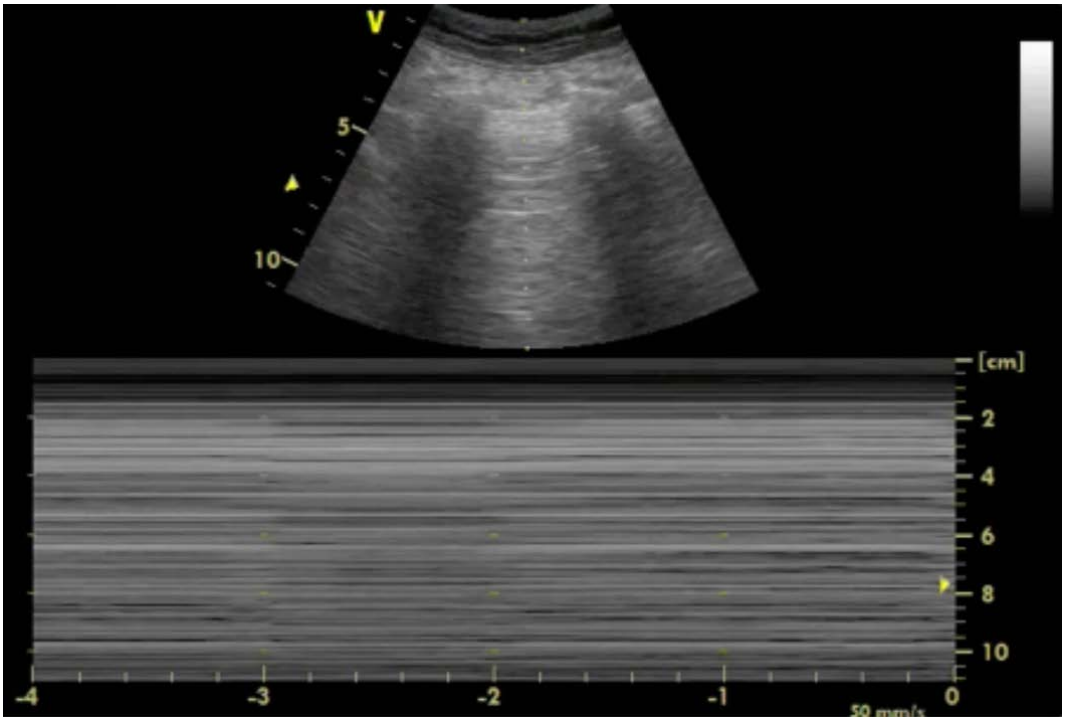

Figure 2. Stratosphere sign. Pleura and lung are indistinguishable as linear hyperechogenic lines. This sign is fairly reliable for diagnosis of a pneumothorax (absence of lung expansion).

lung sliding was recorded. The absence of lung sliding in either window was considered a pneumothorax. A digital chest drain system measurement was registered at the time of the evaluation. Digital air leak measurements of 20 ml/min or less were considered as fully expanded and deemed for chest drain removal if no other indication for a chest drain was present (*i.e.* effusion, discharge, promptness). In all cases, a digital chest X-ray was obtained at a later time, and standard chest drainage management procedure was followed. Data were analyzed as a single group and then divided into two sub-groups based on the type of procedure performed: mainly pulmonary surgery and non-pulmonary surgery. All data collected were submitted to a binomial classification test for analysis. Continuous quantitative values were expressed as means. Sensitivity and specificity were calculated as appropriate and 95% confidence interval (CI) was included for statistical comparison.

3. Results

A sample of 50 patients was obtained. One case had to be excluded due to digital chest drain malfunction. The remaining sample consisted of 49 patients (37 male/12 female), with a mean age of 45.75 years. It yielded a total of 64 hemithoraces for study as bilateral procedures were counted as independent procedures (**Table 1**).

In the evaluation of the full sample (n = 64), lung sliding was found in 53 cases (82.8%), and an air leak value of 20 ml/min or less was seen in 56 cases (87.5%). Sensitivity was 92.8% (95% CI: 82.6% to 97.9%) and specificity 87.5% (95% CI: 47.3% to 97.9%). Positive predictive value was 98.1% and Negative predictive value 63.6% (**Table 2**, and **Table 3**).

3.1. Non-Pulmonary Surgery

This group included 35 hemithoraces, procedures included are listed in **Table 1**. Lung sliding was found in 35/35 (100%). Digital air leak of 20 ml/min or less was present in 100% of cases (35/35). Sympathectomy and sympathectomy reversal patients were also analyzed as a separate subgroup (n = 29) as these cases were part of our out-patient surgical unit and chest X-ray was available within 25 minutes after digital chest drain placement. Full lung expansion was found in 29/29 (100%) of the X-rays, lung sliding was present in 29/29 cases (100%) and a digital air leak measurement of 20ml/min or less was found in 29/29 hemithoraces (100%).

Table 1. Demographics and patients.

Characteristic	Value
Number of patients	49
Number of hemithoraces	64
Gender, n (%)	
Male	37 (75.5%)
Female	12 (24.5%)
Age, mean (SD)	45.7 (12)
Non-pulmonary procedures by type, n	35
Sympathectomy	27
Thymomas	3
Mediastinal tumors	2
Sympathectomy reversal	2
Pleural nodule	1
Pulmonary procedures by type, n	29
VATS, left wedge resection	11
VATS, right wedge resection	9
Lobectomy, left	3
Lobectomy, right	3
Mid sternotomy, right nodule	1
Pneumothorax	2

Table 2. Total number of diagnostic examinations.

	True positive	True negative	False positive	False negative
Total sample	52	7	1	4
Pulmonary procedures	17	7	1	4

Table 3. Evaluation of lung sliding.

Variables	Total sample	Pulmonary procedures
Sensitivity % (95% CI)	92.8% (82.9, 97.8)	80.5% (58.8, 94.4)
Specificity % (95% CI)	87.5% (47.3, 97.9)	87.5% (47.3, 97.9)
Disease prevalence % (95% CI)	87.5% (76.8, 94.4)	72.4% (52.7, 87.2)
PPV % (95% CI)	98.1% (89.9, 99.6)	94.4% (72.6, 99.0)
NPV % (95% CI)	63.6% (30.8, 88.8)	63.6% (30.8, 88.8)

PPV = Predictive Positive Value; NPV = Negative Predictive Value.

3.2. Pulmonary Surgery

Twenty-nine hemithoraces were evaluated. Lung sliding was present in 18 cases (62%). Digital air leak value of 20 ml/min or less was found in 21 cases (72%). Inter-rate agreement (Weighted Kappa) was 0.61. Sensitivity was 80.9% (95% CI: 58.0% to 94.4%), and specificity 87.5% (95% CI: 47.3% to 97.9%). Positive and negative predictive values were 94.4% (95% CI: 72.6% to 99.0%) and 63.6% (95% CI: 30.8% to 88.8%) respectively (**Table 3**).

4. Discussion

Lung ultrasound has been proven to be almost as accurate as CT scanning in detecting the presence of pneu-

mothorax [4] occult pneumothorax and its extension [5]. In the present study and after analyzing 49 patients (64 hemothoraces) we found that ultrasound had a sensitivity of 92.8%, a specificity of 87.5%, a positive predictive value of 98.1%, and a negative predictive value of 63.6%. Our results showed that lung sliding is a good indicator of lung expansion, especially when paired with digital air leak measurements. After analyzing our results we found out that the addition of lung ultrasound evaluation showing lung sliding sign and a digital air leak value of 20 ml/min or less in non-pulmonary surgery patients allows a safe exclusion of pneumothorax.

The results found in our sympathectomy sub-group were identical to those published by Saucier *et al.* [6], who reported a perfect agreement between lung ultrasound and chest radiography to detect pneumothorax in a series of 50 cardiothoracic surgery patients.

Our results were also comparable to those found by Shostak E. *et al.* [7] in a similar study but with minor procedures. They performed transthoracic ultrasound in a series of 185 patients submitted to thoracentesis, transbronchial biopsy and computed tomography-guided needle lung biopsy. The sensitivity and specificity were 88% and 97% respectively.

However, not all the studies have found an optimal accuracy of ultrasound evaluation in the detection of lung expansion. Goudie *et al.* [8] in a prospective cohort trial of 120 patients submitted to thoracic surgery and bedside postoperative ultrasound evaluation, found a sensitivity and specificity in the detection of postoperative pneumothorax of 21.2% and 94.7%. They justified the low sensitivity arguing that postoperative inflammation within the pleural cavity could affect the interpretations of ultrasonographic findings indicative of a pneumothorax. It is accepted that postoperative pleural inflammation makes more difficult to detect pneumothorax, however we believe that with an adequate training this should not become a problem. Surgeons performing echography in Goudi *et al.* al study did not have a large experience in echography, indeed they had an intensive 2-week training period focused on basic chest ultrasound. We believe this is enough training to detect pleural effusions but not sufficient for a high accuracy in detecting lung expansion following thoracic surgery. A longer training is adviced for this purpose—of 1 month at least.

Digital chest drain systems are considered superior to traditional water seal devices and its use is extending [9]. However there is not such a consensus regarding ultrasound benefits in thoracic surgery patients. Different studies have been published proving bedside ultrasound is a valuable tool in the management of these patients [7] [10]-[16], meanwhile other authors have warned about the limitations of the technique [8] [17]-[20].

To our knowledge the present study is the first one demonstrating a high accuracy of bedside ultrasound evaluation combined with digital chest drain systems in the detection of postoperative lung expansion.

Our study has limitations. It is a prospective cohort with a limited number of patients. In the Pulmonary surgery group, we found that the absence of lung sliding can coexist with digital air leak values of 20 ml/min or less. This anomalous situation can be explained by the following: a. Resection volume and site, and b. irregular compensatory lung expansion. Video Assisted Thoracoscopic (VAT) wedge resections do not follow a strict anatomic pattern making compensatory lung expansion less predictable. Larger resections have increased the probability of the probe being placed directly over the resected area thus leading to a false image of pneumothorax. The presence of an air leak value of 20 ml/min or less in these cases supports the fact that it is an anatomical defect of the lung rather than a pneumothorax that yields the false negative result in the ultrasound evaluation.

5. Conclusion

Bedside trans-thoracic ultrasound evaluation combined with a digital chest drain system has the potential to be effective and convenient in the detection of lung expansion after thoracic surgery. Future prospective randomized studies are warranted to confirm these findings and determine whether this postoperative management policy is able to minimize the use of postoperative chest X-rays.

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