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EFFICACY OF USG AND CT IN DIFFERENTIATING PLEURAL EFFUSION TRANSUDATE FROM EXUDATE

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Abstract

Introduction: *Pleural Effusion is a Pathology affecting more than 1 million per annum in U.S. Its treatment poses therapeutic and diagnostic challenges. From decades its diagnosis is done by Lab investigations involving invasive aspirations also and by imaging modalities offering a non-invasive diagnostic toll. For detection and management of pleural effusions computed tomography (CT) and ultrasonography (USG) are thought as crucial tools among diagnostic modalities .*

Objective: *This study investigates the comparative proficiency of USG and cyphered tomography in distinguishing transudative and exudative PE in clinical practice, addressing the critical need for accurate non-invasive diagnostic methods in pleural disease management.*

Methods: *In this retrospective cross-sectional study, data from 79 patients with PE who attended government hospitals were analysed. The ratio of males and females in a study population was 57:43, and 88.6 percent of study participants were above 40 years old. USG and CT were conducted in all the participants, and imaging results were categorized by known standards of transudate and exudate stratification. Imaging characteristics, underpinning diagnoses, and clinical presentations were evaluated systematically. Analyzed with SPSS, the statistical measure applied in observing the relationships in the middle of diagnostic modalities was the chi-square test of independence.*

Results: *The research revealed substantial discordance in the middle of USG and CT findings. Clinical presentations included cough (62.0%), chest pain (59.5%), and shortness of breath after exercise (67.1%). Underlying diagnoses comprised hemothorax (43.0%), pneumonia (29.1%), tuberculosis (16.5%), and empyema (11.4%). CT scan classified 57.0% of cases as transudative and 43.0% as exudative, while USG classified 63.3% as transudative and 36.7% as exudative. A statistically momentous association was found amongst the two diagnostic methods ($\chi^2(1, N=79)=34.620$, $p<.001$), though overall diagnostic concordance was only 20.3%.*

Conclusion: *While both USG and CT demonstrate statistical association in PE classification, substantial inter-modality disagreement was observed. The findings highlight the complexity of non-invasive pleural fluid characterization and underscore the continued importance of biochemical analysis using Light's criteria as the definitive gold standard for transudate-exudate differentiation.*

Introduction

PE epitomizes a hefty clinical entity pigeonhole by the abnormal accretion of fluid within the pleural intergalactic[(1)]. Under physiological conditions, the pleural cavity contains only 5-15 milliliters of fluid, which facilitates smooth movement in the middle of the parietal and visceral pleurae during respiration. When this delicate balance is disrupted, excess fluid accumulates, potentially leading to respiratory compromise and necessitating prompt medical intervention.The clinical importance of PE cannot be overstated, as it affects circa 1.5

million patients per annum in the United States alone[2]. This diagnosis has a wide background of underlying pathologies that can be described as being mild transudative effusion due to heart failure, to a life-threatening malignant exudate effusion. The implications of mortality are quite high, and non-malignant effusions in the pleura can be considered as poor prognostic factors in cardiac (57% mortality at one year), renal (46% mortality at one year), and hepatic failure (25% mortality at one year)[2].

The requirement to singularize the transudative and the exudative PE is the foundation of a proper clinical treatment and prognostic evaluation. This essential difference directly affects the choice of treatment, since transudative effusions are usually caused by widespread diseases that need treatment of diseases caused by the disease, but exudative ones require the need to study a local pathological process. Pathophysiological processes leading to these two types of effusion are substantially different: Transudates form as a result of the disproportion between the hydrostatic and the oncotic forces in the intact capillaries, and exudates are produced because the latter forces can be broken down by the inflammatory or neoplastic processes of the capillaries that increase their permeability.[3]

The current criteria by which PEs are biochemically differentiated are the set of criteria by Light in 1972. They categorize an effusion as exudative under the condition that one or more of the succeeding criteria are achieved. Despite their widespread acceptance and 98% sensitivity for detecting exudative effusions, Light's criteria demonstrate limitations in specificity, particularly in patients receiving diuretic therapy, where approximately one-fifth of patients with congestive heart failure may be misclassified as having exudative effusions[5].

The marketscape of PE assessment has changed in substantial aspects as more non-invasive imagery assessment modes have been undertaken, especially USG and HRCT. The techniques have become useful supplements to conventional diagnostic modalities, and they possess their exclusive benefits in diagnosis and description of pleural fluid accumulation. The speed of evaluation is one of the inherent benefits of the imaging modalities today in the assessment of PE. The ease of application of USG at the bedside has transformed the management of PE in hospitals. With the current portable US machines, it is possible to conduct assessments in difficult clinical settings such as the intensive care units, where transporting a patient to obtain CT scans is not advisable

The detailed anatomical information with the use of CT imaging may provide complementary diagnosis in the evaluation of PE. The high-resolution cross-sectional images obtained with multi-detector CT scanners can demonstrate not only the availability and the degree of pleural fluid but also concomitant alterations of the pathology of pleural, pulmonary parenchyma, and mediastinal structures. Throughout such a thorough anatomical evaluation, it becomes useful in determining the presence of underlying malignancies, in separating simple and complex effusions, or in seeing the need to make use of therapeutic interventions like thoracentesis or insertion of chest tubes.[10]

The sonographic appearances of identifying fluid nature have been analyzed comprehensively and confirmed at several clinical levels. The principle of US differentiation resides in the following acoustic characteristics of transudative and exudative pleural fluid, which are extrapolated into the basic biochemical composition and the presence of cells in this or that biochemical project[11,12,13].

The transudative effusions are usually anechoic (no echoes identified) when examined under USG. Studies consistently demonstrate that transudates maintain their anechoic characteristics in virtually all cases, with one large series reporting anechoic appearance in 99.7% of confirmed transudative effusions. The absence of internal echoes, septations, or loculations serves as a reliable indicator of the transudate nature, although it should be noted that some exudates may also appear anechoic, limiting the specificity of this finding.[14, 15]

Exudative effusions demonstrate complex sonographic patterns that reflect their higher protein content, cellular debris, and

inflammatory components. These effusions commonly present as complex septate (62.5% of cases), echogenic (25%), or intricate non-septate patterns (8.9%), with only a small percentage (3.5%) appearing anechoic.Echogenic effusions typically indicate the presence of hemorrhagic fluid or empyema, requiring immediate clinical attention and often drainage procedures.[16]

Septations and loculations represent key ultrasonographic features that substantially influence clinical management. The presence of septations indicates organized fluid collections that may require more aggressive drainage approaches, including thoracoscopic intervention or surgical decortication. USG demonstrates superior sensitivity (82.6%) and specificity (100%) for detecting septated effusions compared to enhanced chest CT (sensitivity 59.8%, specificity 87.0%). This superiority stems from US's ability to detect thin fibrinous strands and delicate septations that may not be visible on cross-sectional CT images, particularly when imaging is performed in real-time during respiratory motion.[17,18]

The "plankton sign" and other dynamic ultrasonographic features provide additional diagnostic information. The plankton sign, characterized by punctate hyperechoic foci floating within the effusion, indicates the presence of inflammatory debris and strongly suggests an exudative process. Similarly, the "swirling sign," representing echogenic floating particles that move with respiratory motion or heartbeat, has been studied as a potential predictor of malignant effusions, though recent evidence suggests it correlates more with fluid volume and character than specific etiology.[19]

Detection of pleural thickening provides valuable diagnostic information beyond simple fluid characterization. CT demonstrates superior capability in identifying pleural thickening compared to USG, with pleural thickening present in 59% of exudates versus 36% of transudates. When pleural thickness exceeds 1 cm, it strongly suggests an exudative process, though this finding lacks absolute specificity. The ability to detect subtle pleural enhancement and thickening makes CT particularly valuable in cases where malignancy is suspected.[22] .

Methodology

The authors have used a retrospective cross-sectional observational design in evaluating the relative efficacy of diagnosing different types of PE in the middle of USG and CT. The cross-sectional study made it possible to assess the diagnostic performance during a specified period of time, as the prevalence of various effusion characteristics within the investigated population was assessed.The study took place in the Radiology Units of government hospitals in Faisalabad in Pakistan, such as Allied Hospital, District Headquarters, and other facilities of tertiary care. A 4-month duration was used to collect data, and the evaluation of the patients' indicating signs of PE was done systematically.

The research undertaking was also carried out through the ethics of medical research. All the participants were informed and signed a consent form, and their identity as patients was kept confidential. The institutional appraisal board permitted the research protocol of the study.

Results

The study sample (N = 79) consisted of predominantly male (57.0%) participants, with a substantial majo
rity (88.6%) being over the age of 40. Clinically, most participants presented with symptoms such as cough (62.0%), chest pain (59.5%), shortness of breath after exercise (67.1%), and had underlying diagnoses of hemothorax (43.0%) or pneumonia (29.1%). The central analysis compared the classification of PE by CT scan and US, which found a substantial association in the middle of the two methods, $\chi^2(1, N = 79) = 34.620$, $p < .001$.

Table 1 presents the frequency distribution of the participants by gender. The total sample consisted of 79 participants (N=79). The greater part of the participants were male (n = 45, 57.0%), while 34 participants were female (n = 34, 43.0%).

Table 1 frequency distribution of the participants by gender

Gender					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Female	34	43.0	43.0	43.0
	male	45	57.0	57.0	100.0
	Total	79	100.0	100.0	

Table 2 shows the breakdown of the patient sample by age group. Out of a total of 79 participants (N=79), a substantial majority of patients (n = 70, 88.6%) were over the age of 40. The remaining participants were distributed among the younger age brackets: 5 patients (6.3%) were in the 30-40 age group, 3 patients (3.8%) were in the 20-30 age group, and 1 patient (1.3%) was in the 10-20 age group.

Table 2 frequency distribution of the participants by age group

Patient Age					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	10-20	1	1.3	1.3	1.3
	20-30	3	3.8	3.8	5.1
	30-40	5	6.3	6.3	11.4
	above 40	70	88.6	88.6	100.0
	Total	79	100.0	100.0	

Table 3 stipulates the frequency distribution for the presence of a cough among the participants (N=79). The data show that a majority of the sample, 49 participants (62.0%), reported having a cough. The remaining 30 participants (38.0%) reported that they did not have a cough.

Table 3 frequency of symptom of cough

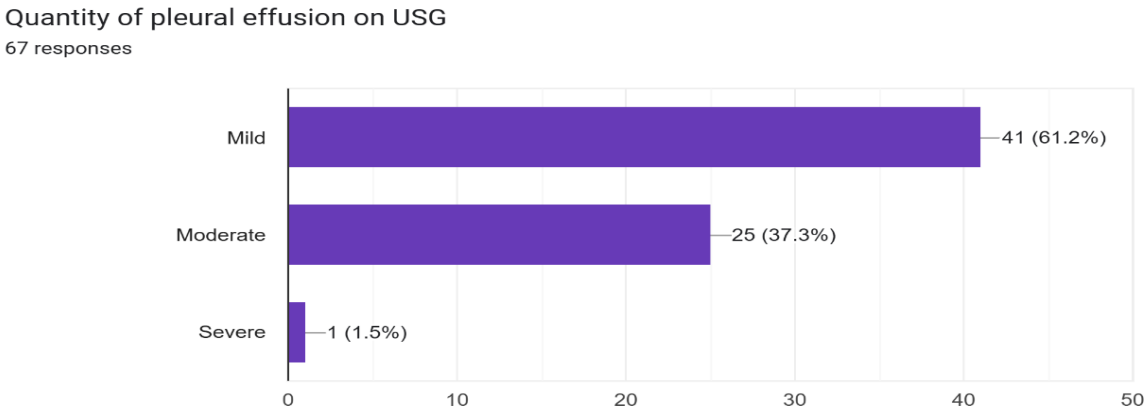
Cough					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	30	38.0	38.0	38.0
	Yes	49	62.0	62.0	100.0
	Total	79	100.0	100.0	

Table 4 frequency of symptom of chest pain

Chest pain					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	32	40.5	40.5	40.5
	yes	47	59.5	59.5	100.0
	Total	79	100.0	100.0	

Table 4 indicate that a majority of the sample, 47 participants (59.5%), reported experiencing chest pain. Conversely, 32 participants (40.5%) reported that they did not have chest pain.

Graph 1 represents majority of individuals were found to have "mild" effusion (n = 41, 51.9%). "Moderate" effusion was noted in 25 participants (31.6%), while "severe" effusion was found in only one case (1.3%). For 12 participants (15.2%), the quantity of the effusion was not specified in the findings.

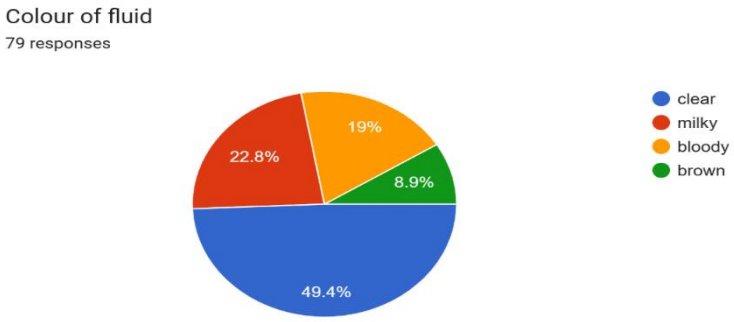


Graph 1: Quantity of Pleural Effusions on USG

A majority of individuals were found to have "mild" effusion (n = 41, 51.9%). "Moderate" effusion was noted in 24 participants (30.4%), while "severe" effusion was found in only one case (1.3%). For 13 participants (16.5%), the quantity of the effusion was not specified.

Quantity of PE					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		13	16.5	16.5	16.5
	Mild	41	51.9	51.9	68.4
	Moderate	24	30.4	30.4	98.7
	Severe	1	1.3	1.3	100.0
	Total	79	100.0	100.0	

Table 5 : Quantity of Pleural Effusions on CT



Pie **Graph below depicts that 49.4% percent participants had clear fluid, 22.8% milky, 19% bloody, and 8.9% brown.**

Graph 4 appearance of Pleural Effusions on USG

The data confirm that a majority of participants (n = 54, 68.4%) had no reported comorbidities. Among the 25 participants who did report comorbid conditions, the most frequent was Congestive Heart Failure (CHF), affecting 9 individuals (11.4% of the total sample). Cirrhosis and nephrotic syndrome were equally prevalent, each reported in 8 participants (10.1% of the total sample for each condition).

Table 10 enlist the comorbidities

if any other comorbidities?					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		54	68.4	68.4	68.4
	CHF	9	11.4	11.4	79.7
	cirrhosis	8	10.1	10.1	89.9
	Nephrotic syndrome	8	10.1	10.1	100.0
	Total	79	100.0	100.0	

The findings were classified as either transudative or exudative*. A majority of the cases were diagnosed as exudative (n = 45, 57.0%), while the remaining 34 cases (43.0%) were diagnosed as transudative via CT Scan and.

Table indicating the findings were categorized as either transudative or exudative*. A majority of the cases were diagnosed as exudative (n = 50, 63.3%), while the remaining 29 cases (36.7%) were diagnosed as transudative.

Table 11 enlist the Final diagnosis using CT Imaging

Final diagnosis using CT					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Exuduative	45	57.0	57.0	100.0
	Transudative	34	43.0	43.0	43.0
	Total	79	100.0	100.0	

Final diagnosis using US					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Exuduative	50	63.3	63.3	100.0
	Transudative	29	36.7	36.7	36.7
	Total	79	100.0	100.0	

Table 12 enlist the Final diagnosis using USG Imaging

Comparison Test

Table 22 presents a crosstabulation comparing the final diagnoses from CT scan and US for all 79 participants (N=79). The results indicate a substantial level of disagreement in the middle of the two diagnostic methods. Notably, for the 34 cases identified as exudative* by CT scan, US classified all of them (100.0%) as transudative. For the 45 cases identified as transudative by CT scan, US concurred in 16 cases (35.6%) but classified the majority (n = 29, 64.4%) as exudative. Overall, the diagnostic findings from CT scan and US were in agreement for only 16 of the 79 cases (20.3%).

Final diagnosis using CT * Final diagnosis using US Crosstabulation					
			Final diagnosis using US		
			Executive	Transudative	Total
Final diagnosis	Exuduative	Count	0	34	34
		% within the Final diagnosis using CT	0.0%	100.0%	100.0%
		% within the Final diagnosis using US	0.0%	68.0%	43.0%
		% of Total	0.0%	43.0%	43.0%
	Transudative	Count	29	16	45
		% within the Final diagnosis using CT	64.4%	35.6%	100.0%
		% within the Final diagnosis using US	100.0%	32.0%	57.0%
		% of Total	36.7%	20.3%	57.0%
Total		Count	29	50	79
		% within the Final diagnosis using CT	36.7%	63.3%	100.0%
		% within the Final diagnosis using US	100.0%	100.0%	100.0%
		% of Total	36.7%	63.3%	100.0%

Table 13 representing the Comparison test

Chi-Square Tests					
	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	34.620[a]	1	.000		
Continuity Correction	31.901	1	.000		
Likelihood Ratio	45.294	1	.000		
Fisher's Exact Test				.000	.000
N of Valid Cases	79				
a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 12.48.					
b. Computed only for a 2x2 table					

Table 14 representing the Pearson Chi-Square

A Pearson's chi-square test of independence was conducted to examine the association in the middle of the final diagnoses determined by CT scan and those determined by US. The analysis revealed a statistically substantial association in the middle of the two diagnostic methods, $\chi 2(1, N=79)=34.620$, $p<.001$. The finding means that the outcome of the method of diagnosis is strongly connected to the outcome of the other method.

Discussion

The classification of PE into transudates and exudates forms a core faculty of a clinical diagnosis, and it is followed by the rest of the investigation and treatment. Differentiation of transudate effusions and exudate effusions lies in the difference in their origins; transudates are caused by the systemic condition and most commonly by CHF and cirrhosis, whereas exudates are local conditions that increase the permeability of the pleural membrane, like infections or malignancies. The current study aimed to assess the performance of the two modalities of USG (US The results of the study will be critically considered by putting them into perspective with contemporary scientific literature and the gaps that have been apparent and paradoxical in the middle of the diagnostic modalities as well as the diagnostic modalities and the mechanical etiologies of the concerned sample of patients.[26]

The key statistical result of the current research is an extremely high value of the Pearson chi-square test of independence, which demonstrated a clear

relationship in the middle of the eventual conclusions made by CT and USG ($\chi 2(1, N=79)=34.620$, $p<.001$). While this result correctly indicates that the diagnostic classifications of the two modalities are not independent of one another, a deeper analysis of the crosstabulation data reveals a strong relation between underlying causes and results. Of the 34 cases identified as transudative by CT, USG classified 100% as transudative. and of the 45 cases classified as exudative by CT, USG categorized the majority (64.4%) as exudative.

Conclusion

Both USG and CT reflects significant association in evaluation of Pleural Effusion and classifying its types. In Identification of Nodules and pleural thickening and better illustration of anatomical features CT scan is performing better while USG offers a non-ionizing diagnostic tool with effective sensitivity in detection of fluid characters. For appropriate management of Pleural Effusion the use of both these modalities is recommended with a clinical correlation and lab investigations to ensure maximum diagnostic accuracy.

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