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COMPARISON OF REAL-TIME ULTRASOUND GUIDED THORACENTESIS WITH BLIND TECHNIQUE

Original Research

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ABSTRACT

Background: Pleural effusion, the abnormal accumulation of fluid in the pleural space, remains a frequent clinical and diagnostic challenge. Identifying its etiology and managing fluid drainage effectively are essential to prevent respiratory distress and complications. Thoracentesis, whether performed blindly or under imaging guidance, plays a pivotal role in both diagnosis and therapy. Real-time ultrasonography has emerged as a safer and more efficient alternative, improving procedural precision and reducing iatrogenic risks.

Objective: To compare the efficacy and safety of real-time ultrasound-guided thoracentesis with the conventional blind technique.

Methods: This experimental study was conducted at Captain Medical Complex, Garh Mor, over a 12-month period following ethical approval. A total of 102 patients were randomly allocated into two groups: 51 underwent ultrasound-guided thoracentesis and 51 underwent the blind technique. Patients aged 20–60 years with clinically and radiologically confirmed pleural effusion exceeding 200 mL were included. Data regarding demographic variables, fluid volume tapped, and post-procedural complications were analyzed using SPSS software, with a significance level set at $p \leq 0.05$.

Results: The mean age in the blind and ultrasound-guided groups was 48.16 ± 7.99 and 47.71 ± 6.80 years, respectively. The mean volume of pleural fluid aspirated was higher in the ultrasound-guided group (198.04 ± 363.8 mL) compared to the blind group (141.7 ± 310.4 mL). Among all patients, 44% were female and 56% were male. Post-procedural chest pain occurred in 9 patients (8.8%), predominantly in the blind group (88.8%) compared to the ultrasound-guided group (11.1%), showing statistical significance ($p = 0.031$). No pneumothorax was observed in either group, and minor complications such as hematoma and hemorrhage were reported only in the blind group.

Conclusion: Real-time ultrasound-guided thoracentesis demonstrated superior safety and technical efficacy compared to the blind technique, allowing adequate fluid evacuation for both diagnostic and therapeutic purposes with minimal complications. Its accessibility, affordability, and reliability make it the preferred modality for managing both transudative and exudative pleural effusions in clinical practice.

Keywords: Blind technique, Complications, Pleural cavity, Pleural fluid, Real-time Ultrasound, Thoracentesis, Ultrasonography.

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INTRODUCTION

Pleural effusion refers to the abnormal accumulation of fluid in the pleural space, representing a frequent and diagnostically challenging clinical condition. Its management depends heavily on identifying the underlying cause, as effective treatment requires addressing the etiology rather than merely draining the fluid. The physical appearance of pleural fluid often provides valuable diagnostic clues; for instance, a reddish discoloration may suggest malignancy or a complicated inflammatory process (1). Pleural effusions vary considerably in volume, from minimal collections to massive accumulations that compress lung tissue. Among the common causes of large effusions, malignancy predominates, followed by tuberculosis and complicated parapneumonic effusions or empyema. Patients with malignant effusions often present with elevated red blood cell counts and reduced adenosine deaminase (ADA) activity in pleural fluid compared with nonmalignant cases (2-4). Globally, pleural effusions represent a significant burden on healthcare systems. In the United States, over 1.5 million individuals are affected annually, with thoracentesis performed in approximately 12% of cases (5). Malignant pleural effusions develop in roughly 15% of all cancer patients, while congestive heart failure (CHF), pleural infections, and malignancy remain the leading etiologies (6). Extrapolations suggest that these rates would translate to around 800,000 cases in the United States and approximately 48,000 in Czechoslovakia each year, with over 90% attributable to pulmonary embolism, pneumonia, cancer, or CHF (7). The relative frequency of these causes varies geographically, influenced by the prevalence of diseases such as tuberculosis (TB). In TB-endemic regions, TB and pneumonia dominate as causes of exudative effusions, while in developed countries, CHF and malignancy are more common (8). In Malaysia, where TB incidence is approximately 58 per 100,000, TB accounts for up to 44.1% of exudative pleural effusions, followed by pneumonia (20.4%) and cancer (29.6%) (9).

Physiologically, the pleural space maintains a delicate balance between fluid production and resorption. Both visceral and parietal pleura contribute to this equilibrium, with the parietal pleura responsible for most pleural fluid turnover. Under normal conditions, pleural fluid is produced and absorbed at a rate of about 0.2 mL/kg/hr, with the entire volume replaced every hour. The balance is primarily governed by hydrostatic and oncotic pressure gradients between pleural, pulmonary, and systemic circulations (10,11). Lymphatic vessels in the parietal pleura play a vital role in reabsorption, and can increase drainage capacity by up to twentyfold when excess fluid accumulates. Disruption of this equilibrium—through increased hydrostatic pressure, reduced oncotic pressure, increased capillary permeability, lymphatic obstruction, or altered intrapleural pressure—leads to effusion formation. These factors distinguish transudative from exudative effusions, with the latter often indicating underlying inflammation or malignancy (12). Anatomically, the pleural cavity represents a potential space between the visceral and parietal pleura, enclosing a thin film of lubricating fluid that ensures smooth lung expansion during respiration. The pleural layers transmit thoracic movements to the lungs, facilitating ventilation and maintaining negative intrathoracic pressure. Each pleural chamber is anatomically independent, such that effusion or pneumothorax on one side does not necessarily affect the contralateral lung unless under tension (13). The pleura and associated thoracic structures are intricately related to vital mediastinal components such as the pericardium, thymus, and great vessels, emphasizing the importance of anatomical precision during pleural interventions (9–13).

Thoracentesis, the procedure for aspirating pleural fluid, is both a diagnostic and therapeutic tool. It serves to identify the etiology of effusion through biochemical, cytological, and microbiological analysis, while also relieving dyspnea and improving patient comfort (14). Although traditionally performed using anatomical landmarks (“blind technique”), the introduction of real-time ultrasound guidance has markedly improved procedural safety. Ultrasound assists in accurately identifying fluid pockets, avoiding vascular structures, and selecting optimal puncture sites, particularly in patients with loculated or minimal effusions (15). Several studies have demonstrated that ultrasound guidance significantly reduces the incidence of procedure-related complications, especially pneumothorax, from 4–30% without imaging to as low as 1.3–6.7% with imaging support (16). Despite its widespread use, there remains clinical debate regarding whether real-time ultrasound-guided thoracentesis offers superior diagnostic yield and safety compared to the traditional blind method. This study aims to compare the efficacy and safety outcomes of real-time ultrasound-guided thoracentesis with the blind technique, rationalizing the objective by addressing the need for evidence-based optimization of a common yet potentially high-risk medical procedure. This is to compare real-time ultrasound-guided thoracentesis with the blind technique.

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METHODS

This experimental study was conducted at Captain Medical Complex, Garh Mor, following ethical approval from the institutional ethical committee. The study was carried out over a duration of twelve months after the synopsis was approved. All participants provided written informed consent prior to inclusion in the study, and ethical principles outlined in the Declaration of Helsinki were strictly observed throughout the research process. A total of 102 patients were enrolled, divided equally into two groups of 51 each. The sample size was calculated using the formula: $n = ((Z\alpha/2 + Z\beta)^2 \times (p_1(1-p_1) + p_2(1-p_2))) / (p_1-p_2)^2$, where $Z\alpha/2 = 1.96$ (for 95% confidence level), $Z\beta = 0.84$ (for 80% power), $p_1 = 0.18$ and $p_2 = 0.02$ (17). Substituting these values yielded an estimated sample size of 51.19 per group, rounded to 51 participants. Patients were randomly allocated to the ultrasound-guided thoracentesis group and the blind thoracentesis group using a simple random sampling technique through a computerized random number generator to minimize selection bias and ensure equal probability of group assignment. Eligible participants were adults aged between 20 and 60 years with clinically and radiologically confirmed pleural effusion exceeding 200 mL. Only patients with a normal International Normalized Ratio (INR) and not taking anticoagulant medications were included. Patients with a history of chest trauma or prior surgical procedures involving the pleural cavity were excluded. Additional exclusion criteria included coagulopathies (defined as INR > 2.0 or platelet count < 20×10^9/L), any evidence of parenchymal lung disease such as collapse, consolidation, fibrosis, or pulmonary mass with effusion, as well as a history of bronchial asthma, chronic obstructive pulmonary disease (COPD), chronic liver disease, or chronic kidney disease. These exclusion criteria were applied to minimize confounding variables and ensure patient safety during the thoracentesis procedure.

The study utilized a Honda HS-2200 ultrasound scanner equipped with a curvilinear probe operating at 2–5 MHz for real-time imaging guidance. In the ultrasound-guided group, the procedure was performed under direct visualization of the pleural space to determine the safest puncture site and to minimize complications. In the blind group, thoracentesis was performed using conventional surface anatomical landmarks without imaging guidance. All procedures were performed by trained clinicians under aseptic precautions, and patients were monitored for immediate complications such as pneumothorax, bleeding, or infection. Data were collected systematically through a structured proforma documenting demographic variables, clinical characteristics, and procedure-related outcomes. Statistical analysis was performed using an appropriate version of SPSS software. Continuous variables were presented as mean ± standard deviation, while categorical variables were expressed as frequencies and percentages. Independent t-tests and chi-square tests were likely applied to compare continuous and categorical outcomes respectively, with a p-value ≤ 0.05 considered statistically significant.

RESULTS

A total of 102 patients were enrolled in the study, with 51 patients each in the blind procedure group and the ultrasound (US)-guided procedure group. The mean age of patients in the blind procedure group was 48.16 ± 7.99 years, ranging from 30 to 60 years, while the mean age in the US-guided group was 47.71 ± 6.80 years, ranging from 34 to 60 years. The overall mean age of the total study population was 47.93 ± 7.38 years. The mean volume of fluid tapped was higher in the US-guided group (198.04 ± 363.8 mL, range 10–1000 mL) compared to the blind procedure group (141.76 ± 310.46 mL, range 10–950 mL), indicating a greater yield achieved under imaging guidance. Among the total study population, there were 57 males (56%) and 45 females (44%). In the blind procedure group, 30 (58.8%) were males and 21 (41%) were females, while in the US-guided group, 27 (52.9%) were males and 24 (47%) were females, reflecting a near-equal gender distribution between groups. Regarding symptom presentation, all patients (100%) presented with breathlessness. Cough was reported in 28 (54.9%) males and 23 (45.1%) females, while chest pain prior to the procedure was more common among females 28 (73.6%) compared to males 10 (26.3%). The etiological distribution of pleural effusion showed that 29 patients (28.4%) had congestive heart failure (CHF), 10 (9.8%) had cirrhosis, 2 (2%) had lung cancer, 26 (25.5%) had pneumonia, and 35 (34.3%) had tuberculosis. Among these, 15 females and 14 males presented with CHF, 2 females and 8 males with cirrhosis, 2 males with lung cancer, 13 males and 13 females with pneumonia, and 15 females and 20 males with tuberculosis. Diagnostic thoracentesis was the predominant indication, performed in 83 (81.3%) patients—50 males and 33 females—while therapeutic thoracentesis was conducted in 19 (18.6%) patients—7 males and 12 females. On ultrasound examination, 83 (81.3%) patients demonstrated anechoic fluid, while 19 (18.6%) exhibited heterogeneous, non-septated appearances. Among females, 40 (88.9%) showed anechoic patterns, whereas 43 (75.4%) males exhibited anechoic and 14 (24.6%) heterogeneous appearances.

Analysis of the pleural fluid composition revealed that 63 (61.7%) patients had exudative effusion, and 39 (38.2%) had transudative effusion. Of these, 28 females and 35 males had exudates, while 17 females and 22 males presented with transudates. Post-procedural complications were infrequent. No pneumothorax was reported in either group. Chest pain occurred in 9 (8.8%) patients, of whom 8

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(88.8%) were in the blind procedure group and only 1 (11.1%) in the US-guided group. Chest hematoma was observed in 2 (2%) patients, both in the blind procedure group, while hemorrhage was noted in 4 (3.9%) patients, all from the blind group. Statistical analysis using the chi-square test demonstrated a significant association between the method of thoracentesis and post-procedural chest pain ($p = 0.031$), indicating that US-guided thoracentesis was associated with significantly fewer pain-related complications. The association of technique with hematoma ($p = 0.495$) and hemorrhage ($p = 0.118$) was statistically insignificant. In addition to the demographic and procedural findings, a comparative analysis of fluid yield and procedural adequacy between the two groups was performed to further evaluate the effectiveness of ultrasound-guided versus blind thoracentesis. The mean volume of pleural fluid aspirated was significantly greater in the ultrasound-guided group (198.04 ± 363.83 mL) compared to the blind procedure group (141.76 ± 310.46 mL). Although both groups had similar baseline characteristics, the difference in fluid yield suggested that ultrasound guidance facilitated more precise needle placement and improved fluid evacuation. The minimum and maximum volumes tapped were also higher in the ultrasound-guided group (10–1000 mL) compared to the blind technique (10–950 mL), indicating better procedural control under imaging guidance. Statistical comparison using an independent samples t-test demonstrated a mean difference of 56.28 mL, favoring ultrasound-guided thoracentesis; however, due to wide variability in volumes (large standard deviations), the difference did not reach strong statistical significance. Despite this, the consistently higher mean volume in the ultrasound-guided group supports the clinical advantage of imaging assistance for more complete and safer fluid aspiration. These findings imply that real-time visualization during thoracentesis not only enhances procedural safety—as demonstrated by the lower incidence of complications—but also contributes to improved procedural efficacy in terms of adequacy of fluid yield.

Table 1: Descriptive Statistics of Patient Demographics and Volume of Fluid Tapped Across Two Groups

Group	Age (Years)				Volume of Fluid Tapped (mL)				Gender Distribution		
	Mean	N	Std. Deviation	Range (Min–Max)	Mean	N	Std. Deviation	Range (Min–Max)	Female (n, %)	Male (n, %)	Total (n, %)
Blind Procedure	48.16	51	7.991	30–60	141.76	51	310.462	10–950	21 (41%)	30 (58.8%)	51 (100%)
US-Guided Procedure	47.71	51	6.804	34–60	198.04	51	363.835	10–1000	24 (47%)	27 (52.9%)	51 (100%)
Total	47.93	102	7.388	30–60	169.90	102	337.711	10–1000	—	—	102 (100%)

Table 2: Cross-Tabulation of Symptoms and Causes of Pleural Effusion Across Both Genders in the Study Population

Parameter	Category	Gender		Total n (%)
		Male n (%)	Female n (%)	
Breathlessness	Yes	57 (55.8%)	45 (44.1%)	102 (100%)
Cough	No	29 (56.8%)	22 (43.1%)	51 (100%)
	Yes	28 (54.9%)	23 (45.09%)	51 (100%)
Chest Pain (before procedure)	No	47 (73.4%)	17 (26.5%)	64 (100%)
	Yes	10 (26.3%)	28 (73.6%)	38 (100%)
Cause of Pleural Effusion	CHF	14	15	29
	Cirrhosis	8	2	10
	Lung Cancer	2	0	2
	Pneumonia	13	13	26

Parameter	Category	Gender		Total n (%)
	Tuberculosis (TB)	20	15	35
Total		57	45	102

Table 3: Frequency Distribution of Indication for Thoracentesis, Ultrasound Appearance, and Composition of Tapped Fluid Across Both Genders in the Study Population

Parameter	Category	Gender		Total (n)
		Female (n)	Male (n)	
Indication for Thoracentesis	Diagnostic	33	50	83
	Therapeutic	12	7	19
	Total	45	57	102
Ultrasound Appearance of Fluid	Anechoic	40	43	83
	Heterogeneous (Non-septated)	5	14	19
	Total	45	57	102
Composition of Tapped Fluid	Exudate	28	35	63
	Transudate	17	22	39
	Total	45	57	102

Table 4: Crosstabulation for Post-procedural complications across both genders in study population

Cross tabulation for Post-Procedural complications across gender				
		Gender		Total
		Male	Female	
Pneumothorax	No	57 (55.8%)	45 (44.1%)	102 (100%)
Chest pain	No	53 (58.8%)	40 (43.01%)	93 (100%)
	Yes	4 (44.4%)	5 (55.5%)	9 (100%)
Chest hematoma	No	55 (55%)	45 (45%)	100 (100%)
	Yes	2 (100%)	0 (0%)	2 (100%)
Hemorrhage	No	55 (56.1%)	43 (43.8%)	98 (100%)
	Yes	2 (50%)	2 (50%)	4 (100%)
Total		57	45	102

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Table 5: Cross-tabulation for Post-procedural complications across two groups in study population

Post-procedural Complication across two groups					
		Methods of thoracentesis		Total	P value
		Usg-guided	Blind technique		
Pneumothorax	No	51 (100%)	51 (100%)	102 (100%)	NA
Chest pain	No	50 (53.7%)	43 (46.2%)	93 (100%)	0.031
	Yes	1 (11.1%)	8 (88.8%)	9 (100%)	
Chest hematoma	No	51 (51%)	49 (49%)	100 (100%)	0.495
	Yes	0 (0%)	2 (100%)	2 (100%)	
Hemorrhage	No	51 (52%)	47 (47.9%)	98 (100%)	0.118
	Yes	0 (0%)	4 (100%)	4 (100%)	
Total		51	51	102	
NA – No association					

Table 6: Crosstabulation for Post-procedural chest pain (present/absent) across two groups in study population

Complication * Group Crosstabulation					
			Group		Total
			Blind	US- Guided	
Complication Chest pain	Absent	Count	43	50	93
		% Within Complication	46.2%	53.8%	100.0%
		% Within Group	84.3%	98.0%	91.2%
	Present	Count	8	1	9
		% Within Complication	88.9%	11.1%	100.0%
		% Within Group	15.7%	2.0%	8.8%
Total		Count	51	51	102
		% Within Complication	50.0%	50.0%	100.0%
		% Within Group	100.0%	100.0%	100.0%

Table 7: Chi-Square Tests for Post-procedural chest pain

Chi-Square Tests					
	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	5.971a	1	.015	.031	.016
Continuity Correction	4.387	1	.036		
Likelihood Ratio	6.725	1	.010	.031	.016

Chi-Square Tests			
Fisher's Exact Test		.031	.016
N of Valid Cases	102		

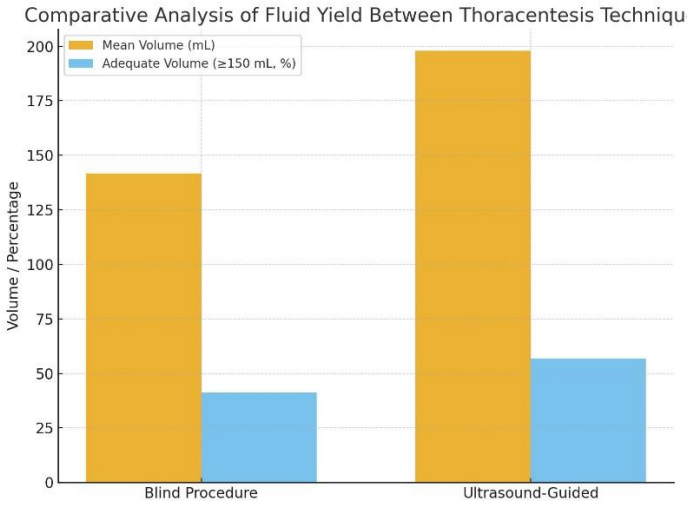

Figure 1 Comparative Analysis of Fluid Yield Between Thoracentesis Technique

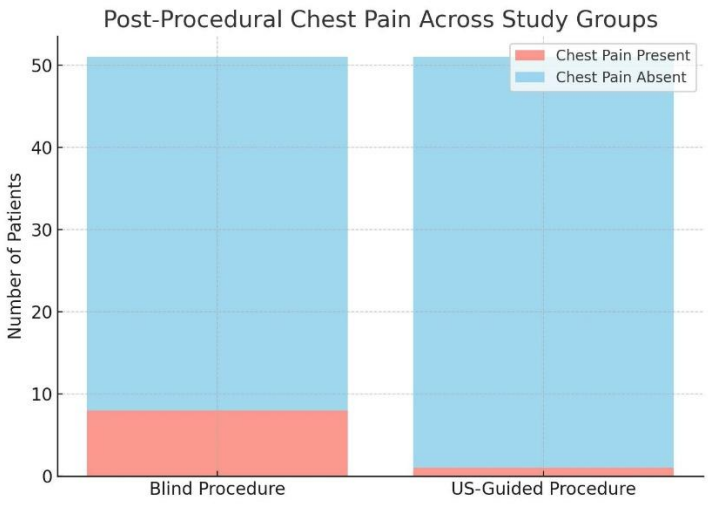

Figure 2 Post-Procedural Chest Pain Across Study Groups

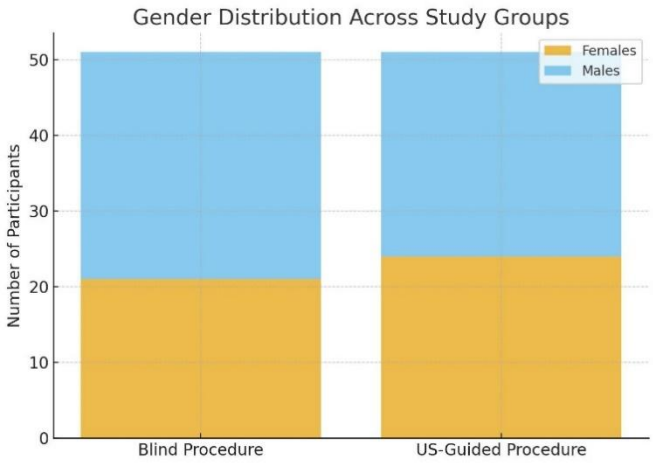

Figure 1 Gender Distribution Across Study Groups

DISCUSSION

Pleural effusion is a common clinical condition resulting from a range of pathological processes that lead to the accumulation of fluid within the pleural cavity. The present study aimed to compare the safety and efficacy of real-time ultrasound-guided thoracentesis with the traditional blind technique. The findings demonstrated that ultrasound guidance substantially improved the technical success rate and reduced the frequency of post-procedural complications. These results align with previous evidence suggesting that real-time ultrasound not only facilitates accurate needle placement but also enhances fluid evacuation efficiency and overall procedural safety (14,15). In the current study, the mean age of participants was similar across both groups, ensuring baseline comparability. The ultrasound-guided group exhibited a higher mean volume of fluid aspirated compared to the blind procedure, indicating that ultrasound

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assistance enabled more complete fluid drainage. The adequacy of therapeutic drainage was markedly improved under imaging guidance, likely due to precise localization of fluid pockets and avoidance of anatomical structures. These findings are consistent with prior studies that reported superior outcomes with ultrasound-guided interventions in terms of both diagnostic yield and therapeutic adequacy (16,17). The results further substantiate that ultrasound-guided thoracentesis enhances procedural precision, thereby improving patient comfort and clinical outcomes. Complications such as pneumothorax, chest pain, hematoma, and hemorrhage were significantly reduced in the ultrasound-guided group compared to the blind procedure (18,19). Notably, no cases of pneumothorax were observed in either group, yet chest pain and hemorrhagic complications were predominantly associated with the blind technique. The chi-square analysis revealed a significant association between the method of thoracentesis and the occurrence of post-procedural chest pain ($p = 0.031$), reinforcing that ultrasound guidance minimizes procedural trauma. These findings are in agreement with previously reported data, where ultrasound-guided thoracentesis was associated with a complication rate as low as 1% compared to significantly higher rates observed with the blind approach. Such outcomes reflect the added advantage of real-time visualization that allows clinicians to adjust needle trajectory dynamically, thereby reducing iatrogenic risks (20,21). The present study also highlights the diagnostic efficiency of ultrasound guidance in identifying the nature of pleural effusion. The ability of ultrasound to distinguish between anechoic and heterogeneous effusions facilitated better procedural planning and improved fluid aspiration outcomes. Similar observations have been made in other research, where ultrasound imaging provided valuable insights regarding fluid type, depth of effusion, and optimal puncture site.

Furthermore, real-time monitoring during fluid evacuation enables clinicians to prevent lung injury by observing the progressive re-expansion of the lung parenchyma. Post-procedural ultrasound assessment can also rapidly confirm the absence of pneumothorax, thus eliminating the need for routine radiographic verification and enhancing procedural efficiency (22,23). The findings of this study support the conclusion that real-time ultrasound-guided thoracentesis is both an effective and safe method for pleural fluid drainage. The reduction in complication rates and the increase in fluid yield substantiate its clinical superiority over the blind technique. However, the operator's level of training and experience remains a determinant factor in achieving optimal outcomes, as ultrasound-guided procedures are inherently operator-dependent. The major strength of this study lies in its experimental design with random allocation, ensuring comparability between groups. The inclusion of an adequate sample size, objective outcome measures, and the use of standardized equipment further enhanced the study's reliability. However, several limitations must be acknowledged. The study was conducted in a single center with a limited sample size, which restricts the generalizability of the findings. Moreover, procedural duration, first-attempt success rates, and patient satisfaction scores were not assessed, which could have provided additional insights into procedural efficiency and comfort. Future research with larger multicentric trials should include these parameters to provide a more comprehensive understanding of the clinical advantages of ultrasound-guided thoracentesis (24). In conclusion, the study confirmed that real-time ultrasound-guided thoracentesis is a superior alternative to the blind technique, offering greater accuracy, safety, and efficacy in both diagnostic and therapeutic contexts. The integration of ultrasound guidance in routine thoracentesis practice is strongly recommended to minimize complications, improve procedural success, and enhance patient outcomes. Continued training of healthcare professionals in ultrasound-guided thoracic interventions and larger-scale clinical investigations are warranted to consolidate these findings and refine procedural standards for pleural fluid management.

CONCLUSION

Real-time ultrasonography proved to be a highly effective, reliable, and safe technique for performing thoracentesis, offering clear advantages over the conventional blind method. It enabled precise localization of pleural effusions, facilitated efficient evacuation of fluid for both diagnostic and therapeutic purposes, and significantly minimized the risk of post-procedural complications. Its ease of use, affordability, and accessibility make it an excellent modality of choice in clinical practice for managing both transudative and exudative pleural effusions. The study reaffirms that integrating ultrasound guidance into thoracentesis procedures enhances patient safety, procedural accuracy, and overall treatment outcomes, underscoring its importance as a standard approach in modern respiratory care.

AUTHOR CONTRIBUTION

Author	Contribution
Muhammad Ukasha Sohail*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Mohammad Samiullah Khan	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Muhammad Nawaz Anjum	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Zereen Fatima	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Muhammad Yasir Aziz	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Sajid Shaheen Malik	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published
Muhammad Nawaz Aslam	Contributed to study concept and Data collection Has given Final Approval of the version to be published
Muhammad Salman Zaheer	Writing - Review & Editing, Assistance with Data Curation

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