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Sonographic Evaluation of Pleural Effusion

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Abstract

Background: Although at times small amounts of pleural fluid is detected on the lateral decubitus chest radiograph, this may be impossible to obtain in severely ill patients. Because of its ready availability and ability for bedside imaging, ultrasonography has become a crucial imaging modality not only in detecting the presence of pleural fluid but also as a guide to aspiration. **Aims:** To sonographically determine the nature of pleural effusions. To analyze predictability of both benign and malignant pleural effusions and to study statistical value of various ultrasound characteristics in differentiating exudative and transudative as well as benign and malignant effusions in correlation with thoracocentesis. **Material and Methods:** Sonographic feature as well as fluid cytology was evaluated. Following categorization into exudates or transudate as well as benign or malignant the diagnosis was then correlated biochemically. **Results:** Transudates were anechoic, while an anechoic effusion may be either a transudate or an exudate. Complex septation, internal echoes, thickened pleura or homogeneously echogenic patterns were always exudates. Sonographic findings of pleural nodules and associated parenchymal lesions in the lung and liver were indicative of malignancy. **Conclusions:** Ultrasound in addition to being highly sensitive for pleural effusion also aided in characterizing the nature and minimizing the complications during thoracocentesis. Pleural effusions were categorized into exudates and transudate as well as benign and malignant with a certain degree of confidence based on sonographic findings.

Keywords

Pleural Effusion, Sonography, Septation, Internal Echoes, Thoracocentesis

1. Introduction

The pleural space is an extremely thin, well defined liquid space which facilitates the sliding of lung within the chest cavity. Minimal fluid in the pleural space (5 - 20 ml) acts as an effective lubricating layer which minimizes loss of energy during the respiration and maximizes the transmission of forces from the chest wall to the lung [1].

Pleura is a serous membrane of mesodermal origin. It covers the surface of the lungs as well as [2] the inner surface of the chest wall and consists of two continuous membranes—the visceral and parietal layers.

Visceral pleura covers the lung and is adherent to all its surfaces including the surfaces within the horizontal and oblique fissures. It provides the lung with a smooth slipping surface enabling it to move freely on the parietal pleura.

Parietal pleura lines the pulmonary cavities, being adherent to the thoracic wall, the mediastinum and the diaphragm. It consists of four parts—Costal, mediastinal diaphragmatic & cervical parts. Both pleurae meet at the hilum of the lung.

The junctional lines consist of four sheets of pleura [two parietal and two visceral].

The initial method for evaluating pleural effusions was thoracic radiography. For orthostatic posteroanterior [PA] radiographs, a minimum of 175 ml of pleural fluid is needed for detection. Lateral radiographs allow detection of volumes starting from 75 ml.

Although at times small amounts of pleural fluid can be detected on the lateral decubitus chest radiograph, this may be impossible to obtain in severely ill patients. Due to its ready availability and ability for bedside imaging, sonography has become a crucial imaging modality not only in determining the presence of pleural fluid but also as a guide to aspiration [3] [4]. Sonography has been used to detect pleural effusions since the late 1960s.

The majority of pleural fluid collections is readily identified at US as anechoic or hypo echoic collections delineated by the echogenic line of visceral pleura and lung. While transudates and exudates have similar radiologic appearances, they can often be differentiated at US.

Normal lung is filled with air so that a distinct image of aerated lung is not possible with ultrasonography [**Figure 1**]. However, when the parenchyma loses air, it appears as a discreet tissue density. For example, an area of alveolar consolidation will appear as a hyper echoic structure with lung ultrasound. The findings of lung ultrasound abnormalities mainly depend on the ratio of air to fluid within the imaged structure.

Sonography has relatively high accuracy in the diagnosis pleural and peripheral lung disease, as compared to conventional radiography in the diagnosis of pleural effusion and its effect on the underlying lung. Differentiation of solid from cystic lesion and differentiating from tapable from non tapable pleural effusion is easier with sonography. It is ideal for site selection on skin to target

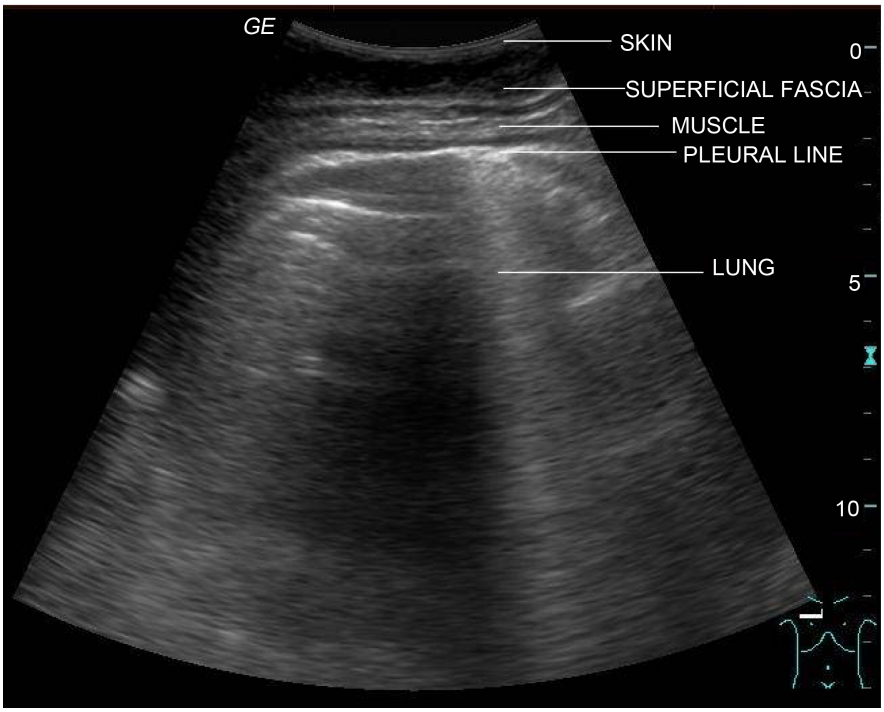

Figure 1. Normal sonographic appearance of chest wall.

measurement, wherever guided aspiration is required. Although sonography is the ideal modality for ill patient, medical literature contains only a few reports on the application of the ultrasonic technique to the diagnosis of diseases of the pleura [5] [6] [7] [8].

2. Method

The type of study was observational prospective in nature from Feb 2014 to Jan 2015. Adults of both sexes who were referred for ultrasound/guided aspiration were included in the study. Patients who refused to give consent and those with pre-existing bleeding disorders were excluded from the study.

A total of 51 patients with clinical diagnosis of pleural effusion resulting from a variety of diseases diagnosed on the basis of thorough history CT skiagram and being sent for ultrasound & ultrasound guided pleural fluid aspiration are included in the study.

Written informed consent was obtained from the patients Sonographic examination was done. We excluded all patients not willing to give consent, with pre-existing bleeding disorders and patients below 18y.

As medical records and follow up of eight of these patients were incomplete and hence they were excluded from the study.

2.1. Brief Explanation of the Procedure

Following detailed history, the patient was subjected to a thorough physical examination. Chest radiographs were taken in all patients and lateral view was taken, if necessary. The quantity of fluid, the side involved, presence of medias-

tinum lymphadenopathy, parenchymal lesions, cavitation and other radiographic abnormalities if any were noted.

Ultrasound examination included screening of Suprascapular, Scapular, Infrascapular, Superior mid axillary, Inferior mid axillary, Apical, Pectoral and Infrapectoral regions.

Thoracic sonography was performed during maximum inspiration with the patient in completely supine/sitting positions using GE Logic P5 PRO ultrasound machine with 3.5 MHz curvilinear/convex array and high frequency [7.5 - 10 MHz] linear probes as required.

With the intercostals spaces used as acoustic windows the high frequency [7.5 - 10 MHz] linear transducer applied at the latero-dorsal part of the chest wall and following findings were noted on ultrasonography, suggestive of pleural effusion.

Hypoechoic fluid separating the visceral and parietal pleura [**Figure 2**]. Moving septations in the pleural space [**Figure 3**]. Floating echogenic particles [**Figure 4**].

Moving lung suspended within the fluid. Color fluid sign on color Doppler imaging. The parietal pleura measured and defined as thickened [**Figure 5**] if the pleural thickness was 3 mm or greater. Evidence of pleural nodules which appeared as hypo echoic nodular lesions with defined margins along the parietal/visceral pleura was noted. Other associated findings such as sono air bronchogram [s/o of consolidation], pleural plaques, linear bands and loculated effusions etc noted.

Abdominal approach was used for lower extent of pleural spaces by use of convex-array [3.5 MHz] transducer directed superiorly from the abdomen with liver and spleen providing sonographic windows from the abdomen to the thorax.

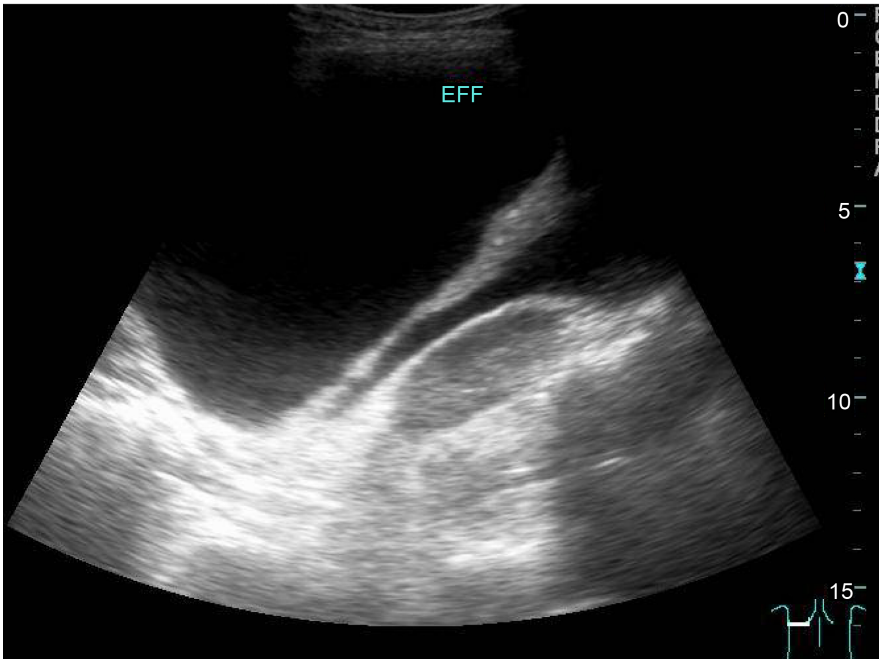

Figure 2. Sonographic appearance of an echo free pleural effusion.

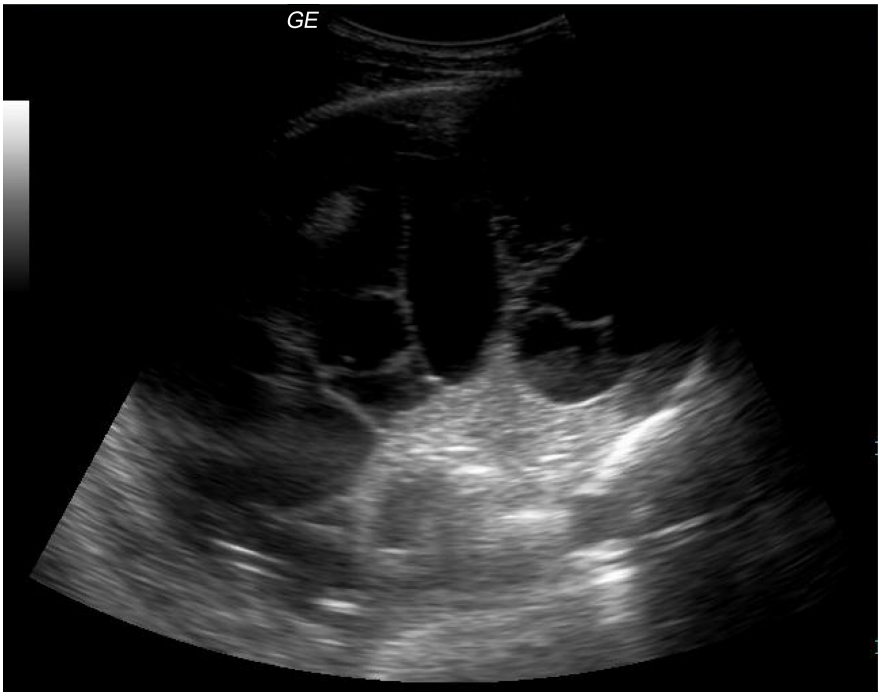

Figure 3. Sonographic septation.

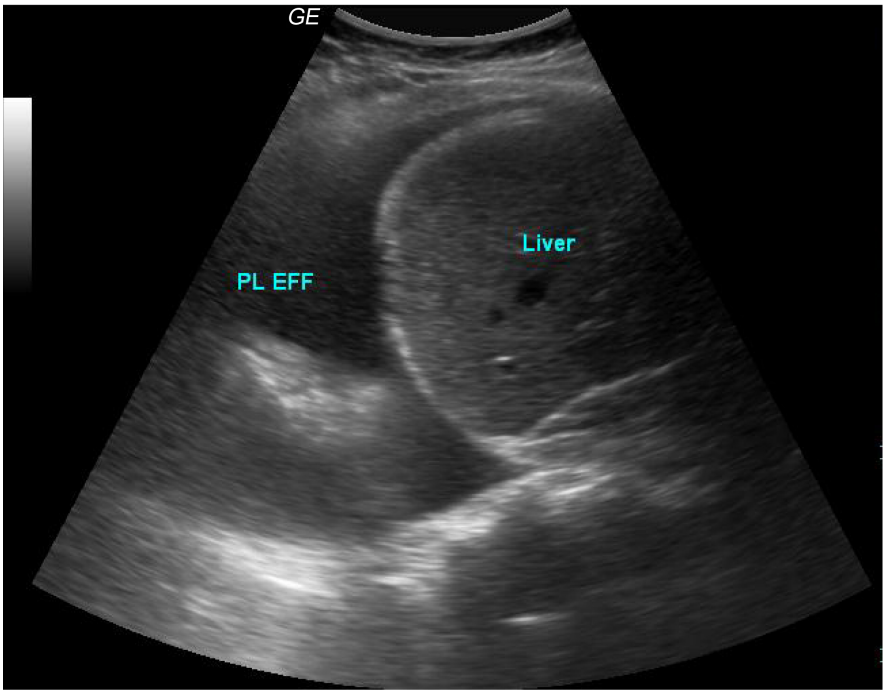

Figure 4. Sonographic appearance of echogenic effusion.

Sonographic criteria of exudative type of effusions were established based pleural effusions with septations/winding bands, echogenic pleural effusions, thickening of parietal pleura by more than 3 mm and associated pleural nodules, plaques and consolidation.

Complete serum haematological/biochemical profiles were done in every

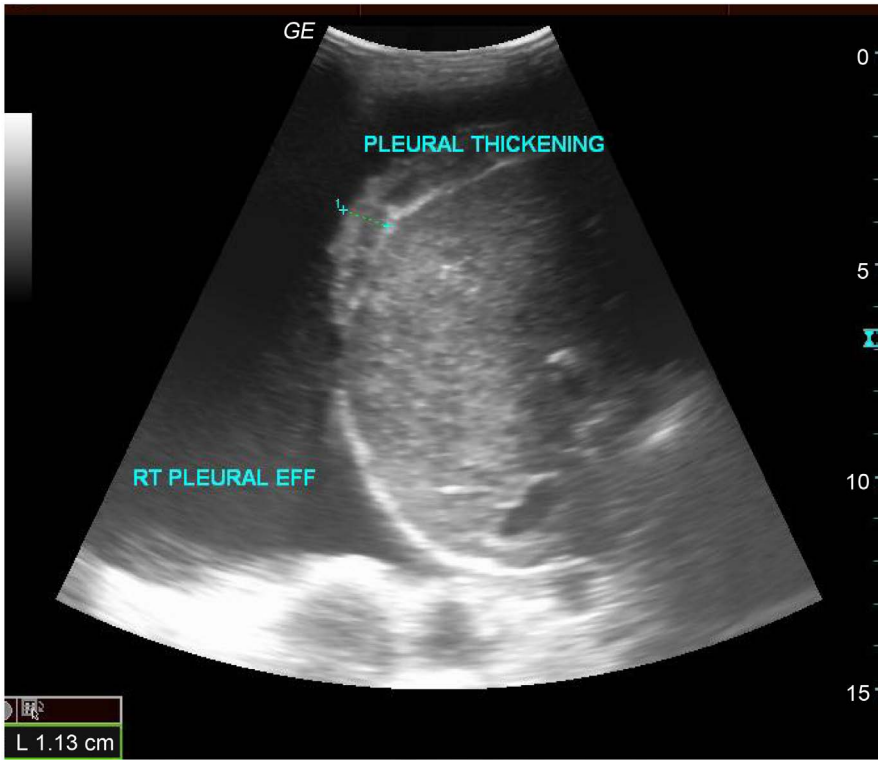

Figure 5. Sonographic appearance of pleural thickening.

patient. Following pleural fluid aspiration using standard methods [9] the nature of fluid and biochemical parameters were assessed.

2.2. Ethical Clearance

The study was approved by the Institutional Medical Ethics Committee.

2.3. Data Collection

Data was tabulated in performa sheets initially which was later entered into excel spread sheets. Biographical and other relevant details pertaining to subject were collected.

2.4. Statistical Methods

Descriptive statistical analysis was carried out in the present study. The analysed data were presented on mean and percentages. With the use of Chi-square and Fisher Exact tests the significance of the study was assessed. Other relevant diagnostic statistics such as Sensitivity, Specificity, PPV, NPV and Accuracy have been computed to evaluate the correlation between USG and Biochemical findings.

3. Results

An observational evaluation clinical study with 43 patients was undertaken to evaluate the usefulness of ultrasound to quantify, characterize the pleural effu-

sion thus correlating with laboratory analysis. The subjects aged from 18 years to 80 years (mean age 44) of whom 21 (48.8%) were males and 22 (51.2%) were females. Of the 43 patients 22 (51.2%) were from General Medicine, 17 (39.5%) were from Pulmonary medicine whereas 4 (9.3%) were from other departments.

Right sided effusion was the most common presentation accounting for 22 (58.1%) followed by left 12 (27.9%). Bilateral effusions were seen in 6 (14%). Greater proportion of patients (25 (58.1%)) had an axial diameter (inter pleural distance) less than 5 cm, while 18 (41.9%) had an inter-pleural distance greater than 6 cm.

As seen in Table 1, age did not show correlation with the nature of fluid however there was a gender predilection noted. Exudates were more common in men while transudates were more common in females. Right sided effusion were exudates predominantly with a moderately significant p value in both USG and Biochemical nature. Septations and internal echoes demonstrated strong significance in both.

As depicted in Table 2, septations and internal echoes were seen in 21 (48.8%) and 18 (41.9%) respectively. Thickened pleura was seen in 16 (37.2%) while associated parenchymal lesion and abnormal vascularity was seen in 7 (16.3%) and 2 (4.7%) patients respectively. Straw colored fluid was the more common fluid type as seen in 35 (81.4%) while hemorrhagic and other types were seen in 6 (14%) and 2 (4.7%) respectively. Sonographically 14 (32.6%) were found to have transudative type of effusion whereas 29 (67.4%) had exudative type. Likewise based on biochemical analysis 11 (25.6%) had transudative type and 32 (74.4%) were exudative. Pleural aspirates subjected to cytology reported malignancy in 7 (16.3%) and remaining 36 (83.7%) were found to be etiologically benign.

ADA was positive in 25 (58.1%) patients and culture positive in 5 (11.6%). 39 (81.4%) had a benign aetiology while 8 (18.6%) patients were found to be malignant, both sonographically and clinically.

Axial diameter, pleural thickening, parenchymal lesion, abnormal vascularity and fluid colour showed poor correlation with fluid type.

Correlation of variables with cytology/biopsy showed strong significance with respect to fluid colour and parenchymal lesions. Hemorrhagic effusion was a

Table 1. Correlation of demographics with fluid type.

Demographics	Variables	Fluid type: USG			Fluid type: Biochemical		
		Transudate (n = 14)	Exudate (n = 29)	*P* value	Transudate (n = 11)	Exudate (n = 32)	*P* value
Age in years	• <45 years	7 (50%)	14 (48.3%)	0.916	5 (45.5%)	16 (50%)	0.795
	• >45 years	7 (50%)	15 (51.7%)		6 (54.5%)	16 (50%)	
Gender	• Male	3 (21.4%)	18 (62.1%)	0.012*	3 (27.3%)	18 (56.3%)	0.097⁺
	• Female	11 (78.6%)	11 (37.9%)		8 (72.7%)	14 (43.8%)	

⁺Suggestive significance [*P* value: 0.05 < *P* < 0.10]. *Moderately significant [*P* value: 0.01 < *P* < 0.05]. **Strongly significant [*P* value: *P* < 0.01].

Table 2. Correlation of sonological parameters with nature of fluid.

Parameters	Variables	Fluid type: USG			Fluid type: Biochemical		
		Transudate (n = 14)	Exudate (n = 29)	*P* value	Transudate (n = 11)	Exudate (n = 32)	*P* value
Side	• Left	4 (28.6%)	8 (27.6%)	0.014*	4 (36.4%)	8 (25%)	0.014*
	• Right	5 (35.7%)	20 (69%)		3 (27.3%)	22 (68.8%)	
	• Bilateral	5 (35.7%)	1 (3.4%)		4 (36.4%)	2 (6.3%)	
Axial diameter	• 1 - 5 cm	9 (64.3%)	16 (55.2%)	0.570	7 (63.6%)	18 (56.3%)	0.736
	• 6 - 10 cm	5 (35.7%)	13 (44.8%)		4 (36.4%)	14 (43.8%)	
Septation	• Absent	14 (100%)	8 (27.6%)	<0.001**	11 (100%)	11 (34.4%)	<0.001**
	• Present	0 (0%)	21 (72.4%)		0 (0%)	21 (65.6%)	
Internal echoes	• Absent	14 (100%)	11 (37.9%)	<0.001**	11 (100%)	14 (43.8%)	0.001**
	• Present	0 (0%)	18 (62.1%)		0 (0%)	18 (56.3%)	
PL thickening	• Absent	11 (78.6%)	16 (55.2%)	0.137	9 (81.8%)	18 (56.3%)	0.166
	• Present	3 (21.4%)	13 (44.8%)		2 (18.2%)	14 (43.8%)	
Parenchymal lesion	• Absent	11 (78.6%)	25 (86.2%)	0.665	8 (72.7%)	28 (87.5%)	0.347
	• Present	3 (21.4%)	4 (13.8%)		3 (27.3%)	4 (12.5%)	
Abnormal vascularity	• Absent	14 (100%)	27 (93.1%)	1.000	11 (100%)	30 (93.8%)	1.000
	• Present	0 (0%)	2 (6.9%)		0 (0%)	2 (6.3%)	
Fluid color	• Straw colored	12 (85.7%)	23 (79.3%)		9 (81.8%)	26 (81.3%)	
	• Hemorrhagic	2 (14.3%)	4 (13.8%)	1.000	2 (18.2%)	4 (12.5%)	0.809
	• Others	7 (50%)	14 (48.3%)		0 (0%)	2 (6.3%)	

†Suggestive significance [*P* value: 0.05 < *P* < 0.10]. *Moderately significant [*P* value: 0.01 < *P* < 0.05]. **Strongly significant. [*P* value: *P* < 0.01].

feature of malignancy whereas straw coloured fluid was seen in both benign as well as malignant conditions. Whilst abnormal vascularity showed moderate significance with cytology biopsy, pleural thickening only suggested significance. Residual variables showed no correlation with cytology.

Correlation of clinical variables with ADA demonstrated strong significance with septations and associated parenchymal lesions ($p < 0.001$). Presence of septations and absence of parenchymal lesions favored ADA positivity. Whilst side and fluid colour suggested significance, the residual variables did not show significance. Straw coloured fluid and right sided effusions were more commonly ADA positive.

USG fluid type correlation with biochemical fluid type depicted strong significance with sensitivity of 90.63%, specificity of 100%, and positive predictive value of 100% and negative predictive value of 78.57%. Likewise, Correlation of Clinical diagnosis with USG diagnosis demonstrated a strong p value with sensitivity of 87.50%, specificity of 97.14%, positive predictive value of 87.50% and negative predictive value of 97.14%.

4. Discussion

Our study showed the mean age of incidence to be 44 yrs similar to study con-

ducted by Zay Soe *et al.* [10]. Majority of our patients were elderly belonging to age group above 60 which was contrary to findings by Anand Patel *et al.* [11]. This could possibly be due to higher incidence of diabetes, low immune status, environmental factors.

Most studies demonstrate a slight male preponderance [3] [10] [11] [12] [13] [14] [15]. However similar to findings by Jeffery R *et al.* our study showed no gender predilection. Interestingly our study demonstrated higher occurrence of transudative type of effusion in women and exudative type in men. This is somewhat similar to findings by Connolly M *et al.* [5] and Anand P *et al.* [11] where the incidence of exudative TB is nearly two fold higher in women.

Unilateral effusions were more frequently right sided, tuberculosis being the most common cause in developing countries [10]. Malignancy remains the most common cause of unilateral pleural effusion in the west [15] [16] [17] [18] [19]. This feature was well demonstrated in our study as well. Some authors however believe that there is no tendency to occur preferentially on either the right or the left side [11]. Logical explanation to this would be the anatomical nature of the right lung which acts as a natural reservoir of choice with a larger surface area.

Contrary to Kalomenidis *et al.* [12] heart failure was the most common cause of bilateral effusions (5 of 6 patients). Valdes *et al.* [13] findings were consistent with our findings. Higher rate of admission of cardiac patients could explain the above finding.

Several studies have found that pleural effusions with complex septated, complex non-septated, or homogeneously Echogenic patterns are always exudates, whereas hypo echoic effusions can be either transudates or exudates [9] [11] [13] [14] [15]. Our findings were found to be consistent with the above studies. Previous school of thought was that the use of sonography to determine the nature of pleural effusions was limited [20]-[30].

An association was demonstrated by a group of authors between Pleural thickening, complex septated pattern, fibrinous strands and tuberculosis [10] [11] [15] [26] [27] [28] [29] [30]. This association was similarly seen in our study as well.

While some studies [31] [32] found that ultrasound lacked specificity in differentiating solid from cystic areas in the pleural cavity and was poor at predicting the nature of the fluid or whether or not it is infected. Another study found that presence of a pulmonary consolidation or lung abscess may suggest an exudate of infectious origin [12] [26] [29] [30]. Our study in addition to the latter finding suggested that the associated parenchymal lesions with abnormal vascularity favored malignancy.

Hemorrhagic effusion was a feature of malignancy as seen in studies by Gopi A [31], Siebert AF [32], *et al* while straw coloured fluid was characteristic of tuberculosis. One patient however presented with a large hemorrhagic effusion which later was found to be of tubercular etiology similar to case report by Charalampos M *et al.* [12].

Similar to many studies [10] [11] elevated ADA levels was associated with tuberculosis. So were the Sonographic features of tuberculosis [Septations and consolidations].

4.1. Limitations

Study included a small group. Hence definitive criteria cannot be established based on the size. Number of patients who underwent biopsy is not significant statistically. Higher number of subjects may be required for confirmatory findings as well as arrival at definitive criteria.

4.2. Conclusions

Septations and internal echoes within a hypoechoic space were useful indicators in differentiating effusion from an underlying mass lesion.

In this study, we noticed that internal echoes and septations were a feature of all kinds of exudates, inclusive of empyema, hemothorax, synpneumonic effusions, and malignant pleural effusions.

Sometimes when the effusion was rich in protein the septa were so extensive that they had a honeycomb appearance.

Apart from the diagnostic utility in cases of pleural effusion, chest sonography also can be used to guide a percutaneous transthoracic needle for aspiration.

We may conclude that sonography is a crucial diagnostic tool for detecting presence and assessing nature of pleural effusions.

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