
**Monaldi Archives for Chest Disease**

eISSN 2532-5264 https://www.monaldi-archives.org/





Monaldi Arch Chest Dis 2025 [Online ahead of print]

*To cite this Article:*
Bajad P, Dutt N, Chauhan N, et al. **Use of a novel ultrasound sign in the management of malignant pleural effusions: a prospective observational trial**. *Monaldi Arch Chest Dis* doi: 10.4081/monaldi.2025.3263

# Use of a novel ultrasound sign in the management of malignant pleural effusions: a prospective observational trial

Pradeep Bajad,[1] Naveen Dutt,[2] Nishant Chauhan,[2] Avinash Babu,[3]
Aditi Joshi,[3] Amartya Chakraborti,[4] Rishabh Kochar,[5] Saumya Shishir[6]

[1]Department of Pulmonary Medicine, Amrita School of Medicine, Amrita Vishwa Vidyapeetham, Faridabad; [2]Department of Pulmonary Medicine, All India Institute of Medical Sciences, Jodhpur; [3]Department of Pulmonary Medicine, Caritas Hospital, Kottayam, Kerala; [4]Department of Pulmonary Medicine, Manipal Hospital, Kolkata, West Bengal; [5]Department of Pulmonary Medicine, Delhi Heart and Lung Institute, New Delhi; [6]Department of Pulmonary Medicine, Yatharth Hospital, Noida, Uttar Pradesh, India

**Correspondence:** Pradeep Bajad, Department of Pulmonary Medicine, Assistant Professor, Amrita School of Medicine, Amrita Vishwa Vidyapeetham, Faridabad, India 122002.
E-mail: Pradeepbajad@gmail.com

**Contributions:** PB, ND, concept/design of the study, acquisition and interpretation of data, manuscript preparation, and final approval, and integrity of work; AC, AB, AJ, SS, RK, acquisition and interpretation of data; NC, AC, acquisition and interpretation of data, manuscript preparation and final approval; AC, data analysis.

**Conflict of interest:** each author declares that they have no commercial associations (e.g., consultancies, stock ownership, equity interest, patent/licensing arrangement, etc.) that might pose a conflict of interest with the submitted article.

**Ethics approval and consent to participate:** ethics approval was obtained from the All India Institute of Medical Sciences, Jodhpur, India. Approval number: AIIMS/IEC/2020/3318.

**Informed consent**: taken from all the patients during enrolment for the study.

**Patient consent for publication:** not applicable.

**Availability of data and materials:** all data underlying the findings are fully available.

**Funding:** this research received no external funding.

**Abstract**

The management of malignant pleural effusion (MPE) is influenced by the lung's ability to re-expand following fluid drainage. Lung entrapment can complicate this process and may be predicted using pleural manometry. Recently, a novel lung ultrasound (LUS) marker—the sinusoidal sign—has emerged as a potential tool to differentiate between expandable and entrapped lung prior to thoracentesis. A prospective observational study was conducted to evaluate the role of pre-drainage LUS in identifying entrapped lung and compare its diagnostic accuracy with pleural manometry. A total of 30 patients with MPE were enrolled. Prior to thoracentesis, targeted ipsilateral LUS was performed at the level of the atelectatic lung. M-mode displacement <1 mm was considered indicative of an absent sinusoidal sign. Simultaneously, pleural manometry was conducted during thoracentesis to measure pressure changes and calculate pleural elastance. Lung expandability was determined based on pleural elastance and post-thoracentesis imaging findings (computed tomography thorax). A pleural elastance >13.6 cm $H_2O$/L was considered diagnostic of lung entrapment. A pleural elastance cut-off of 13.6 cm $H_2O$/L demonstrated 100% sensitivity, 93% specificity, a 100% positive predictive value, and 84.2% negative predictive value. The absence of the sinusoidal sign on LUS had a sensitivity of 78.6% and specificity of 100% in identifying entrapped lung. Both absent sinusoidal sign on pre-drainage LUS and elevated pleural elastance (>13.6 cm $H_2O$/L) during thoracentesis are reliable indicators of lung entrapment in MPE. LUS may serve as a useful, non-invasive bedside tool for early identification of non-expandable lung.

**Key words**: malignant pleural effusion, manometry, USG lung.

**Introduction**

Malignant pleural effusion [MPE] is a leading cause of exudative pleural effusion worldwide, associated with an average survival of 4–7 months [1]. MPEs are primarily caused by lung cancer in men and breast cancer in women, accounting for 50–65% of all cases [2]. The incidence of MPE has been reported to be up to 50% in lung cancer patients over the entire disease course [3]. While some patients may initially be asymptomatic, most eventually experience dyspnea at rest. Given the limited survival [average 4-7 months], treatment aims to relieve dyspnea through minimally invasive, accurate, and definitive procedures to ensure the best quality of life, minimal morbidity, and increased hospital-free days [1]. Standard management options include pleurodesis or repeated therapeutic aspiration, depending on expected survival and post-drainage lung expansion [4]. The selection of definitive therapeutic management depends upon the patient's expected survival and post-drainage expansion of the lung [5].

Pleurodesis often fails in cases of "nonexpandable lung", where the lung cannot fully expand, preventing the visceral and parietal pleura from adhering. This condition may result from active pulmonary or pleural disease, such as malignancy, infection, hemothorax, or lung cancer with endobronchial obstruction (lung entrapment), or from remote disease causing pleural fibrosis or scarring (trapped lung) [6]. Patients with entrapped lung usually do not benefit from therapeutic aspiration in terms of dyspnea relief. However, if there is symptomatic relief, repeated thoracentesis or an indwelling pleural catheter (IPC) is recommended for these patients. Currently, no pre-drainage methods are available to detect lung entrapment, which often necessitates multiple procedures for effective management [7]. Lung entrapment and successful thoracentesis can be predicted by recording pressure changes during the procedure. Monitoring pleural pressure [Ppl] during thoracentesis offers valuable insights into the real-time physiology of the pleural space, helps prevent multiple procedure-related complications, and aids in predicting the success of pleurodesis [8]. An expandable lung does not show significant changes in pleural pressure during thoracentesis, which is why pleural elastance is on the lower side. In contrast, a non-expandable lung shows significant changes in pleural pressure, leading to higher pleural elastance. Appropriate management of malignant pleural effusion [MPE] depends on the lungs' ability to expand after fluid drainage. There is no recommended diagnostic test to guide further management decisions, such as choosing between no aspiration, pleurodesis, or continuous tube drainage. Wong et al. developed an ultrasound sign to differentiate between expandable and non-expandable lung [9]. They hypothesized that an entrapped lung would not show any movement on M-mode lung ultrasound [LUS] due to lack of movement in that region. On LUS, this is reflected by an absent sinusoidal sign [9]. The absent sinusoidal sign is a meaningful early diagnostic indicator of lung entrapment (Figure 1).

The American Thoracic Society [ATS] guideline for malignant pleural effusion [MPE] recommends using LUS for pleural interventions and evaluating for nonexpandable lung before thoracentesis in MPE cases [5]. Nonexpandable lung occurs in at least 30% of MPE patients [10,11]. In patients whose dyspnea improves after thoracentesis, the absence of complete lung expansion following fluid evacuation should prompt clinicians to avoid pleurodesis and use indwelling pleural catheters [IPCs]. Several methods exist to assess post-aspiration lung expansion or entrapment: (1) Large fluid aspiration [at least 500 ml] to confirm symptomatic improvement and detect nonexpandable lung, [12]. (2) Measurement of pleural pressures or elastance [change in pressure over volume drained] to predict lung expansion, and (3) post-procedure imaging to assess lung expansion. Among all these methods, complete lung expansion on post-thoracentesis imaging is the most accurate to predict expandable or non-expandable lung. However, it is not always practically possible because major pressure shifts may limit thoracentesis, especially due to breathlessness or cough in the patient. Therefore, one must rely on other methods as well. In symptomatic MPE patients, large-volume thoracentesis is recommended if it is unclear whether symptoms are related to effusion or if the lung is expandable. IPC is suitable for both expandable and nonexpandable lung and is a viable alternative to pleurodesis in patients with expandable lung [5]. Lung entrapment can be caused by visceral pleural thickening, endobronchial obstruction, or increased elastic recoil. Assessing lung expandability is crucial when considering pleurodesis, as pleural apposition is essential for adequate adhesion [8,13-16]. Pleural manometry estimates pleural elastance [PEL] and lung mechanical properties, with a PEL greater than 20-25 cm $H_2O$/liter indicating a nonexpandable lung [13]. Techniques for pleural pressure measurement include U-tube water manometers, commercial digital manometers, simple manometry systems, and customized manometers. Preprocedural diagnosis of trapped lung using LUS can reduce unnecessary procedures, hospital costs, and complications [13,17].

**Materials and Methods**

We conducted a prospective cross-sectional study at a tertiary care hospital in western India, approved by the ethical committee [approval number: AIIMS/IEC/2020/3318]. Patients with suspected malignant pleural effusion [MPE] secondary to lung malignancy were enrolled, specifically patients with moderate to massive effusion. Exclusion criteria included MPE from extrapulmonary malignancy, lung cancer with non-malignant effusion [e.g., infective, paramalignant, undiagnosed], hemodynamic instability, or cardio-pulmonary failure.

***Study objective***

Primary objective of our study was to assess the diagnostic yield of lung ultrasound (LUS) in identifying entrapped lung and compare its performance with pleural manometry. Secondary objective was to evaluate the utility of LUS in predicting the appropriate management strategies for malignant pleural effusion.

Data was collected using a structured proforma, including demographics, radiology, pathology findings, and performed interventions. Malignant pleural effusion [MPE] was diagnosed based on pleural fluid cytology or pleural biopsy, with cases excluded if follow-up reports did not confirm MPE. Only patients with positive pleural fluid cytology were enrolled, confirming malignant effusion secondary to lung malignancy. Lung ultrasound [LUS] images were obtained before intervention using a 2- to 5-MHz transducer probe. The pleural fluid amount was initially measured in the sitting upright posture. Effusion was considered moderate if it spanned at least three interspaces on ultrasonography with a depth of 3 cm or greater in at least one interspace while upright. At the level of atelectasis, lung displacement was recorded using M mode in the supine posture. The "sinusoid sign," a sinusoidal pattern of atelectatic lung movement within surrounding pleural fluid, indicates an expandable lung. An M mode waveform value of <1 mm was used as the cut-off for identifying an entrapped lung. The absence of sinusoidal respiro-phasic lung motion, known as the "absent sinusoid sign," suggests a nonexpandable lung. The presence or absence of the sinusoidal sign was recorded for each patient (Figure 1).

***Pleural manometry***

Pleural manometry was performed to monitor pressure changes and calculate pleural elastance [PEL]. After administering local anesthesia, a pleural pigtail catheter [10 gauge] was inserted under LUS guidance into the pleural cavity [4th to 5th intercostal space] in the midaxillary line while the patient was supine. The catheter was connected to a pressure transducer and an electric cardiac monitor [Mindray UMEC 12 Patient], with the transducer fixed at the catheter level to nullify height-related pressure differences. A three-way stopcock was placed between the pressure transducer and the pleural catheter, connecting to a drainage bag and a 50 ml syringe (Figure 2). Pleural fluid was aspirated with the syringe and collected in the drainage bag. The pressure zero point was set on the monitor. Repositioning the stopcock handles allowed fluid aspiration, ejection into the drainage bag, and pressure measurement. Initial pressure measurement was taken after aspirating 50 ml of fluid. After every 100 to 200 ml of fluid removal, subsequent measurements were taken, up to 1000 ml. Drainage was stopped if patients experienced chest discomfort, intractable cough, procedural complications, or if pressure dropped below –20 cm $H_2O$ or declined by more than 10 cm $H_2O$ between measurements. The –20 cm H2O limit was based on historical definitions and current practice guidelines [15]. The procedure was done using sterile techniques, and complete fluid evacuation was attempted via manual aspiration with a 50 ml syringe. A minimum of 100 to 150 ml of fluid was aspirated from each patient. Patients were asked about chest discomfort during aspiration. Pleural pressure was recorded in mmHg and converted to cm H2O [1 mmHg = 1.36 cm H2O]. Pleural elastance was calculated as the pressure change [cm H2O] per liter of pleural fluid drained.

The gold standard for diagnosing entrapped or expandable lung was post-drainage CT [Computed Tomography] chest findings. We did not use definitive criteria for the entrapped lung. There had to be air between the visceral and parietal pleura around the lower lobe without an air leak through the chest catheter for an entrapped lung on a CT chest. However, this condition is difficult to achieve due to extreme negative pressure and severe pain during thoracentesis. In our study, a lung was considered entrapped if: (1) Extreme negative pleural pressure (< -10 cm H2O) was recorded. (2) High pleural elastance (> 20 cm H2O/liter) was noted during the procedure. (3) Severe chest pain occurred during the procedure.

Definitive Intervention: Based on pleural manometry and CT chest findings, patients were offered therapeutic options such as therapeutic thoracentesis, indwelling pleural catheter [IPC], pleural pigtail catheter, ICD placement, or pleurodesis. No further intervention was performed if there was no symptomatic relief after drainage. A 16F pleural pigtail was used for long-term drainage. Patients were followed up after 1 month for a definitive entrapped or expandable lung diagnosis.

Statistical Analysis: The data were entered into Microsoft Excel and analyzed using R software version 4.2.0. Quantitative data were summarized using means, standard deviation, median, and interquartile range [IQR]. Statistical analyses included the Chi-square test, t-tests for means, and t-tests for proportions for quantitative data. The diagnostic performance of pleural elastance and the absence of the sinusoidal sign were evaluated using parameters such as Sensitivity, Specificity, Positive Predictive Value [PPV], Negative Predictive Value [NPV], and Likelihood Ratios [positive and negative]. Receiver Operating Characteristic [ROC] curve analysis was performed, and Area Under the Curve [AUC] values were calculated for each parameter. The cutoff value of pleural elastance to predict an entrapped lung was determined using the Youden method. A significance level of $p < 0.05$ was considered statistically significant.

**Results**

41 patients with lung mass and suspected/proven moderate to massive malignant pleural effusion were included in the study. A total of 11 patients were ineligible for the study

[transudate effusion or cytology negative for malignancy (n=7), loss to follow-up (n=2), multiloculated effusion (n=1) and hemodynamically unstable (n=1)]. A total of 30 patients with lung malignancy with malignant pleaural effusion were enrolled in the study.

Thirty patients, with 24 males (80%) and 6 females (20%), aged 63.7 years on average (SD ±10.3, range 34-87 years), were enrolled. Adenocarcinoma was the predominant lung malignancy (70%), followed by squamous cell carcinoma (17%) and small cell carcinoma (13%). Table 1 details manometric measurements, including starting pleural pressure (Ppl), end Ppl, total drained fluid, and pleural elastance (PEL) before drainage. The sinusoidal sign was absent in 11 patients, who had a mean pleural elastance of 27.76 (±7.5 $p<0.005$). In contrast, the mean pleural elastance was significantly lower in the 19 patients who exhibited a positive sinusoidal sign (Table 2). A cutoff PEL value of 13.6 cm $H_2O$/liter predicted lung entrapment with 100% sensitivity, 93% specificity, and a 100% positive predictive value, and 84.2 % negative predictive value (Tables 3 and 4). Fourteen patients had nonexpendable or entrapped lungs, with an absent sinusoidal sign showing 78.6% sensitivity, 100% specificity, and 90% accuracy (OR 108.4, $p<0.005$). ROC curves (Figure 3) showed PEL's high predictive value (AUC=0.99) for entrapped lung.

Based on manometry and CT findings, different interventions were performed. Further interventions were avoided in 9 out of 14 patients with entrapped lung. Five had relief in dyspnea with thoracentesis, so further standard recommended interventions were followed, including repeated thoracentesis or placement of an indwelling pleural catheter [IPC] [5]. A pigtail catheter was placed in one patient instead of an IPC due to cost constraints, while four patients chose repeated thoracentesis and declined both pigtail and IPC insertion. Pleurodesis was performed in ten out of sixteen patients with expandable lung; all achieved successful outcomes without requiring repeat thoracentesis during follow-up. Among the remaining six patients with expandable lung, four had poor ECOG scores and were planned for repeated thoracentesis, while two patients declined pleurodesis and had a pigtail catheter placed instead.

**Discussion**

We enrolled 30 eligible patients, with a male predominance. The mean age was 63.7 years [SD ±10.33], with 76.6% of cases aged between 50 and 70 years, mirroring findings from similar studies [18-20].

Malignant pleural effusion [MPE] occurs in up to 40% of cases, causing breathlessness in 10-15% of patients [1]. Definitive pleural interventions like pleurodesis and IPC can be safely performed in a day-care setting following a thorough evaluation guided by post-aspiration symptoms and radiological findings [5].

During pleural manometry, initial and end pleural pressures (Ppl) ranged from -2.76 to 21.72 cm $H_2O$ and -13.6 to 9.52 cm $H_2O$, respectively, with mean values of 9.88 (±5.31) cm $H_2O$ and 0.54 (±6.49) cm $H_2O$. Study pressure ranges vary; Light et al. initially recorded -21 to 8 cm $H_2O$, dropping to -50 cm $H_2O$ post-aspiration due to various types of pleural effusion, including trapped lung cases [4]. Chopra et al. and Feller-Kopman reported similar ranges, focusing on malignant pleural effusions [21,22]. Pleural elastance (PEL) ranged from 2.18 to 40.8 cm $H_2O$/liter, mean 16.5 (±11.8) cm $H_2O$/liter, consistent with prior studies [21,22]. A PEL cutoff of 13.6 cm $H_2O$/liter predicted lung entrapment with 100% sensitivity, 93% specificity, and high predictive values, supported by an ROC AUC of 0.99 [17,22]. Salamonsen et al. noted lower sensitivity (40%) with a higher PEL cutoff (19 cm $H_2O$/liter) and an AUC of 0.69, attributed to differing effusion etiologies [17]. Historical studies cited varying PEL cutoffs (14-15 cm $H_2O$/liter vs. 19-24 cm $H_2O$/liter) influenced by study populations [8,15,22]. Our study focused on cytology-proven MPE cases, excluding para-malignant effusions [22].

The sinusoidal sign was absent in near 40% (11) of patients. Absent sinusoidal sign correlated with higher mean PEL (27.76 ± 7.5 cm $H_2O$/liter) compared to its presence (10.07 ± 8.5 cm $H_2O$/liter, $p<0.005$), indicating potential lung entrapment with elevated PEL values. Absence of the sinusoidal sign showed 78.6% sensitivity, 100% specificity, and high predictive values (PPV 100%, NPV 84.2%, accuracy 90%) with an odds ratio of 108.4 ($p<0.005$) for predicting entrapped lung. Salamonsen et al. [17] reported lower sensitivity (50%) and near similar specificity (87.5%) in their study on MPE patients with expandable lung, possibly due to the inclusion of non-pulmonary malignancy-related MPEs [17]. Definitive treatment of MPE in our study relied on manometry and post-aspiration radiology. Standard recommended treatments were followed, including repeated thoracentesis or placement of an indwelling pleural catheter (IPC) if thoracentesis relieved dyspnea [5].

Performing lung ultrasound (LUS) before thoracentesis is considered standard of care. By adding sinusoidal sign screening to routine LUS, one can predict potential future management strategies during the first thoracentesis, minimizing the number of future interventions and hospital stay or visits. Therefore, LUS should be practiced in all suspected MPE patients. While pleural manometry is more accurate, screening for the sinusoidal sign can also predict entrapped lung with good accuracy.

The limitations of this study include a small sample size, which restricts the generalizability of the findings to all MPE patients. Using a pressure transducer with an electric cardiac monitor for pleural pressure measurement needs to be validated, necessitating further research for confirmation. We used a pressure transducer with an invasive pressure monitor, which is time-consuming (around 30 to 40 minutes) and a complex procedure; alternatively, a digital pleural manometer can be used as it is easy to use and time-consuming. A single observer performed lung ultrasound without addressing interobserver variability. One limitation of our study is the broad inclusion criteria for patients with entrapped lung, which may result in lower-than-expected elastance values. Consequently, the predictive elastance value may have lower specificity and could lead to the inclusion of patients without true lung entrapment.

**Conclusions**

Absent sinusoidal sign in lung ultrasound and raised pleural elastance in pleural manometry (>13.6 cm H2O/liter) during the thoracentesis can accurately predict an entrapped lung. Pleural manometry is a more confirmatory tool and can predict expandable and entrapped lung with better sensitivity. The routine use of lung ultrasound and pleural manometry can aid in the optimal management of moderate to massive malignant pleural effusions and assist in determining the appropriate timing for pleural interventions. Further studies are needed to evaluate these parameters and establish the threshold for pleural elastance in manometry.

**References**


1. Porcel JM, Gasol A, Bielsa S, et al. Clinical features and survival of lung cancer patients with pleural effusions. Respirology 2015;20:654-9.
2. Mongardon N, Pinton-Gonnet C, Szekely B, et al. Assessment of chronic pain after thoracotomy: a 1-year prevalence study. Clin J Pain 2011;27:677-81.
3. Johnston WW. The malignant pleural effusion: a review of cytopathologic diagnoses of 584 specimens from 472 consecutive patients. Cancer 1985;56:905-9.
4. Ost DE, Niu J, Zhao H, et al. Quality gaps and comparative effectiveness of management strategies for recurrent malignant pleural effusions. Chest 2018;153:438-52.
5. Feller-Kopman DJ, Reddy CB, De Camp MM, et al. Management of malignant pleural effusions. An official ATS/STS/STR clinical practice guideline. Am J Respir Crit Care Med 2018;198:839-49.
6. Antony VB, Loddenkemper R, Astoul P, et al. Management of malignant pleural effusions. Am J Respir Crit Care Med 2000;162:1987-2001.
7. Naito T, Satoh H, Ishikawa H, et al. Pleural effusion as a significant prognostic factor in non-small cell lung cancer. Anticancer Res 1997;17:4743-6.
8. Lan RS, Lo SK, Chuang ML, et al. Elastance of the pleural space: a predictor for the outcome of pleurodesis in patients with malignant pleural effusion. Ann Intern Med 1997;126:768-74.
9. Wong A, Patail H, Ahmad S. The absent sinusoid sign. Ann Am Thorac Soc 2019;16:506-8.

10. Taghizadeh N, Fortin M, Tremblay A. US hospitalizations for malignant pleural effusions: data from the 2012 national inpatient sample. Chest 2017;151:845-54.
11. Roberts ME, Neville E, Berrisford RG, et al. Management of a malignant pleural effusion: British Thoracic Society pleural disease guideline 2010. Thorax 2010;65:32-40.
12. Huggins JT, Sahn SA, Heidecker J, et al. Characteristics of trapped lung: pleural fluid analysis, manometry, and air-contrast chest CT. Chest 2007;131: 206-13.
13. Hu K, Chopra A, Huggins JT, Nanchal R. Pleural manometry: techniques, applications, and pitfalls. J Thorac Dis 2020;12:2759-70.
14. Martin GA, Tsim S, Kidd AC, et al. Pre-EDIT: a randomized feasibility trial of Elastance-Directed intrapleural catheter or talc pleurodesis in malignant pleural effusion. Chest 2019;156:1204-13.
15. Light RW, Jenkinson SG, Minh VD, George RB. Observations on pleural fluid pressures as fluid is withdrawn during thoracentesis. Am Rev Respir Dis 1980;121:799-804.
16. Feller-Kopman D. Therapeutic thoracentesis: the role of ultrasound and pleural manometry. Curr Opin Pulm Med 2007;13:312-8.
17. Salamonsen MR, Lo AK, Ng AC, et al. Novel use of pleural ultrasound can identify malignant entrapped lung prior to effusion drainage. Chest 2014;146:1286-93.
18. Singh N, Agrawal S, Jiwnani S, et al. Lung cancer in India. J Thorac Oncol 2021;16:1250-66.
19. Mohan A, Garg A, Gupta A, et al. Clinical profile of lung cancer in North India: A 10-year analysis of 1862 patients from a tertiary care center. Lung India 2020;37:190-7.
20. Malik PS, Sharma MC, Mohanti BK, et al. Clinico-pathological profile of lung cancer at AIIMS: A changing paradigm in India. Asian Pac J Cancer Prev 2013;14:489-94.
21. Feller-Kopman D, Walkey A, Berkowitz D, Ernst A. The relationship of pleural pressure to symptom development during therapeutic thoracentesis. Chest 2006;129:1556-60.
22. Chopra A, Judson MA, Doelken P, et al. The relationship of pleural manometry with post thoracentesis chest radiographic findings in malignant pleural effusion. Chest 2020;157:421-6.

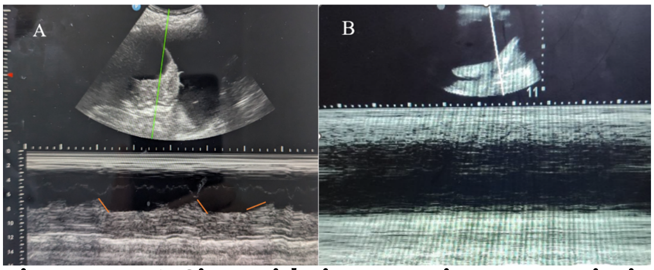

**Figure 1. A) Sinusoid sign, respiratory variation of atelectatic lung; B) absent sinusoid sign, No respiratory variation because of entrapped lung.**

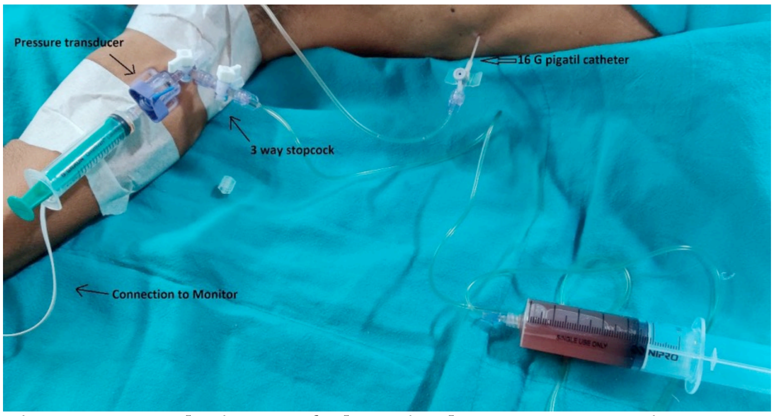

**Figure 2. Technique of electrical manometry via a pressure transducer.**

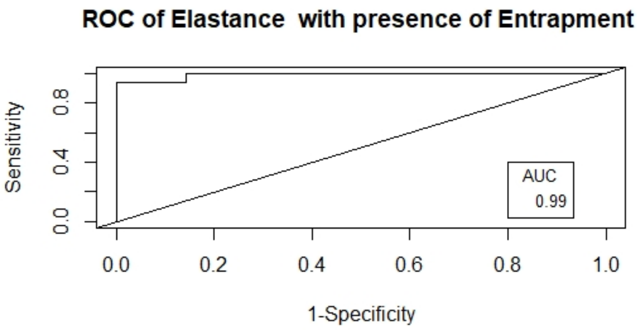

**Figure 3. ROC of fluid drainage with presence of lung entrapment.**

**Table 1. Different descriptive values observed during manometry in the study population.**

| Statistical measures | Starting Ppl [cm $H_2O$] | End Ppl [cm $H_2O$] | PEL [cm $H_2O$/litre] | Fluid drained [liter] |
|---|---|---|---|---|
| Mean | 9.88 | 0.54 | 16.56 | 0.84 |
| Median | 9.52 | 2.04 | 12.24 | 0.75 |
| Mode | 12.24 | 5.44 | 6.80 | 1.00 |
| Standard Deviation | 5.31 | 6.49 | 11.79 | 0.58 |
| Minimum | -2.72 | -13.60 | 2.18 | 0.15 |
| Maximum | 21.76 | 9.52 | 40.80 | 2.50 |

**Table 2. Relation between sinusoidal sign and PEL.**

| Characteristic | Sinusoidal sign [-] [n=11] | Sinusoidal Sign [+] [n=19] | p | Statistical test used |
|---|---|---|---|---|
| PEL [cm H2O/ litre] | 27.76 [±7.5] | 10.07 [±8.5] | 0.00001 | t-test for means |

**Table 3. Cut-off value of pleural elastance to predict Lung entrapment by the Youden method.**

| Variable | Cut off value of PEL to predict lung entrapment |
|---|---|
| Sensitivity | 1 |
| Specificity | 0.93 |
| PPV | 0.93 |
| NPV | 1 |
| Optimal criterion | 0.93 |
| Cut off [cm $H_2O$/litre] | 13.6 |

**Table 4. Odds ratio and accuracy of absent sinusoidal sign in the prediction of lung entrapment.**

| Variable | No | Sensitivity [95% CI] | Specificity [95% CI] | PPV [95% CI] | NPV [95% CI] | Accuracy | Odds ratio [95% CI] | p |
|---|---|---|---|---|---|---|---|---|
| **Absent sinusoidal sign** | 11 | 78.57 [49.2-95.3] | 100 [79.4-100] | 100 | 84.2 [66.2-93.6] | 90 [73.5-97.9] | 108.4 [5.1-2306] | 0.0027 |