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ORIGINAL ARTICLE EMERGENCY MEDICINE

North Clin Istanb 2019;6(3):273–278
doi: 10.14744/nci.2018.46548

How successful is "pleural sound sign" in the identification of pneumothorax?

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ABSTRACT

OBJECTIVE: In the present study, in thorax ultrasonography (USG) Doppler images obtained from cases with occult pneumothorax, we investigated the status of pulsatile pleural sounds over the pleural line and called these as the pleural sound sign (PSS). The purpose of the present study was to identify the efficacy of the proposed PSS in diagnosing pneumothorax and to compare it with the other USG findings including the sliding lung sign (SLS) and seashore sign (SSS).

METHODS: The present study included 66 consecutive patients who were referred to the emergency unit with a blunt trauma from October 2009 to January 2010 at a tertiary university hospital.

RESULTS: Of the 66 patients, 34 were in the patient group, and 32 were in the control group. Males accounted for 66.7% (n=44) of the study population. In predicting pneumothorax, the areas under receiver operating characteristic (ROC) curves of PSSmax and PSSdifference were 0.989 and 0.990, respectively. While the sensitivity of the SLS was 88% and the sensitivity of the SSS was 56%, the specificities of the SLS and SSS were 100%. Based on our findings, accuracy ranking was as follows: PSSmax = PSSdifference > SLS > SSS.

CONCLUSION: New applications of thorax USG are rapidly growing. Our findings have to be confirmed in a large patient series. PSS is not a novel method, but it enhanced the importance of USG in the diagnosis of pneumothorax. We can stipulate that it can replace thorax computed tomography imaging particularly for the diagnosis of occult pneumothoraxes.

Keywords: Emergency medicine, chest; pleural sound sign; pneumothorax; ultrasonography.

Cite this article as: *Goknil Calik S, Calik M, Girisgin S, Karaoglan O, Dundar ZD, Ergin M. How successful is "pleural sound sign" in the identification of pneumothorax? North Clin Istanb 2019;6(3):273–278.*

Trauma is the most common cause of death and disability among people younger than 45 years. Mortality prevention begins with rapid diagnosis of life-threatening trauma or traumas and their simultaneous treatment [1]. Pneumothorax, defined as the collection of air in the pleural cavity, is the second most common complication after rib fractures that are observed particularly due to chest trauma. It is a significant cause of mortality and morbidity [2]. It is often diagnosed using lung X-rays, which provide limited information, and thorax computed tomography (CT) scan is used for more detailed assessment. Among patients with a history of trauma, whose anteroposterior lung X-rays did not show pneumothorax, 2%–15% actually had pneumothorax as demonstrated by CT scans [3]. This is particularly true in the presence of small and anterior-basal pneumotho-

Received: October 11, 2017 *Accepted:* December 20, 2018 *Online:* July 30, 2019

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raxes, which are called occult pneumothorax. Both imaging modalities have limitations, such as the time required for the transfer of patient and completion of the scan, radiation exposure, and increased healthcare costs. Nevertheless, they are invaluable for the assessment of lung pathologies [4]. CT is even considered to be the gold standard for the diagnosis of pneumothorax in patients who can undergo a CT scan [5, 6].

It is not easy to assess trauma patients in the emergency departments. Ultrasonography (USG) is an ideal method for the initial assessment of trauma patients since it can show bleedings, particularly in the pericardial, pleural, and peritoneal regions. Since 1971, it has been used to evaluate the free peritoneal fluids. However, its use for the assessment of thorax began at a later time, in 1986, and interestingly, it was first used on horses. A year later, it was used by Wernecke et al. in humans for the diagnosis of pneumothorax [1, 7].

As gas and/or air prevent the transmission of ultrasound waves, the lung parenchyma cannot be seen beyond the pleura. However, in case of acute lung injury, parenchyma and ventilation of the lungs can be almost fully and correctly evaluated by USG. Actually, the space between the two pleura is a real gap. It is between 0.2 and 0.4 mm and is hard to visualize with ordinary USG devices. When the probe position is vertical to both intercostal spaces, only the parietal pleura appears as a net echogenic line due to acoustic reflections. A hyperechoic and sliding line moving forward and backward during breathing and exhalation is visible 5 mm below the rib line and is called the "pleural line" (Fig. 1, white arrow). The real-time motion image of this line is called the "sliding lung sign" (SLS). In the M-mode (time–motion mode), the immobile pleural line and the homogeneous granular appearance beneath it is called the "seashore sign" (SSS). The absence of this movement is observed in pneumothorax. In the M-mode, this absence of motion can be detected and called as the "barcode or stratosphere sign" [8]. These findings can be demonstrated by M-mode, B-mode, or both modes in USG. The findings used to diagnose pneumothorax include SLS, lung point sign, SSS, and "barcode sign/stratosphere sign" [8–11].

In the present study, in thorax USG Doppler images obtained from cases with occult pneumothorax, we investigated the status of pulsatile pleural sounds over the pleural line (Fig. 1) and called these as the pleural sound sign (PSS). PSS's operating logic is very simple. Although similar pulsatile sounds can also be recorded from the lung tissue below the pleural line, the intensity of the sound decreases as the distance from the pleural line increases (Fig. 2). This sound is weak and continuous in subcutaneous tissues, contrary to the PSS (Fig. 3). We believe that the PSS can be an objective version of the findings obtained in the SLS since we performed an objective measurement [8]. The purpose of the present study was to identify the efficacy of the proposed PSS in diagnosing pneumothorax and to compare it with the other USG findings including the SLS and SSS.

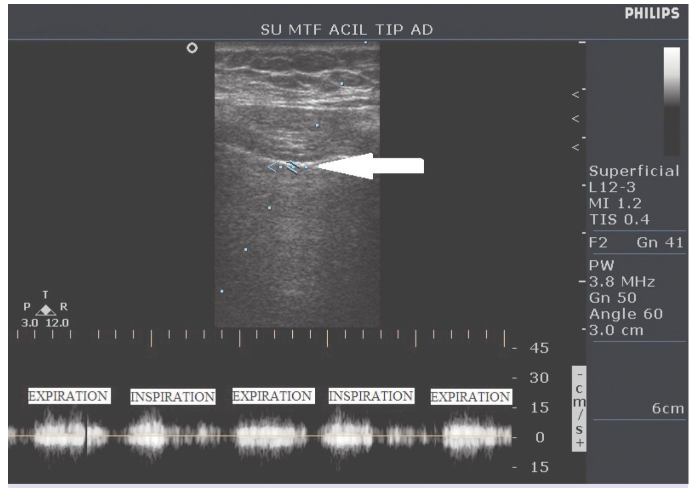

FIGURE 1. Doppler can collect pulsatile pleural sounds in the pleural lines during inspirations and expirations. White arrow indicates the PSS in the pleural line.

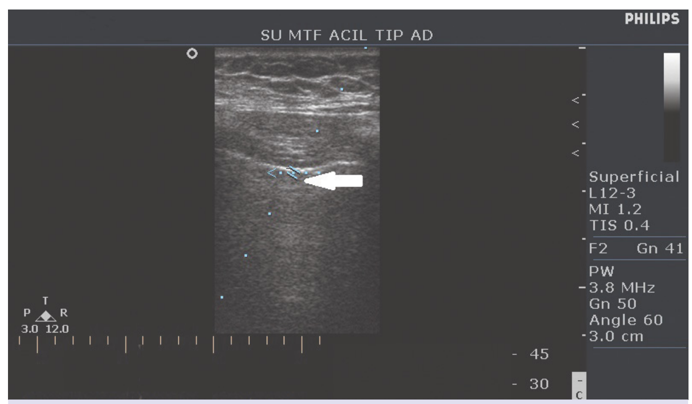

FIGURE 2. In addition, similar pulsatile sounds can be identified in the lungs below the pleural line that was marked with a white arrow.

MATERIALS AND METHODS

The present study was conducted in the emergency unit of the emergency medicine department of a tertiary university hospital between October 1, 2009 and January

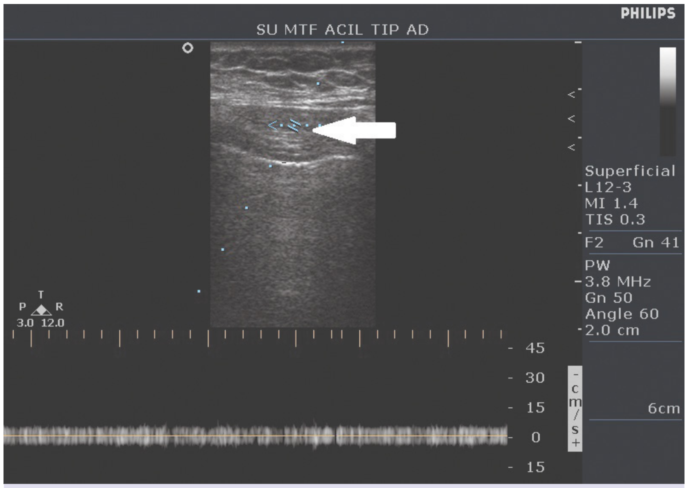

FIGURE 3. On the other hand, the voice’s strength decreases as it moves away from the pleural line (white arrow). This voice in the subcutaneous tissues is slight and permanent, as opposed to pulsatile pleural sounds.

31, 2010. The study was approved by the local ethics committee of a university (2010/047) and conducted in accordance with the principles of good clinical practice. Informed consent was obtained from all the participants in the study prior to the commencement of the research.

Study Population

The study included two groups: patient group and control group. Patients aged ≥18 years who were referred to the emergency unit with a blunt trauma constituted the patient group. Patients who had a serious and life-threatening pathology (serious hypoxia, serious tachypnea, tension pneumothorax, and open pneumothorax) and those who did not sign the informed consent form were excluded from the study.

The control group included healthy subjects aged ≥18 years who provided consent for participation in the study.

Study Protocol

Subjects included in the patient and control groups underwent pleural USG examination performed by independent emergency care specialists. To detect pneumothorax, these examinations involved pleural USG of four different regions of the thorax (from the left and right midclavicular lines of the third or the fourth intercostal space and from between the mid-axillary and posterior axillary lines of the fourth or the fifth intercostal space). USG was performed by emergency care physicians who had received emergency USG training and had been performing emergency USG for at least 2 years. Particular attention was given not to interrupt the clinical follow-up of the patients during the USG procedure.

PSS, SLS, and SSS based on USG were recorded for both groups. USG was performed using 3–12 MHz linear probe of a sonography device (Philips EnVisor C HD M2540A; Bothell, WA, USA). The amplitude of the sound waves observed in duplex Doppler mode was measured in millimeters (mm) and used for the objective estimation of the PSS. The distance between the starting point of the measured sound wave and the basal line was defined as PSSmin, and the distance between the peak value of the sound wave and the basal line was defined as PSSmax. PSS difference was accepted as the numeric difference between PSSmax and PSSmin (PSS difference = PSS max – PSS min).

Subjects in the patient group whose thorax CT confirmed pneumothorax were included into the examinations for comparison to the control group. Since pneumothorax pathology is isolated to a single region of the hemithorax and decreased PSS can only be detected at the region with pneumothorax, the lowest PSS values measured in the patient group were taken into account.

Since there are no normal values defined for the PSS in the literature, the control group was selected among healthy volunteers to estimate the normal interval. It is an expected outcome that all measurements obtained from different regions of the thorax will be similar in a healthy individual without a pleural pathology. The mean value of PSS measurements obtained from four regions of the thorax was taken into account in the control group to minimize the errors associated with the device and measurement methods.

The success of the SLS, SSS, and PSS in diagnosing pneumothorax was compared between the patient and control groups.

Statistical Analysis

Receiver operating characteristic (ROC) curves were constructed to detect the power of PSSmax and PSSdifference parameters in estimating pneumothorax (Fig. 4). Cutoff values were defined for all parameters using the Youden index (sensitivity + specificity – 1). Based on defined cutoff values, the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy rates were calculated for all parameters, along with 95% confidence intervals (CIs).

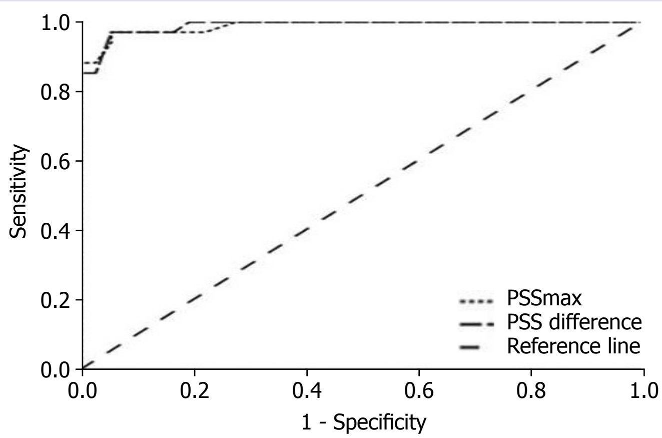

Figure 4. Receiver operating characteristic curves comparing pleural sound sign maximum and difference with respect to predicting pneumothorax.

Cross-tables were drawn for the patient and control groups to determine the diagnostic value of the SLS and SSS. The sensitivity, specificity, PPV, NPV, and accuracy rates were calculated separately for both parameters, along with 95% CIs.

RESULTS

A total of 66 consecutive cases were included in the study. Of the 66 patients, 34 were in the patient group, and 32 were in the control group. Males accounted for 66.7% (n=44) of the study population. The median ages were 48 (26–80) years in the patient group and 40 years in the control group. Age distribution was not significantly different between the study groups. Male/female ratios were 52.9% (n=18)/47.1% (n=16) in the patient group and 68.7% (n=22)/31.1% (n=10) in the control group. Gender distribution was not significantly different between the study groups (p=0.189). The area under ROC curve for PSSmax in predicting pneumothorax was 0.989 (95% CI 0.971–1.006, p<0.001). The optimum cutoff value was found to be 9.25. For this cutoff value, sensitivity was 97%, specificity was 94%, PPV was 94%, and NPV was 97% (Table 1 and Fig. 4). The area under ROC curve for PSSdifference in predicting pneumothorax was 0.990 (95% CI 0.974–1.005, p < 0.001). The optimum cutoff value was calculated as 6.5. For this cutoff value, sensitivity was 97%, specificity was 94%, PPV was 94%, and NPV was 97% (Table 1 and Fig. 4). When the patient and control groups were compared for the SLS, its sensitivity was 88%, specificity was 100%, PPV was 100%, and NPV was 89% (Table 1). When the patient and control groups were compared for the SSS, its sensitivity was 56%, specificity was 100%, PPV was 100%, and NPV was 68% (Table 1). Based on our findings, accuracy ranking was as follows: PSSmax = PSSdifference > SLS > SSS (Table 1).

DISCUSSION

Lichtenstein et al. demonstrated the ability of USG in detecting pneumothorax in their studies performed at different time points using the SLS, comet tail, lung point, or various combinations of these parameters. While one of these studies reported that the SLS had 95.3% sensitivity, 91.1% specificity, 100% NPV, and 87% PPV in predicting pneumothorax, these figures were updated as 100% sensitivity, 78% specificity, 100% NPV, and 40% PPV in a later study [5, 6, 12, 13]. Other studies in the literature also highlighted the NPV of the SLS, at rates ranging between 96.3% and 100%. In other words, the presence of the SLS in a patient at supine position effectively eliminates the diagnosis of pneumothorax, independent of its traumatic or non-traumatic origin [14, 15].

On the other hand, the absence of the SLS does not always mean that a patient has a pneumothorax.

Table 1. Performances of parameters in terms of predicting pneumothorax

	Sens	Spes	PPV	NPV	Accuracy	LR+	LR-
PSS, max	97 (87–100)	94 (84–97)	94 (85–97)	97 (86–99)	96 (86–98)	15.53 (5.29–30.30)	0.03 (0.00–0.15)
PSS, difference	97 (87–100)	94 (84–97)	94 (85–97)	97 (86–99)	96 (86–98)	15.53 (5.29–30.30)	0.03 (0.00–0.15)
SLS	88 (79–88)	100 (89–100)	100 (89–100)	89 (80–89)	94 (84–94)	inf (7.85–inf)	0.12 (0.12–0.24)
SSS	56 (46–56)	100 (89–100)	100 (82–100)	68 (61–68)	77 (67–77)	inf (4.26–inf)	0.44 (0.44–0.61)

PPV: Positive predictive value; NPV: Negative predictive value; PSS: Pleural sliding sound; SLS: Sliding lung sign; SSS: Seashore sign.

Severe chronic obstructive pulmonary disease and bullous diseases may impair the SLS in some regions of the lungs and mimic pneumothorax in USG. Additionally, a history of pneumonectomy, pulmonary fibrosis, high--frequency ventilation, pulmonary fibrosis, and adult respiratory distress syndrome complicate diagnosing pneumothorax by USG [16, 17]. Based on the patient population, its specificity varies between 60% and 99%. While this rate is higher in the overall population, it was found to be lower among intensive care patients and patients with acute respiratory distress syndrome [5, 6, 14, 18]. While studies in the literature underline that the absence of the SLS is not specific to pneumothorax diagnosis, its combination with other USG findings was suggested to increase the possibility of making a correct diagnosis [8–10, 13].

In the present study, the specificity and PPV of the SLS were found to be 100%. Contrary to the previous studies in the literature, the control group consisting of healthy subjects was used in the present study to define a normal range for the PSS. Therefore, the specificity and PPV values in the present study were higher than those in previous studies.

SLS is the dynamic normal sign on the pleural line. M-mode can be used to detect more objective signs of pleural movements. In M-mode, the presence of pleural movement is demonstrated by the SSS. If the SLS is lost, a characteristic image in the form of a "stratosphere sign" can be seen in the M-mode setting [19]. In our literature search, we did not encounter any study reporting the specificity and sensitivity values for the SSS. In the present study, both specificity and PPV were found to be 100%. However, compared with all other signs, SSS had the lowest accuracy.

For the diagnosis of pneumothorax, SLS and SSS can only be assessed as present or absent. Both signs depend on the operator. Cunningham et al. recommended the use of power color Doppler ultrasound for diagnosing pneumothorax to facilitate documentation and interpretation and to reduce operator dependency. They reported that this approach provides a real-time assessment based on a simple sonographic image, instead of recording the dynamic dislocation process of pleural leaflets for a long period of the respiratory cycle [20]. However, in this technique, even the gain adjustment of colored Doppler can result in misinterpretation of an assessment. In the present study, we detected pulsatile pleural sounds over the pleural line by using Doppler property of the ultrasound device, and we used numeric and objective values to measure the amplitude of the sound wave over the basal line [11]. Moreover, we decreased the problems originating from the operator or device settings by making the pleural findings of pneumothorax measurable by numeric values. In the present study, we demonstrated that PSSmax and PSSdifference outcomes are more sensitive than SLS and SSS and have similar specificity to SLS and SSS in diagnosing pneumothorax. Moreover, its accuracy in predicting pneumothorax diagnosis was found to be higher than SLS and SSS. Although we determined a cutoff value for PSS measurements in the present study, this study alone is not sufficient to make any comments on the inter-individual variability of PSS measurements. However, our findings indicated that the PSS based on the measurements obtained from four regions of the thorax was lower on the side with pneumothorax than on the other sides. Even the assessment of intra-individual variability in patients with suspected pneumothorax can provide valuable clinical information.

We believe that the findings of the present study should be confirmed in further studies performed by independent authors. We are also conducting new studies to investigate the efficacy of the PSS in diagnosing pneumothorax in non-traumatic and intensive care patients.

As in any work, there are some limitations to this work in particular, because of the prospective nature of the research. Owing to ethical concerns, the control group consisted of patients for whom CT scans were indicated. This might have led to selection bias.

Several studies in the literature reported the benefits of USG, particularly in the presence of traumatic pneumothoraxes. A recent meta-analysis showed that bedside USG performed by clinicians has high sensitivity and similar specificity compared with lung imaging for the diagnosis of pneumothorax. Another aspect that was highlighted was the experience of clinicians in performing USG.

Conclusion

By its nature, pneumothorax should be diagnosed quickly and treated adequately. New applications of thorax USG are rapidly growing [4]. PSS is one of those new applications, and although it has similar specificity for the diagnosis of pneumothorax compared with the other methods, it has higher accuracy and sensitivity. USG is important as it can be performed bedside by the clinician in the absence of an additional specialist, and as it allows simultaneous diagnosis and treatment without interruption of resuscitation and without transferring patients to other services, such as the radiology unit. Another important aspect of the PSS is that it is based on objective values, and thus it overcomes the subjectivity associated with the clinician's inexperience. Our findings have to be confirmed in a large patient series. PSS is not a novel method, but it enhanced the importance of USG in the diagnosis of pneumothorax. We can stipulate that it can replace thorax CT imaging particularly for the diagnosis of occult pneumothoraxes in critically ill patients who cannot be transferred for diagnosis, such as emergency services and intensive care units, or whose general condition does not permit transfer.

Ethics Committee Approval: This study was approved by the Ethics Committee of the Necmettin Erbakan University (2010/047).

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study has received no financial support.

Authorship Contributions: Concept – SGC, MC, SG, OK, ZDD, ME; Design – SGC, MC, SG, OK, ZDD, ME; Supervision – SGC, MC, SG, OK, ZDD, ME; Materials – SGC, MC, SG, OK, ZDD, ME; Data collection and/or processing – SGC, MC, SG, OK, ZDD, ME; Analysis and/or interpretation – SGC, MC, SG; Writing – SGC, MC, SG; Critical review – SGC, MC, SG.

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