

# Comparing Point-Of-Care Ultrasound Versus CT scan for Pleural Effusion Detection in The Emergency Department of Baghdad Teaching Hospital

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**Abstract** This study evaluated the diagnostic accuracy of ultrasound versus CT scans in diagnosing pleural effusion across 53 patients, incorporating demographic data, medical histories, and diagnostic outcomes. Ultrasound demonstrated a sensitivity of 95.31%, a specificity of 90.48%, a Positive Predictive Value (PPV) of 93.85%, a Negative Predictive Value (NPV) of 92.68%, and an overall accuracy of 93.40%. In the comparative analysis of for characterizing pleural effusion, ultrasound significantly outshone CT in detecting septations or debris, boasting a 100% detection rate against CT's 25%, a disparity underscored by a p-value of 0.007, highlighting ultrasound's superior diagnostic sensitivity for these features. In contrast, for loculation detection, CT demonstrated a higher efficacy with a 100% detection rate, surpassing ultrasound's 66.7%. However, this apparent advantage of CT did not translate into a statistically significant difference, as indicated by a p-value of 0.455, suggesting that the practical difference between the two modalities might be less critical than it appears, potentially due to sample size constraints or the variable nature of loculations. The results obtained demonstrates that in a resource-constrained emergency department setting in Baghdad, point-of-care ultrasound (POCUS) is a highly accurate and feasible tool for diagnosing pleural effusion. It exhibits excellent sensitivity, specificity, and overall diagnostic accuracy comparable to CT scans. Additionally, POCUS offers the advantages of rapid, bedside diagnosis and avoids the radiation exposure associated with CT scans.



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## 1. INTRODUCTION

The pleura, often described as a simple two-layered membrane, plays a remarkably complex and crucial role in facilitating optimal respiration and protecting the lungs <sup>(1)</sup>. As a bridge between the lung tissue and the thoracic cavity, it orchestrates smooth lung movement, maintains essential pressure gradients, and acts as a barrier against infections and external threats <sup>(2)</sup>. Understanding the intricate structure and functions of the pleura illuminates its multifaceted nature and highlights its critical contribution to pulmonary health, while also revealing its susceptibility to various pathological processes <sup>(3)</sup>.

The pleura consists of two distinct layers: the visceral pleura, seamlessly adhering to the lung surface, and the parietal pleura, lining the inner thoracic wall <sup>(4)</sup>. These layers merge seamlessly at the hilum, creating a continuous sac <sup>(5)</sup>. A potential space exists between them, known as the pleural cavity, which houses a small amount of lubricating fluid (around 8ml per side) <sup>(6)</sup>. This fluid, similar in composition to interstitial fluid, minimizes friction during breathing, enabling smooth lung expansion and contraction <sup>(5)</sup>.

Under physiological conditions, a finely tuned interplay exists between:

- **Fluid production:** Primarily from capillaries in the parietal pleura, occurring at a rate of approximately 0.01 mL/kg/h <sup>(7)</sup>.
- **Fluid removal:** Achieved through lymphatic stomata at a significantly higher capacity (0.20 mL/kg/h), ensuring minimal pleural fluid volume for lubrication <sup>(7)</sup>.

Pleural effusions can be broadly categorized based on the underlying pathophysiology and fluid characteristics:

- ✚ **Transudates:** Result from systemic factors altering hydrostatic or osmotic pressures across intact capillary membranes, often without direct pleural injury <sup>(7)</sup>. Examples include congestive heart failure, where increased hydrostatic pressure drives fluid into the pleural space.
- ✚ **Exudates:** Arise from increased capillary permeability due to localized inflammation, infection, or malignancy within the pleura or adjacent tissues <sup>(7)</sup>. These conditions damage capillary integrity, allowing protein-rich fluid to accumulate.



The classification of pleural effusions into exudates or transudates is essential for guiding clinical management, hinging on the analysis of pleural fluid's protein and lactate dehydrogenase (LDH) levels. According to Light's criteria, an effusion is categorized as an exudate if it satisfies one or more of the following benchmarks: a pleural fluid protein to serum protein ratio exceeding 0.5, a pleural fluid LDH to serum LDH ratio above 0.6, or a pleural fluid LDH level surpassing two-thirds of the serum's upper normal limit. Transudates do not meet any of these criteria, indicating a different pathophysiological origin and clinical approach<sup>(10,11)</sup>.

Pleural effusion, an accumulation of fluid in the pleural space, represents a significant global health care challenge with varied prevalence, causes, and burdens on health systems. According to Tian et al. (2021)<sup>(12)</sup>, in China, pleural effusions among hospitalized adults indicate a considerable prevalence and diverse etiology, underscoring the condition's substantial health care burden in a large population. Their findings suggest the need for heightened awareness and improved diagnostic and management strategies to address the multifaceted causes of pleural effusions, ranging from infections to malignancies and other non-infectious conditions.

Similarly, in the United States, pleural effusions, particularly malignant pleural effusions, have been highlighted by Taghizadeh, Fortin, and Tremblay (2017)<sup>(13)</sup> as a significant reason for hospitalizations, with data from the 2012 National Inpatient Sample showcasing the extensive health care utilization and the associated costs. This emphasizes the condition's impact not only from a clinical perspective but also in terms of health care expenditures and resource allocation. Moreover, the emergence of COVID-19 has introduced new complexities in the epidemiology of pleural effusion. Chong et al. (2021)<sup>(14)</sup> reviewed the incidence of pleural effusions in patients with COVID-19 pneumonia, adding a contemporary layer to the condition's epidemiology by highlighting the pandemic's role in exacerbating the occurrence of pleural effusions.

This evolving landscape underscores the importance of continuous research and adaptation of health care strategies to manage pleural effusions effectively, considering the broad spectrum of causes and the dynamic nature of emerging health threats. Pleural effusions manifest with a spectrum of symptoms and physical findings that significantly impact patient health and quality of life<sup>(15)</sup>. These features can be influenced by the underlying cause, volume of fluid, and rate of accumulation.

#### **contribution of the Study are The determination of:**

The sensitivity and specificity of POCUS in diagnosing pleural effusions compared to CT scans in the emergency department setting.

The feasibility and practicality of implementing ultrasound as the primary imaging modality for pleural effusion in

emergency departments in Baghdad, considering local resource availability and clinical needs.

This study was conducted at the Emergency department of Baghdad Teaching Hospital in Medical city complex from August 2023 to December 2023. Patients presenting to the ED with suspected non-traumatic pleural effusion underwent both POCUS and chest CT. POCUS examinations were performed by trained emergency medicine physicians using a handheld ultrasound device. Chest CT scans were independently interpreted by radiologists. The diagnostic accuracy of POCUS for effusion presence, characteristics was compared to CT as the reference standard. The impact of each modality on clinical decision-making was also assessed.

## **2. POINT-OF-CARE ULTRASOUND (POCUS)**

Compared to other imaging techniques, POCUS boasts several key advantages in the context of pleural effusions are Accessibility and portability, no ionizing, radiation, cost-effectiveness and real-time visualization.

Ultrasonography provides prompt, accurate, radiation free, real-time point-of-care imaging. Pleural ultrasound performs better than chest radiographs and is comparable to computed tomography (CT) scans in the assessment of pleural diseases in ambulatory and critically ill patients.<sup>(16, 17)</sup> The portable nature of modern ultrasound machines allows easy bedside examinations and contributes to its growing popularity.

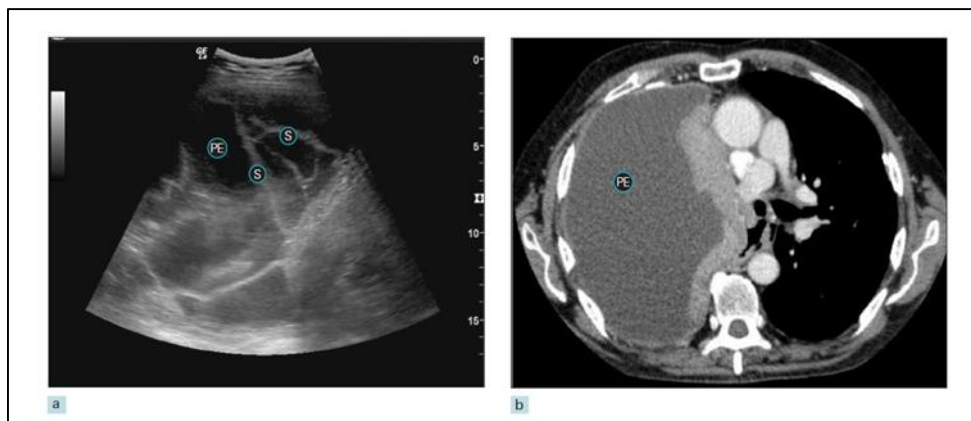
As much as 500 ml of pleural fluid may be present without blunting of the lateral costophrenic angle, and large effusions may be missed on a supine radiograph, as the pleural fluid layers posteriorly.<sup>(18)</sup> A loculated pleural effusion, on the other hand, may occasionally be mistaken for a solid tumor on chest radiograph. Ultrasound can separate fluid from both consolidation and atelectasis. Pleural ultrasound thus improves the yield and safety of thoracentesis in effusions, particularly in small or complex collections.<sup>(19,20,21)</sup>

## **3. THORACIC ULTRASOUND IN DETECTING SEPTATION.**

Septations are areas of fibrin within a single pleural fluid collection that partially and completely divide a single collection into many different "pockets" of fluid. This is not the same as loculation, in which there are multiple separate collections of fluid in different geographical areas of the pleural space. Whereas a 3D imaging modality (such as computed tomography (CT) or magnetic resonance imaging (MRI)) is preferred for the detection and definition of loculations, septations are exquisitely demonstrated on ultrasound and may be visible on MRI, but are in general not seen directly (only implied) on CT. Septations are demonstrated on thoracic ultrasound as linear areas dividing pleural fluid, and may be thin and very light in echogenicity or thicker and heavier.

The early septations tend to be easily deformed as a result of pleural fluid movement, whereas advanced and extensive septations are less so. Furthermore, when extensive septation is evaluated using ultrasound, as illustrated in (Figure 1), no septation is evident when compared to the CT scan of the same patient. Any effusion that is present for a prolonged period may become septated (including transudates), but their presence is

particularly associated with longstanding or previously intervened upon malignant effusions, and in infected pleural collections. There is some early evidence that the presence of sonographic septations may be associated with the need for surgical intervention during treatment for pleural infection, but these findings have not as yet been confirmed in a prospective study.<sup>(22,23,24)</sup>



**Figure 1.** A patient with a right malignant pleural effusion. (a) Multiple septations (S) in pleural effusion (PE) are easily seen on pleural ultrasonography. (b) CT thorax of the same patient with no evidence of septations (PE = pleural effusion).<sup>(25)</sup>

#### 4. PATIENT AND METHODOLOGY

A cross-sectional prospective study of 53 patients was conducted in the emergency department of Baghdad Teaching Hospital - Medical City Complex, spanning from August 2023 through December 2023. The study focused on in-hospital patients with suspected pleural effusion. While data collection days were selected based on convenience, care was taken to ensure a representative sample within the specified timeframe.

##### 4.1 Inclusion Criteria:

**Non-Traumatic Pleural Effusion:** Patients admitted due to pleural effusion that is not caused by trauma.

##### 4.2 Exclusion Criteria:

1. Age Limitation: Individuals younger than 14 years old.
2. Trauma Patients: Patients whose pleural effusion is a result of trauma.
3. Pregnancy: Pregnant patients, due to potential radiation risks.
4. Morbid Obesity: Patients classified as morbidly obese, as obesity may complicate the assessment and management of pleural effusion.
5. Local Skin Infection: Presence of cellulitis or any skin infection around the area intended for ultrasound examination, which could interfere with diagnostic procedures or pose a risk of spreading infection.

##### 4.3 How POCUS was performed:

The POCUS (Point of Care Ultrasound) examination protocol is meticulously designed to ensure optimal imaging of pleural effusion, conducted bedside in the emergency department. The importance of patient positioning is for enhancing ultrasound diagnostic efficacy.

##### 4.3.1 For Ambulatory Patients:

For optimal pleural visualization during the ultrasound examination, the patient is seated, preferably on the edge of a bed, and instructed to lean slightly forward, using a pillow on their lap for additional support. This positioning is complemented by guiding the patient to protract their scapulae, thereby minimizing obstruction, and establishing an ideal posture for the ultrasound probe to access and visualize the pleura effectively.

##### 4.3.2 For Less Mobile or Unconscious Patients or unstable:

Given the gravitational distribution of fluid, a supine position is not favorable for pleural effusion assessment. Thus, such patients are gently rolled into a lateral decubitus position and supported posteriorly with pillows or positioning pads to facilitate access to the pleural space. This adjustment allows the ultrasound probe to access the lateral and posterolateral aspects of the uppermost hemithorax efficiently, aiding in precise diagnostic and intervention guidance.

##### 4.4 Ultrasound Probe Placement:

The probe is placed in a vertical/longitudinal orientation (parasagittal plane) for examining the anterior and posterior

thorax, and in a coronal plane for the lateral thorax. This procedure is performed bilaterally to ensure comprehensive pleural assessment.

Convention dictates the probe marker be directed towards the patient's head. The ultrasound screen's orientation marker is positioned in the upper left corner, with the transducer marker pointing cephalad (towards the head). By sliding the transducer longitudinally along the anterior, lateral, and posterior chest walls, near-complete visualization of the pleura is achievable, enhancing the diagnostic process.

#### 4.5 Devices used:

In this research, three advanced portable ultrasound devices were utilized, each notable for its specific features enhancing bedside high-definition imaging capabilities:

##### 1. **Clarius Phased Array (PA) HD2 (Clarius Mobile Health, Canada):**

A wireless, app-based, as shown in handheld high-definition scanner tailored for cardiac imaging yet adaptable for lung ultrasounds, FAST exams, abdominal, bladder, superficial examinations, and obstetrics and gynecology assessments. Its unique piezo-electric crystal technology and octal beamforming provide up to eight times faster frame rates compared to conventional hospital ultrasound systems.

##### 2. **Butterfly iQ+ (Butterfly Network Inc., Burlington, MA, USA):**

Distinct from traditional systems that use piezoelectric crystals, this innovative portable ultrasound system utilizes non-

piezoelectric Ultrasound-on-Chip technology, featuring a comprehensive 2D array of 9,000 micro-machined sensors. It connects seamlessly to an iPad Pro, providing a multifaceted tool for high-quality imaging across a spectrum of clinical scenarios, including FAST exams for abdominal evaluations and pulmonary assessments. Uniquely, the Butterfly iQ+ as shown in (figure 2.4) boasts a single probe that integrates linear, curved, and phased array capabilities, enhancing its versatility and application in various diagnostic contexts.

##### 3. **SonoHeart Elite (SonoSite, Bothell, WA, USA):**

Manufactured in 2002, the SonoHeart Elite as shown in (figure 2.) stands as a testament to enduring utility in ultrasound technology. Despite its age, this device excels in providing exceptional visualization of pleural effusion. It is equipped with a phased array probe that utilizes piezoelectric crystals, ensuring detailed and accurate imaging even by today's standards. This feature underscores the device's capability to deliver high-quality diagnostic images, particularly beneficial in evaluating pleural conditions.

Each device was operated using its standard factory settings, with imaging presets selected to suit the examination type—whether for cardiac, pulmonary, or other specialized assessments. This standardized approach helped ensure consistent quality and accuracy in diagnostic imaging across various medical evaluations.

All devices employed in this study utilize room temperature **Aquasonic 100 Ultrasound Transmission Gel** to enhance image quality during ultrasound examinations.



**Figure 2.** Clarius Phased Array (PA) HD2 (Clarius Mobile Health, Canada)





Figure 3. SonoHeart Elite (SonoSite, Bothell, WA, USA)



Figure 4. Butterfly iQ+ (Butterfly Network Inc., Burlington, MA, USA)

#### 4.6 Ultrasound report and CT scan report format

After the ultrasound examination, the report identifies the presence of pleural effusion, any septation or loculation, and the occurrence of swirling debris. Subsequently, patients are recommended for a confirmatory chest CT scan to corroborate the ultrasound findings. The ultrasound assessment specifically aims to establish whether pleural effusion exists and to document any floating debris, septation, or loculation observed during the examination.

#### 4.7 Study data collection:

The questionnaire for the study was developed collaboratively by the researcher and their supervisor, comprising four distinct sections. The initial section gathers sociodemographic data, including gender, age, occupation, and marital status. The subsequent section delves into the patient's medical background, detailing the reason for admission, previous medical history, and vital signs. The third segment focuses on

radiological findings, while the final part addresses various investigations conducted as part of the study.

#### 4.8 Statistical Analysis:

Data was introduced into Microsoft Excel® for Microsoft 365 and then transferred to SPSS (Statistical Package for Social Sciences) version (20) for analysis. Parametric data are shown as means and standard deviations, while categorical data are displayed as frequencies and percentages. A p-value of less than 0.05 was considered indicative of statistical significance.

### 5. RESULTS

The research involved 53 patients diagnosed with non-traumatic pleural effusion. The subsequent section will analyze the findings obtained from this data.

#### 5.1- Age Analysis and Distribution:

The age of patients with pleural effusion in the dataset ranges from (16 – 88) years, with a mean age of approximately 58.75

years with standard deviation of around 17.06 years as shown in figure (5.)

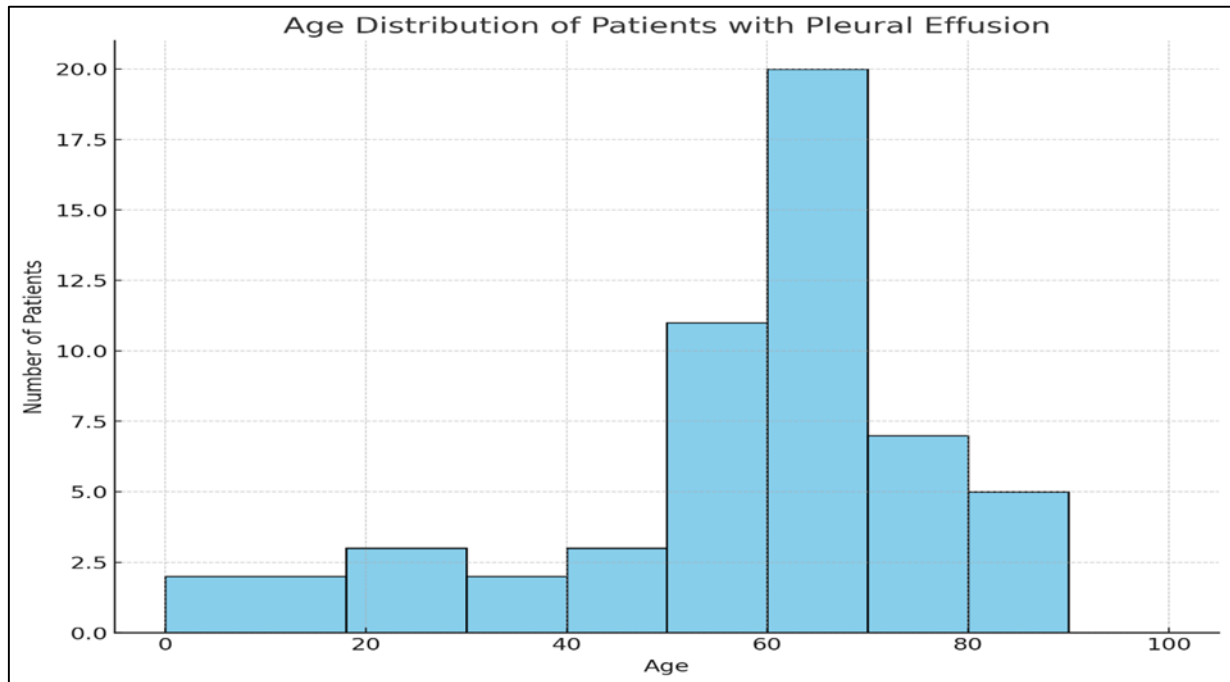


Figure 5. the age distribution of patients with pleural effusion.

### 5.2- Gender Distribution:

The analysis of the dataset highlights a remarkably balanced gender distribution, with males representing approximately 50.94% (27 patients) and females accounting for 49.06% (26 patients) as shown in (figure 6.).

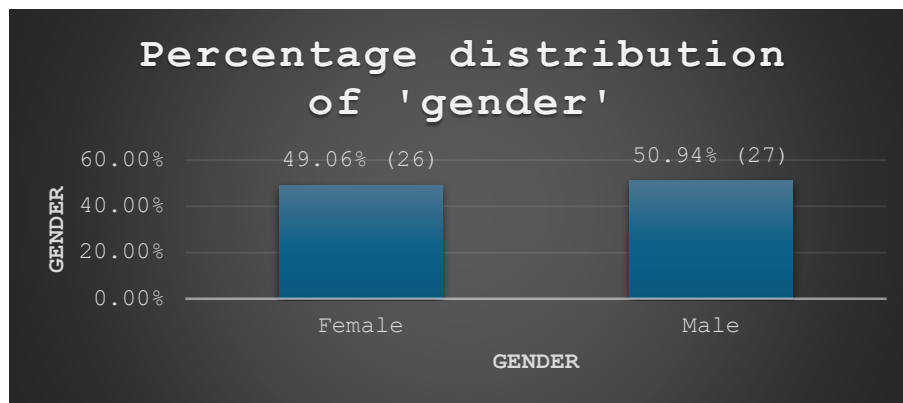


Figure 6. Gender distribution of patients

#### 5.2.1 Admission Cause Analysis

This study evaluated the presenting complaints of 53 patients diagnosed with pleural effusion to identify patterns and frequencies of symptoms associated with the condition. The findings reveal a diverse range of symptoms as shown in (Table 1.), with shortness of breath being the most prevalent

complaint, reported by 90.57% of the patients. Contrastingly, chest pain and cough were less frequently reported, with prevalences of 11.32% and 28.3%, respectively. Fever was present in 30.19% of the cases, highlighting the association between pleural effusion and infectious or inflammatory processes.

Table (1.) Frequencies of Admission Causes

Presenting complaints	Frequency, N=53	Percentage (%)
<b>Shortness of breath</b>		
Present	48	90.57%



Absent	5	9.43%
<b>Chest pain</b>		
Present	6	11.32%
Absent	47	88.68%
<b>Cough</b>		
Present	15	28.3%
Absent	38	71.7%
<b>Fever</b>		
Present	16	30.19%
Absent	37	69.81%
<b>Decreased oral intake</b>		
Present	9	16.98%
Absent	44	83.02%
<b>Altered mental status</b>		
Present	3	5.66%
Absent	50	94.34%
<b>Hemoptysis</b>		
Present	5	9.43%
Absent	48	90.57%
<b>Weight loss</b>		
Present	9	16.98%
Absent	44	83.02%

### 5.2.2 Past Medical Status of Patients

The dataset provides an overview of the prevalence of various comorbid conditions among a cohort of 53 patients diagnosed with pleural effusion. It is observed that Diabetes Mellitus (DM) and Hypertension are the most common comorbidities, each affecting 45.28% of the patients. Additionally, chronic kidney disease (CKD) is present in 33.96% of the cohort, while

Heart Failure is observed in 35.85% of the patients. A further breakdown of the data indicates the presence of other significant conditions, such as ischemic heart disease (IHD) and malignancy, in 22.64% and 18.87% of the patients, respectively. Tuberculosis (TB) is identified in 5.66% of the cohort, with less prevalent conditions including esophageal varices, Hepatitis B Virus (HBV), and cerebrovascular accidents (CVA), each found in 1.89% of the patients.

Table 2. The Frequency of Different Comorbidities Observed in This Study.

Comorbidity		no	Prevalence (%)
Negative		6	11.32%
Yes	Diabetes Mellitus (DM)	25	45.28
	Hypertension	26	45.28
	Chronic Kidney Disease (CKD)	18	33.96
	Heart Failure	19	35.85
	Ischemic Heart Disease (IHD)	12	22.64
	Malignancy	8	18.87
	Tuberculosis (TB)	3	5.66
	Esophageal Varices	1	1.89
	Hepatitis B Virus (HBV)	1	1.89

	Cerebrovascular Accidents (CVA)	1	1.89
<b>Total = 53</b>			
<b>Note: past medical history percentage is more than 100% because of overlaying of more than one disease for each patient.</b>			

### 5.3.1 Type of Transducer Used

The bar chart (figure7.) below illustrates the distribution of transducer types used in the diagnosis or treatment of pleural

effusion among patients. SonoSite transducers are the most used, accounting for approximately 39.62% of cases. Butterfly iQ+ follows closely at 33.96%, with Clarius transducers being used in 26.42% of the cases.

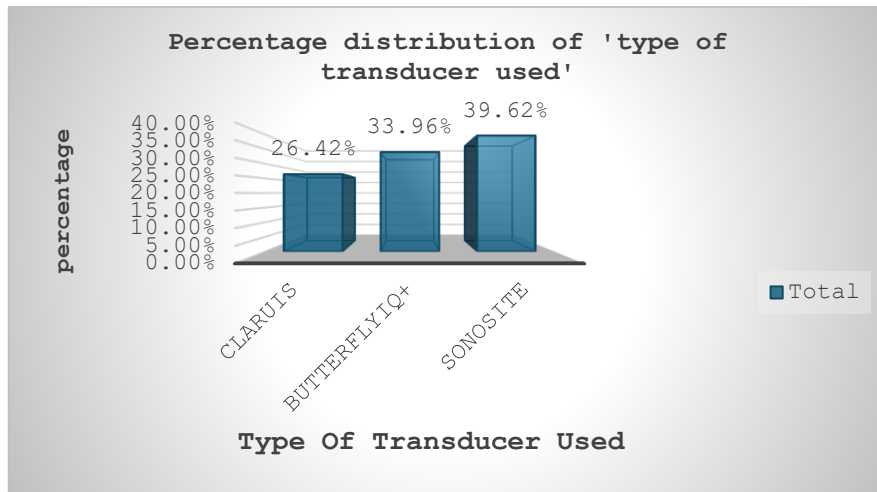


Figure 7. shows the percentage of distribution of transducer types used.

### 5.3.2 Site of Pleural Effusion Distribution and Percentage

The distribution of pleural effusion locations among the 53 patients shows a preference for right-sided effusions, with 23

cases (43.4%) occurring on the right side. This is followed by 18 cases (34%) of left-sided effusions and 12 cases (22.6%) of bilateral effusions, where the condition is present on both sides.

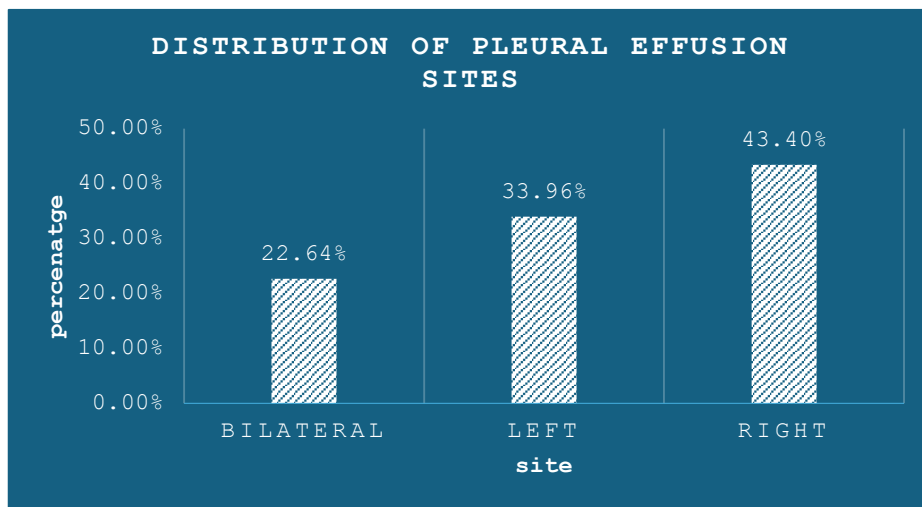


Figure 8. distribution of pleural effusion sites.

### 5.4 Diagnostic Performance of Point-of-Care Ultrasound



A total of 106 lungs (53 patients) were evaluated. Compared to CT as gold standard, the following diagnostic parameters were determined:

- True Positives (TP): 61
- False Positives (FP): 4
- True Negatives (TN): 38
- False Negatives (FN): 3

Ultrasound had a sensitivity of 95.31%, specificity of 90.48%, Positive Predictive Value (PPV) of 93.85%, Negative Predictive Value (NPV) of 92.68% and overall accuracy of 93.40%; as shown in table (3.).

**Table 3 Accuracy of ultrasound in the detection of pleural effusion.**

Ultrasound	CT		Total
	Positive	Negative	
Positive	61 (TP)	4 (FP)	<b>65</b>
Negative	3 (FN)	38 (TN)	<b>41</b>

### 5.5 Practical utility of ultrasound and CT in the detection of pleural effusion characteristics

To further characterize pleural effusion detected in the study population, a detailed analysis of specific features (loculations, septations, and debris) was conducted using both ultrasound and CT imaging.

#### 5.5.1 Loculation

Of the 6 exams where loculations were present, ultrasound successfully detected these features in 4 cases (66.7% detection rate). CT demonstrated a higher detection rate for loculations, identifying them in all 6 cases (100%). Statistical analysis of

the difference in detection rates between the two modalities yielded a p-value of 0.455, indicating no statistically significant difference.

#### 5.5.2 Septation or Debris

When evaluating septations or debris, ultrasound detected these characteristics in all 8 relevant cases (100% detection rate). CT detected septations or debris in a significantly lower number of cases, only 2 instances out of 8 (25.0% detection rate). This difference highlights ultrasound's superior performance in visualizing septations or debris, as illustrated by the statistically significant p-value of 0.007.

**Table 4. pleural effusion characteristics analysis**

Pleural effusion characteristics	Ultrasound	CT	P value
<b>Loculation (N= 6)</b>			
Detected	4	6	0.455
	66.7%	100.0%	
Not detected	2	0	
	33.3%	0.0%	
<b>Septation or debris (N=8)</b>			
Detected	8	2	0.007
	100.0%	25.0%	
Not detected	0	6	
	0.0%	75.0%	

#### 5.6.1 Blood pressure interpretation

The average systolic blood pressure among patients was 128.10 mmHg, with a standard deviation of 28.841 mmHg, indicating a range from 70 to 190 mmHg. This suggests variability in the cardiovascular status of patients, with some experiencing potentially hypertensive conditions (as high as 190 mmHg) and

others presenting with normal or low values (as low as 70 mmHg).

The mean diastolic blood pressure was recorded at 78.08 mmHg, with a standard deviation of 19.462 mmHg. The diastolic pressures ranged from 40 to 130 mmHg, reflecting diverse cardiovascular responses possibly due to the varying severities of pleural effusion or other comorbid conditions.



**Table 5. blood pressure parameters**

	Systolic Blood Pressure	Diastolic Blood Pressure
Mean	128.10	78.08
Std. Deviation	28.841	19.462
Minimum	70	40
Maximum	190	130

**5.6.2 Heart Rate:**

The heart rate showed a mean value of 107.37 beats per minute (bpm) and a standard deviation of 18.828 bpm, with the observed range spanning from 61 to 157 bpm. This elevated mean heart rate indicates that tachycardia is common, possibly as a compensatory mechanism to hypoxia or as a response to fever and stress.

**Table 6. heart rate parameters**

	Heart Rate
Mean	107.37
Std. Deviation	18.828
Minimum	61
Maximum	157

**5.6.3 SpO2 (Oxygen Saturation):**

Oxygen saturation had a mean value of 91.2692%, with a deviation of 6.88880%, and ranged from critically low (60.00%) to normal (100.00%). This indicates significant respiratory compromise in some patients, necessitating careful monitoring and management of oxygenation.

**Table 7. oxygen saturation parameters**

	Spo2
Mean	91.26%
Std. Deviation	6.888%
Minimum	60.0%
Maximum	100.0%

**5.6.4 Respiratory Rate:**

The mean respiratory rate was 26.85 breaths per minute, with a standard deviation of 4.118 breaths per minute, ranging between 22 and 33 breaths per minute.

**Table 8. respiratory rate parameters**

	Respiratory Rate
Mean	26.85
Std. Deviation	4.118
Minimum	22
Maximum	33

**5.6.5 Temperature:**

The average body temperature was found to be 37.10°C, with a variability (standard deviation) of 0.680°C, and a range from 36.00°C to 38.70°C. The trend towards fever (meaning temperature above the normal 37°C) could be indicative of infectious or inflammatory causes of pleural effusion, with some patients exhibiting significant febrile responses.

**Table 9. temperature parameters**

	Temperature
Mean	37.10
Std. Deviation	.68
Minimum	36.00
Maximum	38.70

**5.7 Blood investigations parameter Interpretations**

The analysis of blood parameters in the patient cohort reveals critical insights into the prevailing health conditions, particularly highlighting indicators of inflammation, infection, renal and liver function, and hematopoietic health. The interpretations of these parameters are essential for understanding the underlying pathophysiological mechanisms in patients, especially those with pleural effusion.

**5.7.1 White Blood Cell (WBC) Count**

The mean WBC count observed in the study was 11,780.38 /μL, indicating an elevated level above the normal range. This elevation suggests an ongoing inflammatory or infectious process, which is commonly seen in patients suffering from pleural effusion. The range of WBC count, extending from 4,390 to 23,000 /μL, further

emphasizes the diversity in the degree of infection or inflammation present within the patient population.

### 5.7.2 Platelet Count

The mean platelet count was recorded at  $226.75 \times 10^9/L$ , positioning it within the standard limits and indicating satisfactory hematopoietic function across the cohort. Nevertheless, the broad range observed ( $100$  to  $460 \times 10^9/L$ ) hints at potential underlying conditions that may be influencing the platelet count variability among patients.

### 5.7.3 Hemoglobin (HB)

With a mean hemoglobin level of  $10.473 \text{ g/dL}$ , the data points towards a prevalence of anemia within the cohort, as this value is slightly below the normal range for adults. This condition could be attributed to factors related to chronic disease processes or acute blood loss scenarios among the patients.

**Table 10.** investigations of patients shown. WBC: white blood cells, HB, hemoglobin.

	WBC	platelet	HB
Mean	11780.38	226.75	10.473077
Std. Deviation	4797.411	91.510	2.3876410
Minimum	4390	100	5.3
Maximum	23000	460	17.9

### 5.7.4 Blood Glucose

The mean blood glucose level among the patients was found to be  $202.73 \text{ mg/dL}$ , with a standard deviation of  $99.9 \text{ mg/dL}$ . This indicates a significant variance among the patient population, ranging from a minimum of  $85 \text{ mg/dL}$  to a maximum of  $499 \text{ mg/dL}$ . The elevated mean suggests a tendency towards hyperglycemia in the patient cohort.

**Table 11.** investigations of patients shown. ALT, AST: alanine and aspartate transaminase.

Mean	blood glucose	urea	creatinine	AST	ALT
Mean	202.73	96.98	3.98	53.33	52.43
Std. Deviation	99.9	76.62	8.80	53.63	48.41
Minimum	85	20	0.310	10.70	5.80
Maximum	499	380	63	249	236

### 5.7.5 Urea

The mean urea level was  $96.98 \text{ mg/dL}$ , with a standard deviation of  $76.62 \text{ mg/dL}$ , reflecting a wide range of kidney function status among patients. Urea levels ranged from  $20 \text{ mg/dL}$  to  $380 \text{ mg/dL}$ , highlighting some instances of severe uremia.

### 5.7.6 Creatinine

The mean creatinine level was recorded at  $3.98 \text{ mg/dL}$ , with a standard deviation of  $8.80 \text{ mg/dL}$ . The creatinine levels spanned from  $0.310 \text{ mg/dL}$  to  $63 \text{ mg/dL}$ , suggesting a broad spectrum of renal function impairment across the study population.

### 5.7.7 Aspartate Aminotransferase (AST) & Alanine Aminotransferase (ALT)

The liver function tests showed mean AST and ALT levels of  $53.33 \text{ U/L}$  and  $52.43 \text{ U/L}$ , respectively, with comparable standard deviations (AST:  $53.63 \text{ U/L}$ , ALT:  $48.41 \text{ U/L}$ ). These results indicate a moderate elevation in liver enzymes, suggesting liver

involvement or injury among some patients. The range of AST and ALT levels (AST:  $10.70$  to  $249 \text{ U/L}$ , ALT:  $5.80$  to  $236 \text{ U/L}$ ) further supports the presence of varying degrees of hepatic dysfunction.

## 6. DISCUSSION

The analysis of the age distribution of patients diagnosed with pleural effusion in our study revealed a mean age of  $58.75$  years ( $SD = 17.06$  years), encompassing a wide age range from  $16$  to  $88$  years. The median age was determined to be  $62$  years, with interquartile ranges at the  $53$ rd and  $68$ th percentiles. This distribution highlights a significant prevalence of pleural effusion among individuals in the late middle-aged to early elderly demographic, underscoring the impact of aging on the incidence of pleural effusion.

The demographic trends observed in our study align with the broader literature on pleural effusion, albeit with variations across different studies reflecting diverse etiological factors and population characteristics. For instance, Shah and Gurnani (2022) reported a markedly younger mean age of presentation



at  $6.8 \pm 3.2$  years, primarily among children under 10 years, suggesting a distinct etiological profile, such as tuberculous pleural effusion, in pediatric populations <sup>(26)</sup>. Conversely, Rahman et al. (2023) identified a mean age of  $44.5 \pm 12.86$  years in patients with exudative pleural effusion, indicating a broader age distribution that includes middle-aged adults, with a notable male predominance (male to female ratio of 2.1:1) <sup>(27)</sup>. Additionally, Saini et al. (2022) observed that the majority of patients with unilateral pleural effusion were concentrated in the (20 – 60) year age group, further illustrating the variable age distribution of pleural effusion based on its underlying causes and the demographics of the studied population <sup>(28)</sup>.

The variations in age distribution among patients with pleural effusion underscore the multifactorial nature of its etiology and the impact of demographic factors on its prevalence. While our study emphasizes the significance of pleural effusion in older adults, the comparison with other studies highlights its occurrence across a wide age spectrum, from children to the elderly. These differences necessitate a nuanced understanding of pleural effusion, tailored to the specific etiological and demographic contexts.

### 6.1 Gender Distribution and Pleural Effusion

The near-equal gender distribution observed in this study (males: 50.94%, females: 49.06%) highlights a unique finding within the context of non-traumatic pleural effusion. Several studies demonstrate a male predominance in pleural effusions, predominantly in those associated with malignancies <sup>[29,30]</sup>. In contrast, parapneumonic effusions exhibit a higher incidence in females <sup>[31]</sup>. However, our data indicates a potential lack of significant gender predilection in the overall landscape of non-traumatic pleural effusions. This balanced distribution could reflect evolving epidemiological patterns, with diminishing gender-based variations in lifestyle and occupational risk factors linked to pleural effusion <sup>[32]</sup>. Additionally, our findings potentially hint at a more gender-neutral pathophysiology in conditions like heart failure, renal disease, and pneumonia – primary drivers of non-traumatic pleural effusions <sup>[33]</sup>.

### 6.2 Analysis of Pleural Effusion Sites

The distribution of pleural effusion locations in our study cohort of 53 patients shows a notable preference for right-sided effusions, with 43.4% (23 cases) of the effusions occurring on the right side. This is closely followed by left-sided effusions at 34% (18 cases) and bilateral effusions at 22.6% (12 cases), indicating the presence of the condition on both sides. These findings are in line with the existing literature that suggests a variability in the distribution of pleural effusion depending on the underlying cause.

Our observation of a higher prevalence of right-sided pleural effusion aligns with the findings of Mood, Narayan et al. (2022), who also reported a predominance of right-sided

pleural effusion cases. This correlation may suggest a commonality in the underlying pathophysiological mechanisms or patient demographics between the two studies <sup>(66)</sup>.

The presence of bilateral pleural effusions in our study, constituting over a fifth of the cases, is also supported by literature. Строгова, H. A. (2022) reviews various diseases associated with bilateral pleural effusions, including cardiac, hepatic, and renal insufficiency, alongside inflammatory and tumor processes <sup>(67)</sup>. This broad spectrum of causes underscores the complexity of pleural effusion as a clinical finding and highlights the necessity of a comprehensive diagnostic approach.

Furthermore, the case of bilateral pleural effusion due to pleural metastasis of breast carcinoma reported by Nabou et al. (2022) illustrates the critical role of identifying the underlying etiology, as it significantly impacts the management and prognosis of patients <sup>(68)</sup>. Although our study did not specifically focus on the etiological factors leading to pleural effusion, the cited references emphasize the importance of considering both unilateral and bilateral effusions in the diagnostic evaluation.

In conclusion, our findings contribute to the growing body of evidence regarding the distribution patterns of pleural effusion, corroborating the notion that right-sided effusions are more common, yet highlighting the substantial incidence of bilateral cases. This suggests that while certain patterns may be discernible, the underlying causes of pleural effusions are diverse and multifactorial, necessitating a thorough and individualized assessment of each patient.

## 7. COMPARATIVE ANALYSIS OF DIAGNOSTIC PERFORMANCE FOR PLEURAL EFFUSION

The diagnostic accuracy of point-of-care ultrasound (POCUS) in the detection of pleural effusion, as evidenced in this study, highlights its significant utility and reliability within clinical settings. Employing computed tomography (CT) scans as the reference standard, this study has meticulously assessed POCUS across 106 lung evaluations from 53 patients. The outcomes revealed a sensitivity of 95.31%, specificity of 90.48%, positive predictive value (PPV) of 93.85%, negative predictive value (NPV) of 92.68%, and an overall accuracy of 93.40%. These metrics not only underscore the high reliability of POCUS but also its potential as an indispensable diagnostic tool in clinical practice.

This section presents a comparative analysis with existing literature to underline the evolutionary trajectory and the pivotal role of POCUS in medical diagnostics, especially for pleural effusion.



Walsh et al. (2021) <sup>(34)</sup> conducted a comparative study focusing on the accuracy of bedside ultrasound examination against physical examination for pleural effusion detection. Their findings advocate for the superiority of ultrasound, aligning with the current study's demonstration of ultrasound's enhanced diagnostic capabilities. This comparison accentuates the advancement in imaging techniques, offering a substantial improvement over conventional examination methods in diagnosing pleural effusions.

Similarly, the research by Dr. J Muraliswar Rao et al. (2019) <sup>(35)</sup> on the efficacy of ultrasonography in diagnosing pleural effusion supports the current study's conclusions. It reiterates the significance of ultrasonography, emphasizing its critical role in facilitating accurate and non-invasive diagnostic processes within clinical settings.

In the realm of specialized care, Shameek et al. (2023) <sup>(36)</sup> explored the application of POCUS in Intensive Care Units (ICUs), illustrating its utility in critical care. This study's findings parallel the broader applicability and reliability of POCUS, endorsing its integration across various medical disciplines, including the critical care environment.

The systematic review by Grimberg et al. (2010) <sup>(37)</sup> provides a historical perspective on the diagnostic accuracy of sonography for pleural effusion. It lays the groundwork for understanding the evolution of ultrasound technologies in medical diagnostics, emphasizing the consistency and reliability of these methods over time.

Lastly, Zdenek Monhart (2023) <sup>(38)</sup> highlighted the use of POCUS in internal medicine, reinforcing the current study's findings. His research supports the notion of POCUS as a transformative tool in medical diagnostics, advocating for its widespread adoption given its proven diagnostic accuracy and potential benefits in patient management.

In conclusion, the comparative analysis with existing literature underscores the diagnostic accuracy of POCUS in detecting pleural effusion, reinforcing its critical role in enhancing clinical outcomes. The alignment of this study's findings with previous research emphasizes the evolution of diagnostic methodologies, advocating for the integration of POCUS into standard diagnostic pathways. This analysis not only affirms the reliability and utility of POCUS but also highlights its potential in revolutionizing patient care across various medical settings. Further research and exploration into its applications are essential to unlock even greater benefits, solidifying POCUS's position as an indispensable asset in modern medical practice.

## 8. DISCUSSION ON ULTRASOUND'S ABILITY TO DIFFERENTIATE PLEURAL EFFUSION CHARACTERISTICS

Discussion on the Diagnostic Performance of Ultrasound and CT in Characterizing Pleural Effusion

This section provides a comparative analysis of the diagnostic capabilities of ultrasound and computed tomography (CT) in detecting specific characteristics of pleural effusion, such as loculations, septations, and debris, within the study population. The analysis is further contextualized with reference to existing literature, enhancing the understanding of the strengths and limitations of each modality in pleural effusion characterization.

Regarding loculation analysis, the study observed a 66.7% detection rate of loculations via ultrasound, with CT scan imaging demonstrating a superior detection rate of 100% in the same parameter. Despite this disparity, statistical analysis revealed no significant difference between the detection rates of the two modalities (p-value of 0.455). This outcome suggests that while ct may visually identify loculations more reliably, the difference in detection capabilities does not reach statistical significance, indicating a potential role for ultrasound in initial assessments where ct is unavailable or contraindicated.

Regarding the detection of septations or debris, ultrasound outperformed CT significantly, with a 100% detection rate compared to CT's 25%. This stark difference, supported by a statistically significant p-value of 0.007, underscores ultrasound's superior sensitivity in identifying septations or debris within pleural effusions. This finding aligns with literature suggesting ultrasound's effectiveness in visualizing pleural thickening and encysted effusions, as well as its utility in guiding management by assessing pleural fluid volume and character .

The diagnostic accuracy of ultrasound and CT in differentiating transudate from exudate in patients with pleural effusion has been a subject of extensive study. Isani et al. (2023) <sup>(39)</sup> highlighted both modalities' diagnostic accuracy, while Soni et al. (2022) <sup>(40)</sup> emphasized the role of ultrasound in measuring pleural fluid echogenicity, contributing to the differentiation between transudative and exudative effusions. Similarly, Ahmed et al. (2017) <sup>(41)</sup> demonstrated ultrasound's utility in diagnosing pleural effusion, further validating its role in clinical assessments.

Research by Ch. et al. (2018) <sup>(42)</sup> and EL-Sheikh et al. (2020) <sup>(43)</sup> corroborates these findings, delineating the efficacy of ultrasound and CT in differentiating pleural effusion types and detecting its causes, respectively. These studies collectively affirm the complementary nature of ultrasound and CT in pleural effusion diagnosis, with each modality exhibiting specific strengths in visualizing different pleural effusion characteristics.



The comparative analysis between ultrasound and CT in this study, contextualized within the broader literature, underscores the complementary diagnostic roles these modalities play in pleural effusion characterization. Ultrasound demonstrates particular efficacy in detecting septations or debris, highlighting its utility in specific clinical scenarios where detailed visualization of pleural effusion characteristics is essential. Conversely, CT's superior detection of loculations suggests its indispensable role in comprehensive pleural effusion assessments, especially in complex cases where detailed anatomical visualization is paramount.

## 9. DISCUSSION AND COMPARISON OF COMPLETE BLOOD COUNT FINDINGS IN PLEURAL EFFUSION

Regarding white blood cell (WBC) Count, the study identified an elevated mean WBC count of 11,780.38 / $\mu$ l in pleural effusion patients, suggesting an inflammatory or infectious process. This elevation correlates with the findings of Balci and Aydin (2021) <sup>(44)</sup>, who noted significant differences in CBC parameters between malignant pleural effusion (MPE) and benign pleural effusion (BPE). Higher WBC counts, alongside elevated neutrophil, monocyte, and various inflammatory ratio values were indicative of MPE. The range observed in the current study (4,390 to 23,000 / $\mu$ l) not only highlights the variability among patients but also aligns with the notion that elevated WBC counts may signal a more severe or malignant process.

Regarding platelet count, the mean platelet count recorded at 226.75 x 10<sup>9</sup>/L falls within normal limits, indicating satisfactory hematopoietic function. However, the broad range (100 to 460 x 10<sup>9</sup>/L) suggests variability that could reflect underlying conditions affecting platelet production or destruction. Balci and Aydin's research <sup>(44)</sup> does not specifically address platelet counts in pleural effusion differentiation; however, it is known from other studies that thrombocytosis can be associated with malignancy and inflammation, potentially serving as a marker for more aggressive disease forms.

Now regarding hemoglobin (HB) level, the prevalence of anemia, indicated by a mean HB level of 10.473 g/dL, underscores the chronicity of disease processes underlying pleural effusions. Anemia's association with chronic diseases or acute blood loss scenarios is well-documented and can significantly impact patient management and prognosis. While Balci and Aydin (2021) <sup>(44)</sup> do not explicitly discuss HB levels in their differentiation of pleural effusions, anemia's presence in pleural effusion patients could be reflective of chronic inflammation or malignancy, factors that are critical in the assessment and management of pleural effusion.

The CBC parameters in pleural effusion patients—elevated WBC counts, variable platelet counts, and prevalent anemia—have significant diagnostic and prognostic implications. According to Balci and Aydin (2021) <sup>(44)</sup>, CBC parameters, including WBC count and inflammatory ratios such as NLR and MLR, are instrumental in distinguishing between MPE and BPE. Furthermore, these parameters can offer prognostic insights, particularly in patients with MPE, where elevated inflammatory markers may indicate a poorer prognosis.

## 10. DISCUSSION ON BLOOD PRESSURE PARAMETERS AND PLEURAL EFFUSION

The exploration of blood pressure parameters in the context of pleural effusion presents a nuanced understanding of the cardiovascular implications inherent to this condition. The observed average systolic blood pressure (SBP) of 128.10 mmHg and diastolic blood pressure (DBP) of 78.08 mmHg among pleural effusion patients encapsulate a broad spectrum of cardiovascular health statuses, from normotensive states to potential hypertension. This variability is crucial for interpreting the cardiovascular impact of pleural effusion, necessitating a comparison with relevant studies, such as the work by AL-Saray and Ali (2023) <sup>(80)</sup>, which investigates volume status in maintenance hemodialysis patients using lung ultrasound and caval indices.

The range of SBP from 70 to 190 mmHg highlights the significant diversity in patient conditions. The higher end of this range suggests that some individuals with pleural effusion may experience increased cardiovascular stress, potentially due to the effusion's impact on pulmonary and cardiac function. This aligns with AL-Saray and Ali's findings, where lung ultrasound and caval indices were pivotal in assessing volume status, indicating that fluid accumulation, whether in the pleural space or within the circulatory system, has profound effects on cardiovascular parameters (2023) <sup>(45)</sup>. The application of lung ultrasound could similarly enhance understanding of the relationship between pleural effusion severity and blood pressure changes, offering insights into the fluid dynamics affecting cardiac preload and afterload.

Conversely, the lower spectrum of SBP and the observed range of DBP (40 to 130 mmHg) in pleural effusion patients reflect the potential for volume depletion or vasodilatory responses. These responses could be attributed to various factors, including the mechanical effects of pleural fluid on cardiac filling and systemic inflammation. AL-Saray and Ali's study <sup>(45)</sup> underscores the utility of non-invasive imaging modalities in evaluating hemodynamic changes, suggesting that similar approaches could benefit patients with pleural effusion by enabling tailored fluid management strategies to mitigate the risks of hypotension or hypertension.

The assessment of blood pressure variability in pleural effusion patients reveals the condition's complex interplay with cardiovascular health. This analysis, when juxtaposed with the methodological approaches of AL-Saray and Ali (2023) <sup>(45)</sup>

In conclusion, the study of blood pressure parameters in pleural effusion patients offers valuable insights into the cardiovascular implications of this condition. The significant variability observed underscores the need for individualized patient assessment and management strategies. Comparatively, the research by AL-Saray and Ali (2023) <sup>(45)</sup> highlights the relevance of non-invasive diagnostic techniques in understanding and managing the volume status and its cardiovascular effects in patients. This comparative analysis suggests a promising direction for future research and clinical practice, emphasizing the integration of diagnostic modalities like lung ultrasound to enhance the care of patients with pleural effusion and related cardiovascular alterations.

As a feature work one can use arterial intelligent techniques in such analysis to get a precise comparison by applying

transformation like Wavelets and multiwavelets transforms [46, 47, 48]. As well as some useful hybrid transforms like Walidlet and mixed transforms [49, 50, 51]. Such study available in literature for example [52, 53, 54, 55].

## 11. CONCLUSIONS

This study has comprehensively evaluated the diagnostic accuracy of point-of-care ultrasound (POCUS) compared to CT scans for detecting pleural effusion in the emergency department setting. The findings underscore the efficacy of POCUS as a reliable, rapid, and less invasive diagnostic tool that aligns closely with CT scan results, the current gold standard. Despite some limitations, including a small sample size and occasional device failures, the research highlights POCUS's potential in enhancing patient care by facilitating quicker diagnosis and treatment decisions. This study advocates for the integration of POCUS into routine emergency medicine protocols for pleural effusion detection, considering its advantages in terms of accessibility, cost-effectiveness, and patient safety.

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