"EFFICACY OF ULTRASONOGRAPHY AND COMPUTED TOMOGRAPHY IN DIFFERENTIATING TRANSUDATE FROM EXUDATE IN PATIENTS WITH PLEURAL EFFUSION"

By

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In partial fulfilment of the requirements for the degree of

DOCTOR OF MEDICINE

IN

RADIODIAGNOSIS

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DECLARATION BY THE CANDIDATE

I hereby declare that this dissertation entitled **"EFFICACY OF ULTRASONOGRAPHY AND COMPUTED TOMOGRAPHY IN DIFFERENTIATING TRANSUDATE FROM EXUDATE IN PATIENTS WITH PLEURAL EFFUSION"** is a bonafide and genuine research work carried out by me under the guidance of **Dr. N. RACHE GOWDA**, Professor & H.O.D, Department of Radiodiagnosis, Sri Devaraj Urs Medical College, Kolar, in partial fulfilment of University regulation for the award "**M.D. DEGREE IN RADIODIAGNOSIS**", the examination to be held in May 2018 by SDUAHER. This has not been submitted by me previously for the award of any degree or diploma from the university or any other university.

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Dr. RAMYA CHANDRA BANDARU

LIST OF ABBREVIATIONS

ADA - Adenosine deaminase

AP - anteroposterior

CCF – congestive cardiac failure

CKD- chronic kidney disease

COPc - colloid osmotic pressure in the capillaries

COPif - colloid osmotic pressure in the interstitium

CPE - complicated parapneumonic effusions

CT – computed tomography

F – females

HPc - mean capillary hydrostatic pressure

HPif - mean interstitial, in this case intrapleural, pressure

HU – attenuation value

ICU - intensive care units

IV - intravenous

K - filtration coefficient

Kvp - Kilovolt peak

l – large

LDH - lactate dehydrogenase

M - males

m – moderate

MHz – megahertz

mm – millimeter

MRI – magnetic resonance imaging

n – number

NPV - negative predictive value

NT-proBNP - N-terminal pro-b-type natriuretic peptide

PA – posteroanterior

PE – pulmonary embolism

LIST OF ABBREVIATIONS

PPE – parapneumonic effusion

PPV - positive predictive value

RA – rheumatoid arthritis

ROC – receiver operating characteristic curve

s – small

SD – standard deviation

TB - tuberculosis

USG – ultrasonography

ABSTRACT

Introduction:

Pleural effusion is a commonly encountered clinical problem. The first step in assessing pleural effusion is to decide whether the pleural fluid is a transudate or an exudate. Ultrasonography and computed tomography are frequently used to evaluate pleural effusion and associated conditions.

Although clinical and radiological findings may provide significant evidence about the cause of pleural effusion, diagnostic thoracocentesis may still be necessary to evaluate the nature of pleural effusion which is associated with certain complications and has some relative contradictions.

We evaluated the efficacy of USG & MDCT in distinguishing the nature of pleural effusion which could act as a non-invasive tool and would be beneficial in patient management.

Aims and objectives:

1. To evaluate USG and CT findings in differentiating transudative and exudative pleural effusion and to correlate with biochemical and cytological analysis.
2. To assess USG and CT findings for the probable etiology.

Materials and methods:

This prospective observational study included 80 patients with pleural effusion who were referred to department of Radio-Diagnosis at R. L. Jalappa Hospital and Research Center attached to Sri Devaraj Urs Medical College for USG, MDCT and underwent diagnostic thoracocentesis. Pleural effusions were classified as exudates or transudates according to the Light's criteria. USG appearances and CT attenuation values along with additional findings like presence of pleural thickening, pleural nodules and loculation were evaluated.

Results:

Twenty four (30%) of the 80 pleural effusions were transudates and 56 (70%) were exudates. Transudative effusions were more often bilateral (87.5 %) in comparison to exudative effusions which were unilateral (89.2 %). Transudative effusions were always anechoic (100%). Exudative effusions were complex septated (62.5%), echogenic (25%) or complex non-septated (8.9%) on ultrasound with very few being anechoic (3.5%).

Loculations were better appreciated on ultrasound than CT. Pleural thickening and pleural nodules were better seen on CT compared to USG. Mean attenuation values were significantly higher in exudative (14.65 ± 6.07; mean ± SD, range: 4.5 to 34) effusions than transudates (4.66 ± 2.29; mean ± SD, range: 1.3 to 8.2) with a P value <.001.

Effusions can be considered as transudative if the CT attenuation value is < 8, with a sensitivity of 91.6%, specificity of 82.7%, PPV of 73.3% and NPV of 96% with a significant P value < 0.001.

Pleural thickening, nodules and loculations were seen commonly in exudates than transudates with a high specificity (91.6 %, 95.8% and 100% respectively), although they are less sensitive.

Conclusion:

We conclude that ultrasonography is a very helpful non-invasive and bedside tool in determining the nature of pleural effusion. CT attenuation values play a useful role in differentiating the nature of pleural effusion. Transudative effusions can be considered when HU values are < 8, where diagnostic thoracocentesis associated with potential complications could be avoided. As there is an overlap in HU values, correlation with additional CT findings like pleural thickening, pleural nodules and loculations which show higher prevalence among exudative effusions is necessary.

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INTRODUCTION

Pleural effusion is a common clinical problem and can arise from many diseases[1,2,3,4]. The first step in assessing pleural effusion is to decide whether the pleural fluid is a transudate or an exudate[1]. Transudate is caused by imbalances in hydrostatic and oncotic forces. It results from diseases such as heart failure, kidney failure, and cirrhosis. However, an exudate occurs when local factors influencing the accumulation of pleural fluid are altered. Exudates can be caused by clinical conditions such as pneumonia, malignancy, chylothorax and pulmonary embolism (PE)[1,4,5].

Several imaging methods such as conventional radiography, ultrasonography (USG), computerized tomography (CT) scan and magnetic resonance imaging (MRI) are being used to diagnose and assess the etiology of pleural effusion[6]. Ultrasonography is the most commonly used modality with higher accuracy in detecting pleural effusion in comparison with chest X-rays (93% vs. 47%)[7,8]. It has a much higher sensitivity than conventional radiology in the diagnosis of small amounts of effusion, nature of effusion[9] and differentiation of the loculated pleural fluid and the thickened pleura5,7[,10,11,] CT is frequently used to assess patients with pleural abnormalities associated with neoplasm, pneumonia, and empyema. It has better spatial resolution in detection of pleural nodules and pleural thickening, which help in discrimination of transudates and exudates4.

Although clinical and radiological findings may provide significant evidence about the cause of pleural effusion, diagnostic thoracocentesis may still be necessary to evaluate some cases to differentiate the nature of pleural effusion using Light's criteria[12]. However, diagnostic thoracentesis is associated with certain complications like pain, hematoma, pneumothorax and splenic laceration and also has some relative contradictions such coagulation disorders, inability of patient to cooperate and skin disease at the puncture site[1,3,13].

As there is paucity of literature regarding the use of ultrasonography, CT attenuations values and associated findings as an aid in characterizing pleural effusion in Indian subcontinent, evaluating such a non-invasive tool would be beneficial for patients with contradictions to invasive diagnostic methods and helps in further management.

AIMS AND OBJECTIVES

The objectives of the study are as follows:

1. To evaluate USG and CT findings in differentiating transudative and exudative pleural effusion and to correlate with biochemical and cytological analysis.
2. To assess USG and CT findings for the probable etiology.

REVIEW OF LITERATURE

ANATOMY OF PLEURA

Each lung is covered by pleura, a serous membrane arranged as a closed invaginated sac which is divided into visceral and parietal pleura. The visceral or pulmonary pleura adheres closely to the pulmonary surface and its interlobar fissures. The parietal pleura, lines the corresponding half of the thoracic wall and covers much of the diaphragm and structures occupying the middle region of the thorax. The visceral and parietal pleurae are continuous with each other around the hilar structures, and they remain close, though sliding, are in contact at all phases of respiration[14].

The potential space between them is the pleural cavity, which is maintained at a negative pressure by the inward elastic recoil of the lung and the outward pull of the chest wall. The right and left pleural sacs form separate compartments and touch only behind the upper half of body of the sternum, although they are also close to each other behind the oesophagus at midthoracic level. The region between them is the mediastinum (interpleural space)[14].

Because the total thickness of the pleural space and its visceral and parietal pleurae is only 0.2-0.4 mm, it is not usually identified on plain radiographs or CT scans except when outlined by extrapleural fat fascia[15]. The interlobar fissures and posterior azygo-oesophageal and retrosternal pleural reflections are the only aspects of normal pleura that can be visualized on a chest radiograph or CT scan (Figure 1-4)[14].

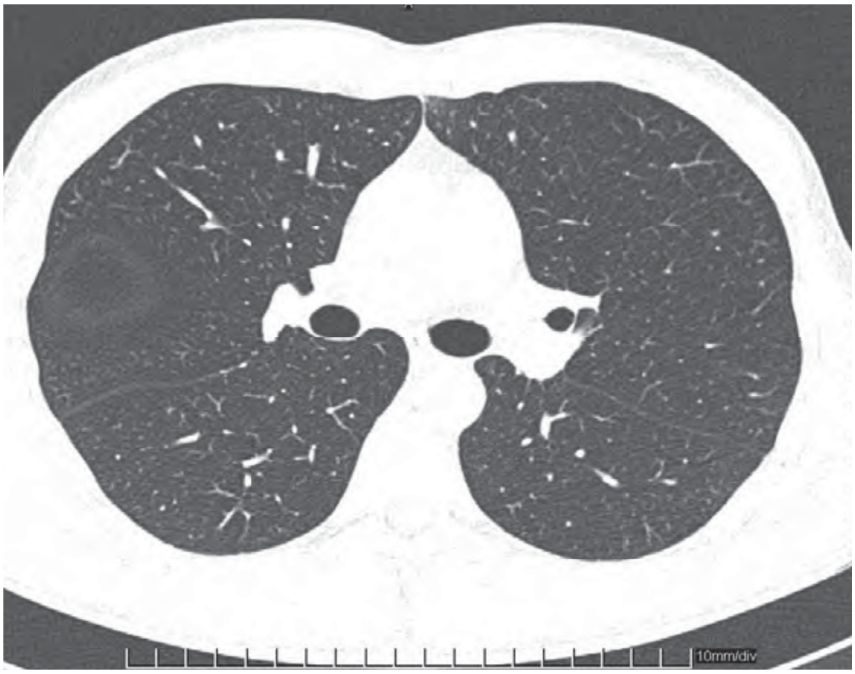

Figure 1: Axial section of lungs below the carina demonstrates the left and right major fissures. The circular avascular area anterior to the right major fissure and surrounded by a halo of white is due to the horizontal (minor) fissure.

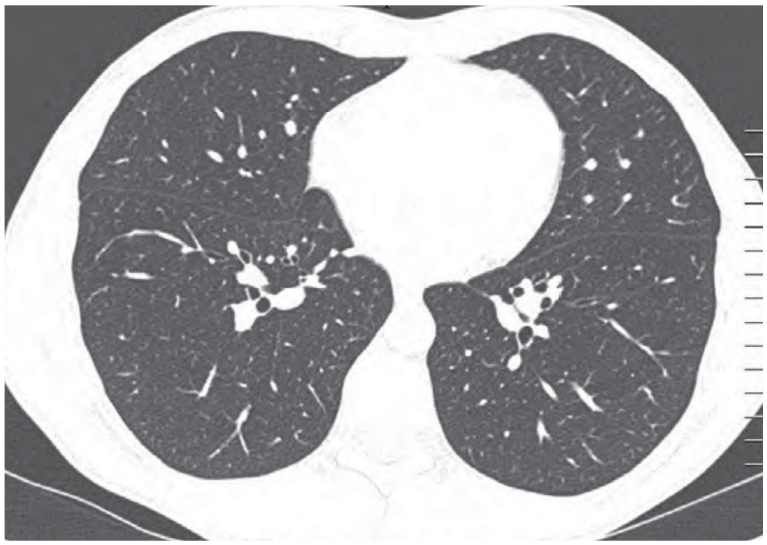

Figure 2: Axial section through the lungs at the mid left atrial level demonstrating the left and right major fissures as they pass more anteriorly and separate the lower lobes from the lingula and middle lobes

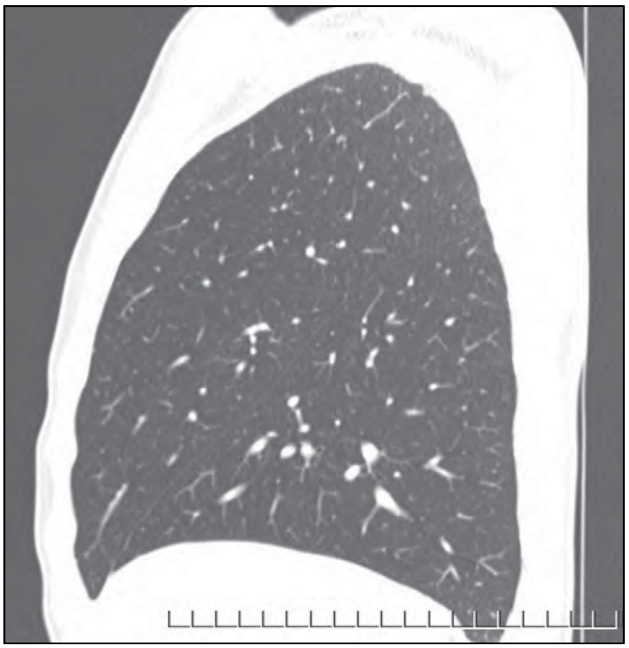

Figure 3: Sagittal section through the right lung demonstrating the major and minor fissures.

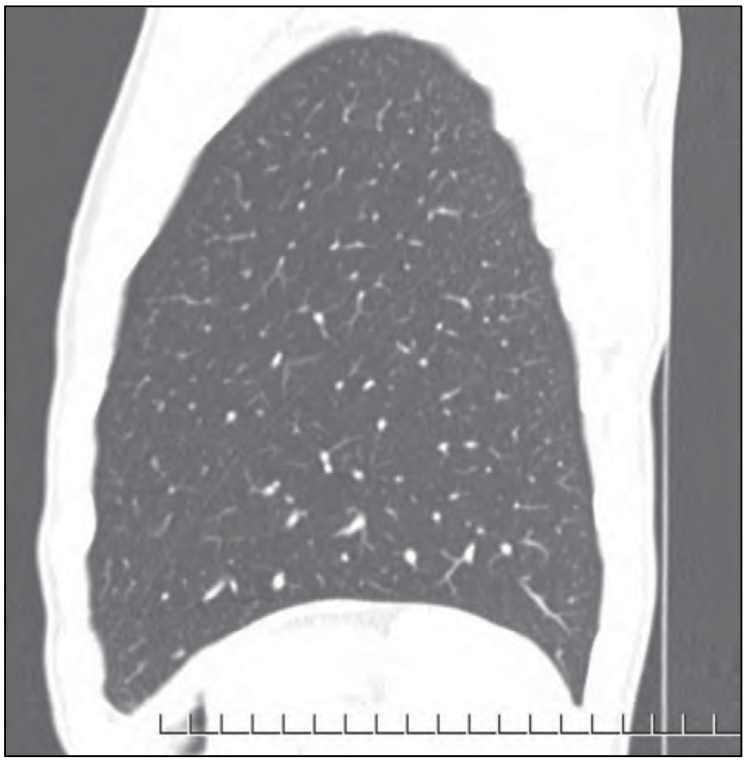

Figure 4: Sagittal section through the left lung demonstrating the major fissure.

Different regions of parietal pleura are customarily distinguished as following[14]:

- Costovertebral pleura - lines the internal surface of the thoracic wall and the vertebral bodies.
- Diaphragmatic pleura - lines the thoracic surface of the diaphragm.
- Cervical pleura - lies over the pulmonary apices.
- Mediastinal pleura - lies between the lungs.

Costovertebral pleura

Costovertebral pleura lines the sternum, ribs, transversus thoracis and intercostal muscles and the sides of the vertebral bodies; normally it is easily separated from these structures. Anteriorly, the costal pleura begins behind the sternum, where it is continuous with the mediastinal pleura along a junction extending from sternoclavicular joint to the midline behind the sternal angle, inferomedially. From here, the right and left costal pleurae descend in contact with each other to the level of the fourth costal cartilages and then diverge. On the right side, the line descends to the back of the xiphisternal joint, while on the left the line diverges laterally and descends at a distance of 2–2.5 mm from the sternal margin to the sixth costal cartilage, forming the cardiac notch. On each side, the costal pleura sweeps laterally, lining the internal surfaces of the costal cartilages, ribs, transversus thoracis and intercostal muscles. Posteriorly, it passes over the sympathetic trunk and its branches to reach the sides of the vertebral bodies, where it is again continuous with the mediastinal pleura[14].

The costovertebral pleura is continuous with the cervical pleura at the inner margin of the first rib and it becomes continuous with the diaphragmatic pleura below. On the right, this line of costodiaphragmatic reflection begins behind the xiphoid process, passes behind the seventh costal cartilage to reach the eighth rib in the midclavicular line, the tenth rib in the midaxillary line, and then crosses the twelfth rib level to the upper border of the twelfth thoracic spine. On the left, the line initially follows the ascending part of the sixth costal cartilage, but then follows a course similar to that on the right, although it may be slightly lower[14].

Diaphragmatic pleura

The diaphragmatic pleura is a thin, tightly adherent layer which covers most of the upper surface of the diaphragm. It is continuous with the costal pleura and with the mediastinal pleura along the line of attachment of the pericardium to the diaphragm on its medial aspect[14].

Cervical pleura

The cervical pleura is a continuation of the costovertebral pleura over the pulmonary apex. It ascends medially from the internal border of the first rib to the apex of the lung, as high as the lower edge of the neck of the first rib, and then descends lateral to trachea to become the mediastinal pleura. As a result of the obliquity of the first rib, the cervical pleura extends 3–4 cm above the first costal cartilage, but not above the neck of the first rib. The cervical pleura is strengthened by a fascial suprapleural membrane, which is attached in front to the internal border

of the first rib, and behind to the anterior border of the transverse process of the seventh cervical vertebra. It contains a few muscular fibres, which spread from the scaleni. Scalenus minimus extends from the anterior border of the transverse process of the seventh cervical vertebra to the inner border of the first rib behind its subclavian groove, and also spreads into the pleural dome, which it therefore tenses: it has been suggested that the suprapleural membrane is the tendon of scalenus medius.

The cervical pleura (like the pulmonary apex) reaches the level of the seventh cervical spine approximately 2.5 cm from the midline. Its projection is a curved line from the sternoclavicular joint to the junction of the medial and middle thirds of the clavicle, its summit being 2.5 cm above it. The subclavian artery ascends laterally in a furrow below the summit of the cervical pleura (Figure **5**)[14].

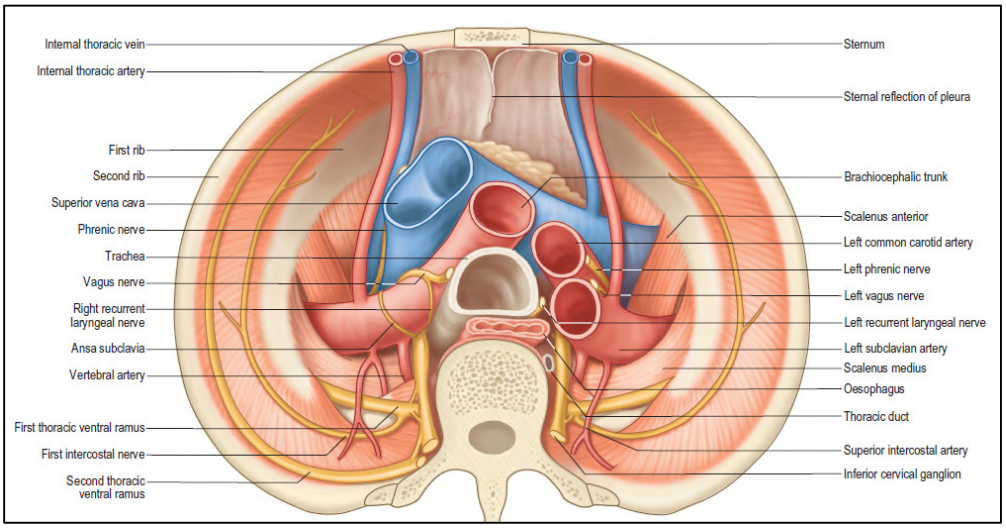

Figure 5: Structures related to the cervical pleura, as seen from below.

Mediastinal Pleura

The mediastinal pleura is the lateral boundary of the mediastinum and forms a continuous surface above the hilum of the lung from sternum to vertebral column. On the right it covers the right brachiocephalic vein, the upper part of the superior vena cava, the terminal part of the azygos vein, the right phrenic and vagus nerves, the trachea and oesophagus. On the left it covers the aortic arch, left phrenic and vagus nerves, left brachiocephalic and superior intercostal veins, left common carotid and subclavian arteries, thoracic duct and oesophagus. At the hilum of the lung it turns laterally to form a tube that encloses the hilar structures and is continuous with the pulmonary pleura[14].

Visceral Pleura

The pulmonary pleura is inseparably adherent to the lung over all its surfaces, including those in the fissures, except at the root or hilum of the lung and along a line descending from this, which marks the attachment of the pulmonary ligament (Figure 6).

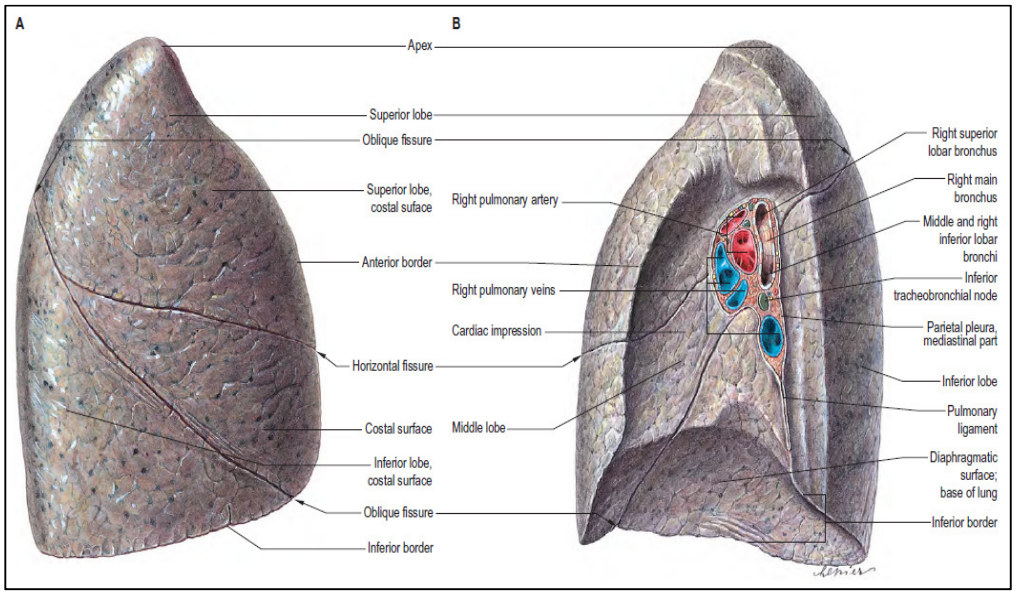

Figure 6: The right lung. A, Lateral surface. B, Medial surface.

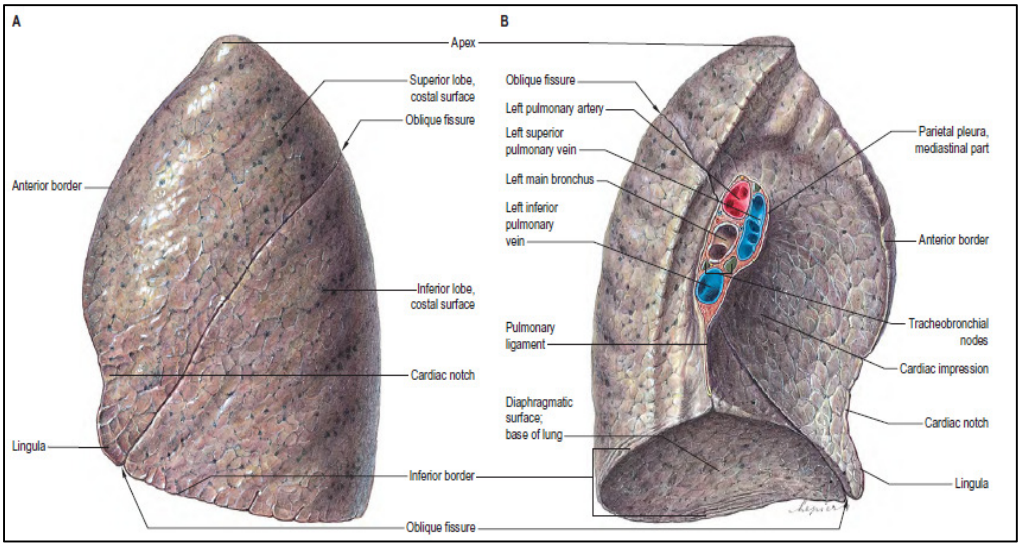

Figure 7: The left lung. A, Lateral surface. B, Medial surface.

Inferior Pulmonary Ligaments

Below the hilum the mediastinal pleura extends as a double layer, the pulmonary ligament, from the lateral surface of the oesophagus to the mediastinal surface of the lung, where it is continuous with the parietal pleura (Figure 6 & Figure 7). It is continuous above with the pleura around the hilar structures and below it ends in a free sickle-shaped border[14].

Pleural Recesses

The pleura extends considerably beyond the inferior border of the lung, but not as far as the attachment of the diaphragm, which means that the diaphragm is in contact with the costal cartilages and intercostal muscles below the line of pleural reflection from the thoracic wall to the diaphragm. In quiet inspiration the inferior margin of the lung does not reach this reflection, and the costal and diaphragmatic pleurae are separated merely by a narrow slit, the costodiaphragmatic recess. In quiet inspiration the lower limit of the lung is normally 5 cm above the lower pleural limit[14].

A similar costomediastinal recess exists behind the sternum and the costal cartilages, where the thin anterior margin of the lung falls short of the line of pleural reflection. The extent of this recess, the anterior costomediastinal line of pleural reflection, and the position of the anterior margin of the lung all exhibit individual variation. The inferior border of the right costodiaphragmatic recess is an important consideration in the surgical posterior approach to the kidney. Usually the pleura crosses the twelfth rib at the lateral border of erector spinae, so that the medial

region of the kidney is above the pleural reflection. However, if the twelfth rib does not project beyond the muscle, the eleventh rib may be mistaken for the twelfth in palpation, and an incision prolonged to this level will damage the pleura. Whether the lowest palpable rib is the eleventh or twelfth can be ascertained by counting from the second rib (identified at its junction with the sternal angle)[14].

Normally, the intercostal stripe is visible as a thin white line. Although it represents the combined thickness of visceral and parietal pleurae, the fluid-filled pleural space, endothoracic fascia, and innermost intercostal muscle, it primarily represents the innermost intercostal musde. The intercostal stripe is seen as separate from the more external layers of the intercostal musdes because of a layer of intercostal fat. Posteriorly, the intercostal stripe is visible anterior to the lower edge of a rib. Only a very thin line (i.e., the paravertebral line) is visible in the paravertebral region (Figure 8)[15].

External to the parietal pleura is a layer of loose areolar tissue (extrapleural fat), which separates the parietal pleura from the endothoracic fascia. This fatty layer is very thin in most locations but can be markedly thickened over the lateral or posterolateral ribs, resulting in extrapleural fat pads several millimeters thick. The thoracic cavity (Figure 9) is lined by the fibroelastic endothoracic fascia that covers the surface of the intercostal muscles and intervening ribs, blends with the perichondrium and periosteum of the costal cartilages and sternum anteriorly and posteriorly is continuous with the prevertebral fascia that covers the vertebral bodies and intervertebral discs[15].

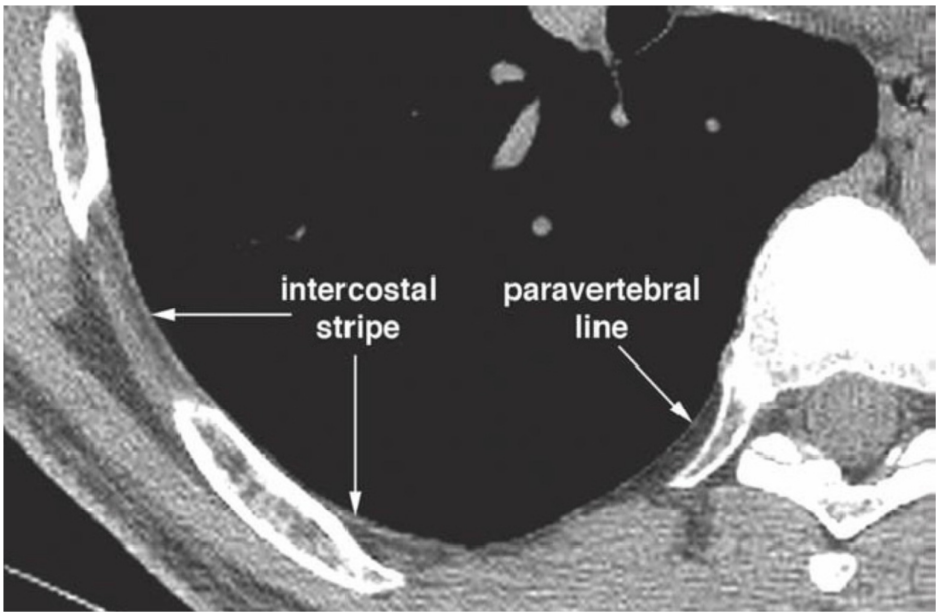

Figure 8: On HRCT in a normal subject, thin white line which represents the intercostal stripe and paravertebral line

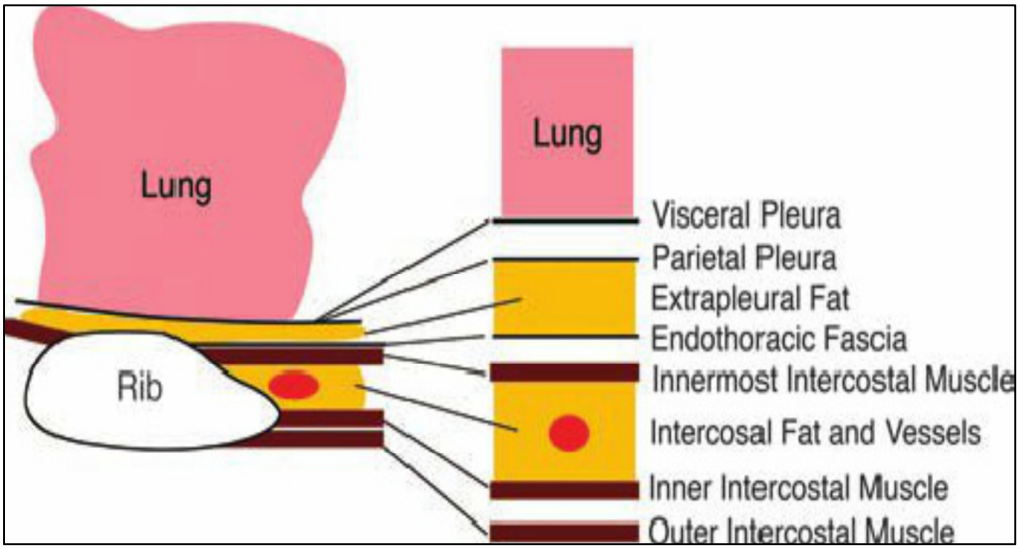

Figure 9: Normal structures at the pleural surface

Vascular Supply and Drainage:

The parietal pleura is supplied by systemic capillary vessels and drains into the right atrium via the azygos, hemiazygos, and internal mammary veins. The visceral pleura is supplied by pulmonary arterial capillaries and drains mainly into the pulmonary veins[16,17,18](Figure 10).

Normal pleural fluid essentially represents interstitial fluid from the parietal pleura, which, being supplied and drained by systemic vessels, has higher capillary hydrostatic pressure than the pleural space[16,19]. Because the visceral pleura is supplied and drained by the low-pressure pulmonary circulation under normal circumstances, it probably contributes very little to pleural fluid formation and it may absorb fluid formed by the parietal pleura[16,18,19].

Lymphatic drainage:

Lymphatic drainage of the visceral pleura is by way of a lymphatic plexus that covers the surface of the lung just beneath the visceral pleura[20,21,22]. This elaborate plexus connects to bronchial lymphatics that drain centrally along the bronchovascular bundles to the pulmonary hilum, but these lymphatics do not communicate with the pleural space[20,22,23].

The parietal pleura is the primary drainage route for the pleural space. It begins with lymphatic stomata located mainly in the mediastinal, intercostal, and diaphragmatic portions of the parietal pleura[16,19]. The stomata connect with lymphatic lacunae located just beneath the mesothelial layer. These drain into larger

lymphatic channels to the intercostal, internal mammary, and mediastinal lymph node chains and eventually into the mediastinum, right lymph duct, and thoracic duct[16,18,19,20].

The pleural space contains only a thin coating of fluid[16,20,23]. Fluid moves across the capillary membranes of the visceral pleura into the pleural space and then is reabsorbed by the lymphatic system[20,24](Figure 10).

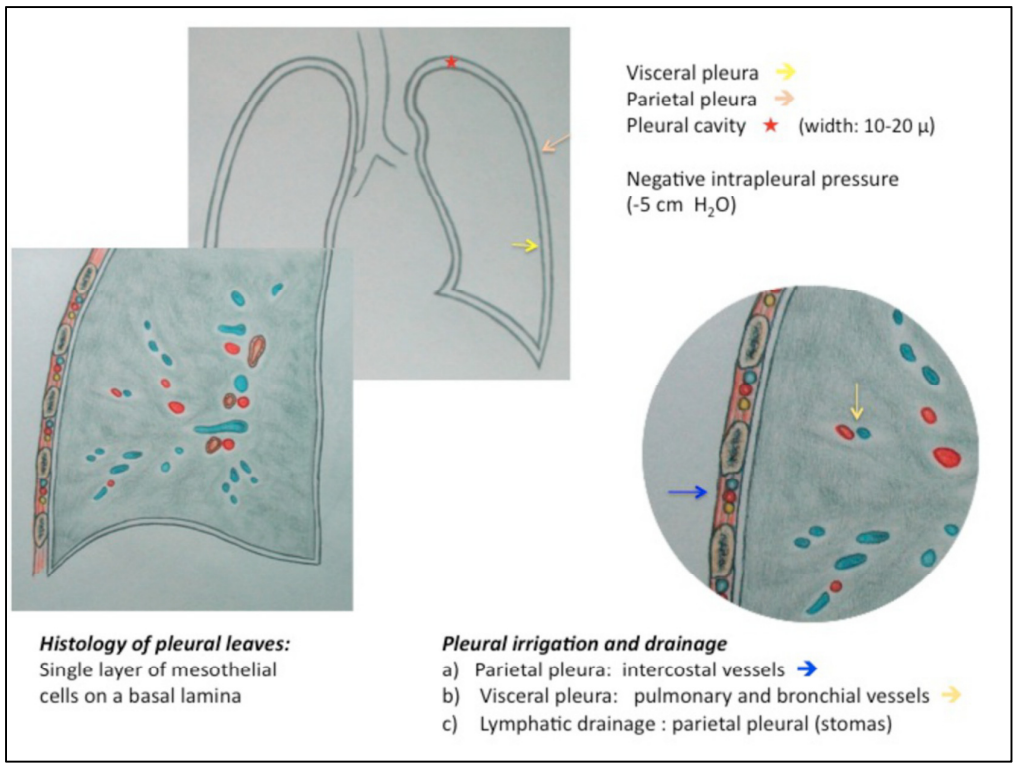

Figure 10: Normal pleura, its blood supply and drainage.

Pleural Fluid Formation

Normally, approximately 10 ml of pleural fluid is formed each day[16,19]. The formation of pleural fluid, like that of interstitial fluid, can be explained by the Starling equation transcapillary exchange of fluid[16,25].

According to the Starling equation,

Fluid movement = k(HPc - HPif) - (COPc - COPif), in which

k = filtration coefficient;

HPc = mean capillary hydrostatic pressure;

HPif = mean interstitial, in this case intrapleural, pressure;

COPc = colloid osmotic pressure in the capillaries; and

COPif = colloid osmotic pressure in the interstitium, that is pleural space.

Increased pleural fluid may result from one of six mechanisms[16,19]:

- Increase in hydrostatic pressure in the microvascular circulation. The most common causes are increased systemic venous pressure and increased pulmonary capillary wedge pressure in congestive heart failure[16,26,27].
- Decrease in oncotic pressure in the microvascular circulation as seen in patients with hypoalbuminemia.
- Decrease in pressure in the pleural space. Atelectasis due to any cause can lead to a more negative intrapleural pressure and thus favor the development of pleural effusion[16,28].
- Increased permeability of the microvascular circulation, such as is seen in inflammatory and neoplastic processes of the pleura.

- Impaired lymphatic drainage from the pleural space resulting from blockage in the lymphatic system due to tumor or fibrosis.
- Movement of fluid from the peritoneal space via diaphragmatic lymphatic vessels or through diaphragmatic defects.

Pleural Fluid Analysis by Lights Criteria

Clinically, it is important to determine whether the effusion is a transudate or exudate which result from different mechanisms[16,29].

Transudates result from an increase in the capillary hydrostatic pressure or a decrease in colloid osmotic pressure. When a transudate is diagnosed, no further diagnostic procedures are required and treatment is directed to the underlying cause, most commonly congestive heart failure[16,29].

Exudates most commonly result from an increase in the permeability of the microvascular circulation due to inflammatory or neoplastic processes The presence of an exudate usually requires thorough investigation to determine the cause of the pleural effusion.

Classically, pleural fluid protein >30 g/l indicates an exudate and <30 g/l a transudate. This classification is not accurate when serum protein is abnormal or when the pleural fluid protein is close to 30 g/l and, as this is very common, the application of Light's criteria is always recommended[33].

An exudate is considered to be present when the pleural fluid meets at least one of the following three Light's criteria[16,29,30].

- Pleural fluid protein divided by the serum protein greater than 0.5;
- Pleural fluid lactate dehydrogenase (LDH) level divided by the serum LDH level is greater than 0.6; or
- Pleural fluid LDH level is greater than two thirds of the upper limit of normal for the serum LDH level.

Pitfalls in light's criteria

Although Light's criteria are almost 100% sensitive for exudates, patients with heart failure on diuretics have also met Light's criteria for an exudate[31,32,33]. In such instances, additional biochemical criteria mainly the serum-effusion protein or albumin gradients are useful to make an accurate diagnosis

- Serum protein minus fluid protein < 31 gr /l[34]
- Serum albumin minus fluid albumin < 12 gr /l[35]

Of note, a large percentage of exudates will be misclassified if these gradients are used as the only method of differentiating between transudates and exudates[12]. Various other tests can be used to determine the nature and etiology of a pleural fluild (Table 1).

Table 1: Pleural Fluid Tests Performed in Patients with Pleural Effusion[12,32,33,36].

Test	Test value	Suggested diagnosis
Biochemical analysis		
Lactate dehydrogenase (LDH) LDH fluid to serum ratio Protein fluid to serum ratio	>2/3rd of upper limits of normal for serum LDH >0.6 >0.5	Any condition causing an exudate
Adenosine deaminase (ADA)	>40 U per L	Tuberculosis (TB)
Glucose	<60 mg per dL	CPE/empyema, TB, malignancy, Rheumatiod arthritis (RA)
Amylase	>Upper limit of normal	Pancreatic disease, Esophageal rupture
Cholesterol	>45 to 60 mg/dl	Any condition causing an exudate
pH	<7.20	Empyema, Esophageal rupture, RA, Malignancy
PCR	Positive	TB or other infection
Triglycerides	>110 mg per dL	Chylothorax
Interferon	Different cutoff points	TB
NT-proBNP	>1,500 pg per mL	Heart failure
Tumor markers*	>Upper limit of normal	Malignancy
Histopathological analysis		
Cytology	Neoplastic cells seen	Malignancy
Red blood cell count	>100,000 per mm3	Malignancy, trauma, parapneumonic effusion (PPE), PE
WBC and DLC • • Lymphocytes • Neutrophils	>10,000 per mm3 >50 percent >50 percent	Empyema, other exudates (uncommon) Malignancy, TB, PE, coronary artery bypass surgery PPE, PE, abdominal diseases
Microbiological analysis		
Culture	Positive	Infection
Zielh Lowenstein stain	Positive	tuberculosis
Gram stain	Positive	Bacterial pneumonia

*ADA = adenosine deaminase; NT-proBNP = N-terminal pro-b-type natriuretic peptide.*For example, carcinoembryonic antigen (CEA), CA 15.3 and CA 549 (markers for breast carcinoma), CYFRA 21-1 (marker for lung carcinoma), CA 125 (marker for ovarian and endometrial carcinoma), human epidermal growth factor receptor (HER-2/neu) gene amplification.*

Etiology of Pleural Effusion

Pleural effusion may result from variable causes (Table 2). Categorisation of pleural effusions into transudates and exudates is an important early step in narrowing the differential diagnosis[33]. The most common conditions that result in effusions are cardiac failure, pneumonia, and malignant neoplasm[32].

Table 2: causes of pleural effusion

Incidence	Transudate	Exudate
Commonest	Congestive cardiac failure Cirrhotic liver disease	Parapneumonic effusions Empyema Malignant neoplasm
Less common	Hypoalbuminaemia Peritoneal dialysis Hypothyroidism Nephrotic syndrome Mitral stenosis	Pulmonary embolism Rheumatoid arthritis and other autoimmune pleuritis Benign asbestos effusion Pancreatitis Dressler syndrome
Rare	Constrictive pericarditis Urinothorax Meigs' syndrome Superior vena cava obstruction Ovarian hyperstimulation Pulmonary embolism	Subphrenic, hepatic, or splenic abscess Chylothorax Drug induced Radiotherapy Esophageal rupture Yellow nail syndrome (and other lymphatic disorders eg, lymphangioleiomyomatosis)

Congestive cardiac Failure

Pleural effusion is present in about half of patients with CCF. CCF is the most common cause of transudative effusion, although exudative effusions may also occur following diuretic therapy. Pleura fluid accumulates in CCF primarily because pulmonary interstitial edema: fluid crosses into the pleural space. Bilateral effusions are present in 70% of cases; when unilateral, pleural effusion is more common on the right (20%) than on the left (10%). Although unilateral effusion may be seen, a large unilateral pleural effusion suggests an alternative diagnosis. They may be associated with features of pulmonary edema or pericardial effusion[15].

Cirrhotic liver disease

Cirrhosis is associated with pleural effusion, but the frequency of effusion is much higher if ascites is present. Effusions are typically right-sided or bilateral; isolated left-sided effusions are less common. Most important in the development of effusion is the passage of fluid into the chest through diaphragmatic defects. Reduction in plasma oncotic pressure due to hypoalbuminemia may also contribute to the formation of effusions. The effusions are transudates and may be large[15].

Pleural disease from infection

Pleural effusion is common in patients with pneumonia, termed parapneumonic effusion (PPE). It can be simple or complex, which can be differentiated by pleural fluid analysis[15,20]. PPE are typically exudates; they are small and sterile and have normal glucose and pH values.

While simple parapneumonic effusions are treated conservatively with appropriate antibiotics for the underlying pulmonary infection, empyemas and complicated parapneumonic effusions (CPE) require chest tube drainage in addition to antibiotics[16,20].

Empyemas develop in three distinct phases that have important therapeutic implications. Acutely, during the exudative phase, inflammation of the visceral pleura results in increased capillary permeability and weeping of high protein fluid into the pleural space without significant thickening of the pleural surfaces[20]. They are small to moderate in size and are dependent in location. They do not show evidence of loculations. They show a meniscus on plain radiographs, and appear crescent-shaped on CT[15,16].

In the fibrinopurulent phase, inflammatory cells and neutrophils pour into the pleural space and fibrin is deposited on the inflamed pleural surfaces. On CT, elliptical or lenticular shape in nondependent location with sharp demarcation from the adjacent lung[15]. It typically shows thickened visceral and parietal pleurae separated by fluid the "split pleura" sign[15,20].

In the organizing phase of empyema, recruitment of fibroblasts and capillaries results in deposition of collagen and granulation tissue along the visceral and parietal surfaces, producing pleural fibrosis[20]. Smooth pleural thickening is typically visible on plain radiographs or CT. Extrapleural fat thickening is frequently visible on CT, separating the thickened parietal pleura from the intercostal muscle or rib. Calcification, which usually is focal in its early stages, may become extensive[15].

Neoplasm

Pleural effusion is common in patients with primary or metastatic pleural tumors. Effusions are usually exudative and may be bloodstained. Malignant effusions are always exudates, but not all exudative effusions in cancer patients are malignant. Exudative effusions in patients with malignancy may reflect pleural involvement by tumor, lymphatic obstruction, or pneumonia[15].

Malignant effusions may be small or large and unilateral, bilateral, or asymmetrical. A large unilateral effusion suggests malignancy or infection[15]. The most common causes of malignant effusion are lung cancer (40% of cases) and breast cancer (20% of cases)[16,20]. Pleural fluid cytology is positive in 80% to 90% of patients with pleural malignancy, with the highest frequency in patients with adenocarcinoma[15].

Nodular pleural thickening at chest radiography or CT is often the first indication of a malignant pleural effusion. Malignant pleural effusions are usually due to metastasis (95% of cases), with mesothelioma being a relatively rare cause (5% of cases). Other tumors that affect the pleura include lymphoma (10% of eases) and metastatic carcinoma of the colon, pancreas, kidney, or ovary[20].

Imaging of pleural effusion

Radiographic Findings

The initial method for evaluating pleural effusions was thoracic radiography. On orthostatic PA radiographs, presence of at least 175 ml of pleural fluid usually leads to blunting of the lateral costophrenic sulcus, although sometimes up to 500 ml or even more may be present without any blunting[15,15,37,38]. Lateral radiographs allow diagnosis with volumes starting from 75 ml, since the fluid tends to first accumulate in the posterior costophrenic recess[15,37].

Radiographs in the supine position show lower sensitivity, and sometimes large effusions can be missed if they are bilateral[16,37]. The main sign that leads to a diagnosis of pleural effusion from supine radiographs is greater opacity of the hemithorax, with no blurring of vascular structures[16,37]. The view that is most sensitive for detecting fluid in the pleural space is lateral decubitus, which can detect effusions starting at 5 ml[37,39]. However, not all patients can undergo this radiographic view, especially patients in intensive care units (ICUs) and trauma victims in the emergency room. Some technical issues can further limit the quality of the radiographs produced when the patient is on a bed, such as movement of the thoracic wall, patient rotation and supine position with the film placed behind the patient and short focus film distance[8,37].

Presence of pleural fluid is easily confirmed using ultrasonography, especially in ICU patients and in cases of loculated effusion.

Ultrasonography

Sonography has been used to detect pleural effusions since the late 1960s[37,40]. A study in 1976, using A-mode sonography to detect pleural effusion found sensitivity of 93%[37,41]. Other studies have been conducted over the years, many of them comparing the sensitivity of sonography and radiography, and better results have been shown with sonography. However, the use of sonography is not as widespread as the use of radiography for this purpose.

Although small amounts of pleural fluid can be detected on the chest radiograph obtained with the patient in the lateral decubitus position, this may be impossible to obtain in severely ill patients[16]. In recent years, studies have shown that sonography achieves better results than radiography in measuring the effusion volume[10,37,42].

Because of its ready availability sonography has become a major imaging modality not only in determining the presence of pleural fluid but is also highly useful in guiding diagnostic and therapeutic aspiration[16].

Advantages of ultrasonography [5,16,37]

- Fast
- Portable
- Low cost and easy to repeat
- Lack of ionizing radiation
- Best method to detect small pleural effusions (from 5 ml) and in volume measurement
- More sensitive than CT to depict the internal structure (septa) of pleural collections
- Clarify the nature of opaque lesions such as effusions, atelectasis, masses and consolidations

Chest Ultrasound Examination Technique

The patient may be in a sitting position or in supine position. The pleural space is superficial and promptly examined by ultrasound, both via direct intercostal and abdominal approaches. A high frequency linear transducer (5 to 7.5 MHz) applied directly to the chest or a sectorial or convex transducer (3.5 to 5 MHz) conducted superiorly from abdomen provides a view of the pleural space[5,43].

Direct intercostal approach

The pleural space is at a 1 cm depth from the rib interface. The air-filled lung, covered by the visceral pleura, is a powerful reflector of the ultrasound beam, blocking a deeper penetration of ultrasound into the chest, producing a bright linear interface that moves with respiration.

The bright linear interface is the visceral pleura ultrasonographic marker. Normally, there is a thin and dark line of pleural fluid separating the parietal pleura from the visceral pleura. The parietal pleura is seen as a thin echogenic line, less distinct, in general obscured by reverberation effect. Its location is inferred based on its relationship with the ribs and the visceral pleura. The pleural fluid, in its greater part, is relatively anechoic and easily recognized as an area of echolucency separating the parietal pleura from the visceral pleura[5,43].

Abdominal approach

When an image is obtained from the abdomen, the diaphragm appears as a bright and curved echogenic line, which moves with respiration. The normal diaphragm is 5mm thick and is covered by parietal pleura in its thoracic face and by the peritoneum in its abdominal face. The lung acts as a specular reflector (similar to a mirror). A specular reflection of the liver and of the spleen is seen above the diaphragm, and this sign is a definite evidence of pleural fluid absence above the diaphragm. The signs of pleural effusion in an abdominal approach include anechoic fluid below the diaphragm, visualization of the chest cavity through the fluid accumulation, liver and spleen specular reflection absence above diaphragm and in large effusions[5,43].

Ultrasonographic Signs of Pleural Effusion

The ultrasonographic signs of pleural effusion include the detection of an anechoic space immediately deep to the thoracic walls. As the pleural effusions are sound conducting, deeply situated structures in relation to the effusions which are not normally visible, become visible when such a condition is present. Normally, when examining the thoracic wall thorough the liver, nothing is visible through it as the aerated lung interrupts the ultrasound beam. However, in the presence of pleural effusion, the posterior thoracic wall becomes visible[5,43,44].

A pleural effusion appears as a hypoechoic collection immediately above diaphragm and adjacent structures. One can separate the subjacent consolidated lung from the effusion, because the pulmonary consolidation is much denser and contains multiple aerial echogenic areas (air bronchograms) in its interior. A non-complicated effusion is totally anechoic, while a complex collection such as hemothorax or empyema has a thicker fluid with septations[5,45].

The free fluid flows about the pleural space according to patient position. In dorsal decubitus, the fluid flows to the back of the liver and the lungs. If the patient is standing, the fluid flows between the lung and the diaphragm[5].

There are two findings that have proven to be predictive of pleural fluid: the presence of a definite alteration in the form of a pleural density during inspiration and expiration, and the presence of mobile septations within the pleural lesion. Presumably, septations are fibrin bundles. The back and forth movement is unequivocal evidence that the fluid has a relatively low viscosity[5,45].

Doppler can also be helpful in distinguishing a pleural effusion from a pleural thickening. When a free pleural effusion is present, there is a colored sign between the visceral and parietal pleurae or near the costophrenic angle which is related with the respiratory movements. An organized pleural thickening appears like pleural lesion with no Doppler signals[5].

Diaphragm sign – When liver or spleen are used as acoustic windows and a fluid is seen adjacent to these organs, the location of the fluid is determined by reference to the position of the diaphragm. If the fluid is inside the diaphragm and centrally positioned this fluid is ascites. If the fluid is outside the diaphragm and more peripherally located, it is within the pleural space[5].

Sign of the displaced diaphragmatic crus – The fluid is within the pleural space if there is interposition of fluid between the diaphragmatic crus and the vertebral column, displacing the crus and increasing its distance to the column[5].

Sign of naked area – The anterior space of the liver right lobe is directly held to the posterior diaphragm without peritoneum. Therefore, the ascitic fluid in the subhepatic or subphrenic space cannot extend behind the liver up to the level of the naked area[5].

Quantification of Pleural Effusions

Although various ultrasound methods have been described for the quantification of the volume of pleural effusions[5,7,10,10,46], they require several measurements. Knowledge of the exact amount of fluid has limited usefulness in clinical practice[7]. An easy qualitative approach, is summarized in Table 3. Pleural effusion is classified as minimal, if the hypoechoic space is seen only at the costophrenic angle; small if it covers the costophrenic angle but limited within the image formed by the transducer; moderate if the space is larger than the image but limited within two images; and large or massive if it is larger than two images formed by the transducer[5,47].

Table 3: Quantification of pleural effusion on ultrasonography

Amount of fluid	**Ultrasound visualization**	**Volume estimation (mL)**
Minimal	Costophrenic angle	≤ 100
Small	Range, one probe	100-500
Moderate	Range, two probes	500-1,500
Large or massive	Range, three or more probes	>1,500

Characterization of effusion

The majority of pleural fluid collections are readily identified at USG as anechoic or hypoechoic collections delineated by the echogenic line of visceral pleura and lung. Although the classification of transudate or exudate is not absolute, they can often be differentiated at USG[9,16.]

Effusion can be subclassified as anechoic, complex nonseptated, complex septated, and homogenously echogenic based on internal echogenicity of effusion which helps in differentiating transudates from exudates[9,47,48] (Table 4). Transudates are anechoic, whereas an anechoic effusion can be either a transudate or an exudate[9]. On the other hand, pleural effusion with complex non-septated, complex septated, and homogenously echogenic patterns are always exudates[9,48]. Other findings indicative of exudative effusion were the presence of a thickened pleura or effusion associated with hypoechoic masses forming obtuse margins with chest wall (pleural nodules), pulmonary parenchymal lesions[16].

Table 4: Classification of type of effusion on USG

USG Appearance	**USG Finding**	**Nature of Effusion**
Anechoic	Echo-free spaces between pleural layers	Transudate Exudate (sometimes)
Complex non septated	Echogenic material in anechoic fluid	Exudate
Complex septated	Fibrin strands or septa floating in anechoic fluid	Exudate
Echogenic	Homogeneously echogenic fluid	Exudate

Computed tomography

Computed tomography is considered to be the gold standard for detection of pleural effusions. In addition to enabling evaluation of the pleural space, it allows accurate and detailed evaluation of the thoracic wall, lung parenchyma and mediastium[37,49,50,51]. Computed tomography is more sensitive than both conventional chest radiography and USG for differentiating pleural fluid from pleural thickening and for the identification of focal masses involving the pleura or the chest wall[2,52].

Its limitations are its low availability in remote centers, high cost and high radiation dose, and the need to take patients to the examination room, which delays the diagnosis[8,38].

Advantages[2,53]:

- Differentiate pleural fluid collections from solid masses.
- Identify the underlying cause of the effusion (e.g., lung cancer, pneumonia, pulmonary embolism, pericardial or aortic diseases, hemothorax).
- Guide pleural procedures.
- More sensitive than USG for differentiating pleural fluid from pleural thickening.

CT examination technique:

CT scans should be performed in suspended respiration at total lung capacity. Standard techniques for examination of the thorax include 5 mm collimation with slices obtained at 5 mm intervals from the thoracic inlet to the level of adrenal glands, and viewing at both soft-tissue and lung windows. The routine use of intravenous (IV) contrast material is not necessary. However, contrast enhancement may be useful in differentiating lung abscesses from empyemas, in identifying areas of necrosis, and in differentiating cystic from solid lesions. Ideally the contrast material should be administrated in a bolus with rapid injection, preferably by using a mechanical injector[52].

At CT, with the patient supine, free-flowing pleural fluid produces a sickle-shaped opacity as it accumulates in the posterior pleural recesses. Loculated fluid collections are seen as lenticular opacities of fixed position[15].

Subpulmonic effusion and pleural fluid in the costophrenic angles can be seen below the lung bases on CT and may mimic collections of fluid in the peritoneal cavity. The parallel curvilinear configuration of the pleural and peritoneal cavities at the level of the perihepatic and perisplenic recesses allows fluid in either cavity to appear as a crescentic collection displacing liver or spleen away from the adjacent chest wall. However, pleural fluid collections and ascites may be distinguished in several ways[15].

Signs to distinguish pleural fluid from ascites:

Pleural fluid can usually be readily distinguished from abdominal fluid by means of careful analysis of four signs:

- Diaphragm sign
- Interface sign
- Bare area sign
- Displaced crus sign

The diaphragm sign refers to the different distribution of pleural effusion compared with that of intraabdominal fluid in relation to the diaphragm. The lungs and pleura lie adjacent and peripheral to the convexity of the hemidiaphragm, while the abdominal structures and fluid lie adjacent and central to the hemidiaphragm. Fluid posterior or lateral to the diaphragm is pleural[15,52,54].

The interface sign refers to the interface between the fluid and the liver or spleen. In ascites the interface is sharp, whereas in pleural effusion the interface is ill defined, presumably because the diaphragm is interposed between the fluid and the liver or spleen[15,52,55].

The displaced crus sign refers to the anterior displacement of the diaphragmatic crus by pleural effusion, which occurs because the fluid is interposed between the crus and the vertebral column. Intraabdominal collections do not produce such displacement[15,52,56].

The bare area is the portion of the right lobe of the liver that lacks peritoneal covering. In this area, the liver is directly attached to the posterior abdominal wall, and therefore ascites is prevented from extending behind the liver at this level.
To distinguish pleural effusions from intra-abdominal fluid collections, all four signs should be assessed in each case, because if used individually any given sign may be indeterminate or misleading[15,52,57].

In a review of the CT findings of 52 patients with pleural effusion, ascites, or both, four independent radiologists correctly identified all fluid collections when using all four signs[58].

Quantification of pleural effusion

On CT scans, the effusion dimensions can be measured easily, but effusion volume determination is difficult[59]. Various methods of quantification of pleural effusion amount can be performed on CT by automatic quantification using special software[60]; measurements in three planes[61], single planar measurement[59] or by anteroposterior (AP) quartile method[62].

An easy three-point scale for quantification of pleural effusion using the AP quartile and maximum AP depth is summarized in Figure 11 and Table 5.

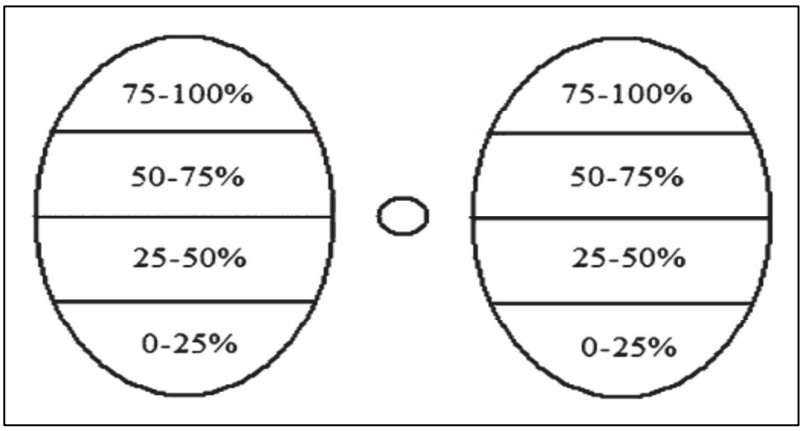

Figure 11: Diagram depicting assessment of the anteroposterior quartile

Table 5: Three-point scale for quantification of pleural effusion

Effusion Size	**AP Quartile**	**AP Depth (cm)**
Small	0%-25%	< 3.0 cm
Moderate	25%-50%	3.0-10.0 cm
Large	50%-75% or 75%-100%	>10.0 cm

Another simple method in quantification of volume of effusion can be determined by measuring the AP diameter of effusion. It can be stated, after slight rounding, that the greatest effusion depths of 2, 4, 6, 8, and 10 cm represent volumes of 200, 500, 800, 1100, and 1400 mL of pleural effusion, respectively[59].

Characterization of effusion

CT has been evaluated for the diagnosis of pleural exudates and transudates[1,4,13,64]. It is shown that exudative effusions have higher attenuation, but there was an overlap in the overall accuracy of attenuation values for identifying exudates and transudates[2,4,13,63].

The presence of pleural thickening at CT in patients with pneumonia or neoplasm was found to be highly indicative for the presence of an exudate[1,64]. Parietal pleural thickening is present in about 60% of exudative effusions, and although the parietal pleural thickening can be seen in some patients with transudative effusion, the value of this finding in predicting the presence of an exudate is high (85% to 95%)[15].

Smooth thickening and contrast enhancement of visceral and parietal pleura surrounding the abnormal fluid collection ("split pleura" sign), as well as the presence of enhanced subpleural fat (increased attenuation of extrapleural fat) strongly argue for diagnosis of empyema[65]. Although not specific for empyema, the split pleura sign does indicate that an exudative effusion is present, whether it be due to infection, neoplasm, or inflammatory disease[16,20]. Loculation, pleural nodules, and increased density of extrapleural fat were more frequently encountered in CT of patients suffering from empyema[1].

Certain CT findings are most specific in diagnosing malignant pleural disease. If one or more of these findings are considered to indicate malignancy, the overall diagnostic accuracy is about 75%[15].

- Nodular pleural thickening[64]
- Circumferential pleural thickening (surrounding the lung)[20]
- Parietal pleural thickening greater than 1 cm[64]
- Mediastinal pleural thickening[20]

MATERIALS AND METHODS

Source of data:

Individuals with clinically/radiographically suspected pleural effusion who were referred for ultrasonography and CT thorax to Department of Radiology, R. L. Jalappa Hospital and Research Centre were screened for the study.

This prospective study included patients who underwent ultrasonography, CT thorax and thoracentesis between January 2016 and December 2017.

They were included in the study if they meet the inclusion/exclusion criteria.

An informed consent was taken from individuals for their willingness to participate in the study.

Inclusion Criteria:

1. Patients > 18 years of age with pleural effusion
2. Patients who have undergone USG, CT and diagnostic thoracocentesis.

Exclusion Criteria:

1. Pregnant women.
2. Patients with minimal pleural effusion.
3. Patients with history of acute trauma

Method of collection of data:

USG and CT were performed in patients with pleural effusion.

USG was performed using SIEMENS® ACUSON X300 (Figure 12) in supine and sitting posture by both direct intercostal and abdominal approaches. Both curvilinear (2.2 – 5.0 MHz) and linear (4.7 –8.0 MHz) transducers were used.

Figure 12: SIEMENS® ACUSON X300 USG machine used in the study

CT was performed using SIEMENS® SOMATOM EMOTION 16 (Figure 13) taken from the level of thoracic inlet to adrenal glands.

CT parameters used:

- Axial sections of 5 mm thickness
- Kilovolt peak: 130 Kvp
- Milli ampere second: Automatically adjusted according to the patient's body habitus.

Post study reconstructions were done at 0.75 mm in sagittal and coronal planes.

IV contrast material was not administered when renal function tests were abnormal, in patients with high risk for contrast nephropathy (dehydration, diabetes mellitus, etc.), in patients with an allergy to contrast material, or when the indication for CT did not necessitate the use of contrast material. IV contrast material was administered in 58 patients. In 54 patients, standard chest examination was performed after a standard injection protocol (100 mL of iopromide 300) and in 4 patients, an angiographic examination was performed with 120 mL of IV contrast material (iopromide 300). The image data were assessed on our Myrian® 64 1.18.1 software.

Imaging findings were correlated with biochemical and cytological analysis using Light's criteria which was considered the gold standard.

Figure 13: SIEMENS® SOMATOM EMOTION 16® CT scanner used in the study

Image Assessment:

Ultrasonography was performed by two experienced radiologist. They also reviewed the CT images. The radiologists were blinded to results of diagnostic thoracocentesis and they assessed the studies independently. The radiologists were however aware of the clinical history and probable diagnosis in all the patients. Each study was evaluated by both the radiologists in random order.

The radiologists evaluated the studies with regard to location, extent, presence of loculations, pleural nodules, thickening and nature of pleural effusion on both USG and CT.

On USG, the parietal pleura was measured and arbitrarily defined as thickened if the pleural thickness was 3 mm or greater. The pleural nodules were hypoechoic nodular lesions with defined margins located in the parietal or visceral pleura, while focal pleural thickenings were echogenic areas of increased thickness in the parietal pleura that had poorly defined margins[9].

On CT, an effusion was considered loculated when it showed septations, was compartmentalized or in nondependent portion of the pleura, or when it showed a convex shape. Otherwise, a concave shaped effusion in the dependent portion of the pleural space was classified as free pleural fluid. The presence of pleural nodules in the parietal or visceral pleura was also evaluated. CT scans were also evaluated for the presence of pleural thickening. Parietal pleural thickening was diagnosed only if a pleural line was visible internal in relation to the ribs. Visceral pleural thickening was diagnosed only if a pleural line was visible on the surface of the lung adjacent to the fluid and could be reliably differentiated from the compressed lung[1,66].

The mean value in Hounsfield units of an effusion was determined using a region of interest (area – 1 cm^2) at the greatest quantity of fluid on CT images. The radiologist took care not to include adjacent ribs, lung parenchyma, or areas of pleural thickening. Probable etiology was recorded.

Statistical Analysis

Data was recorded into Microsoft® Excel® and was analyzed using SPSS® software. The Pearson chi-square test was used to compare categorical variables between groups. Continuous data are described as mean value ± SD using independent *t* test. The difference between the mean attenuation values of transudates and exudates was evaluated using a Mann-Whitney test. A receiver operating characteristic (ROC) curve was constructed to determine the accuracy of attenuation values in the identification of exudates using the area under the ROC curve. The ROC curve was also used to determine the optimal threshold value to classify transudates and exudates on the basis of mean Hounsfield units.

The usefulness of each feature for identifying exudates and transudates was also evaluated by calculating the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). A p value <0.05 was considered significant.

RESULTS

A total of 112 patients were screened for the study between January 2016 and September 2017. Of which, 13 patients did not undergo computed tomography, 7 patients did not undergo diagnostic thoracocentesis, 5 had insufficient laboratory data to characterize their effusion according to Light's criteria and 7 patients had history of trauma and were excluded from the study. Finally, the study population constituted of 80 patients who underwent ultrasonography, CT and diagnostic thoracocentesis within 72 hours.

The study population constituted 52 males and 28 females (age range, 18–98 years; mean age, 53.2 years) (Figure 14).

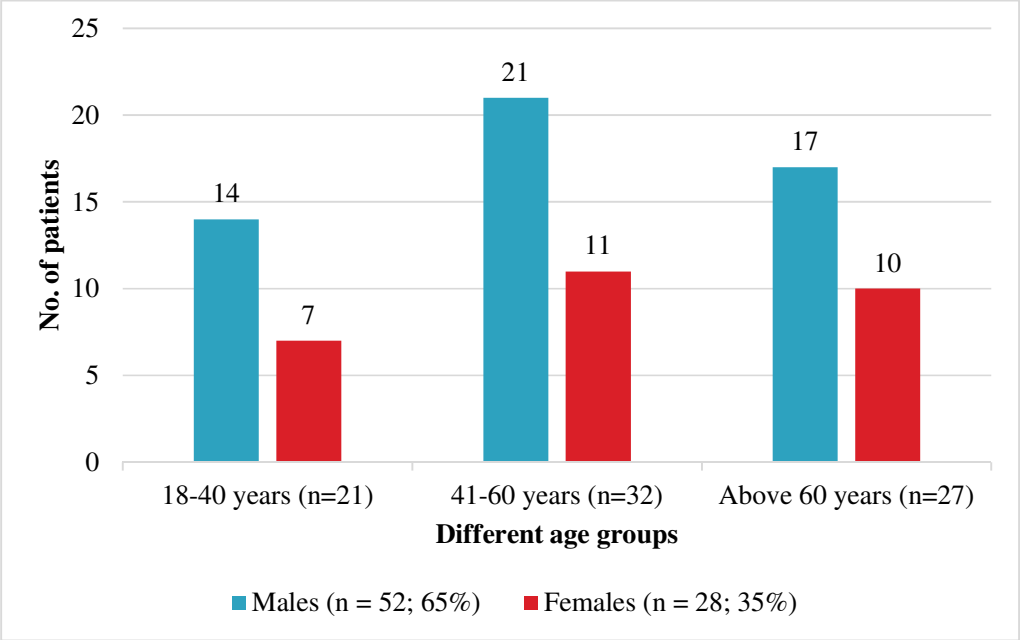

Figure 14: Demographics of patients with pleural effusions

According to Light's criteria, 24 of the 80 pleural effusions were transudates (30%) and 56 were exudates (70%) (Figure 15).

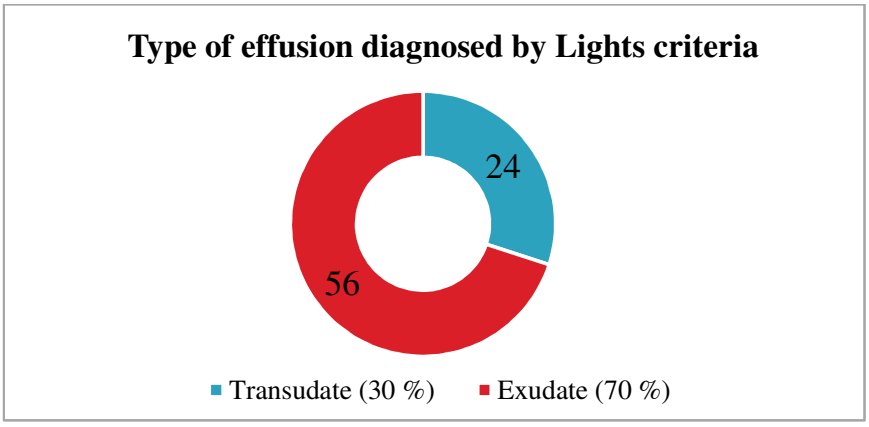

Figure 15: Showing distribution of patients based on Light's criteria

Transudative effusions were more often bilateral (87.5 %) in comparison to exudative effusions which were unilateral (89.2 %) with a significant p <.001 (Figure 16). Most of the pleural effusions were unilateral (66.7%) and more common on right side (75.4 %) (Figure 17).

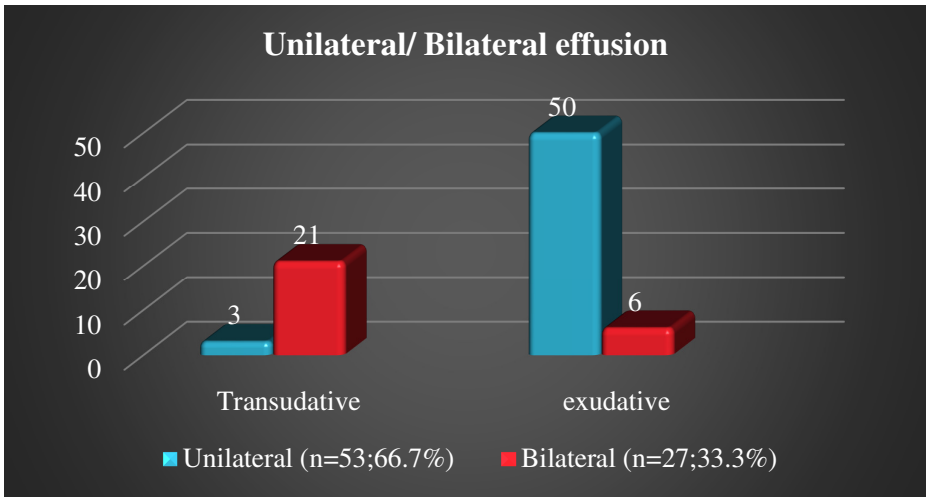

Figure 16: Laterality of pleural effusion in transudate and exudative effusions

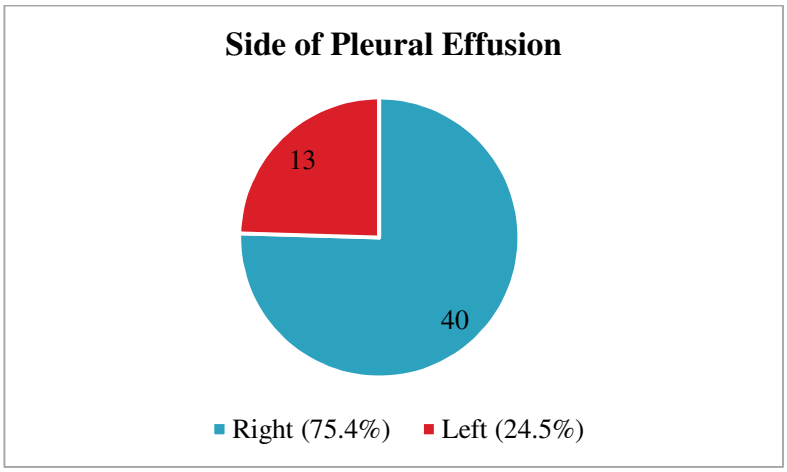

Figure 17: Laterality of pleural effusion among patient with unilateral effusion

Various etiologies of effusions are listed in Figure 18. They included malignant (18, 22%), infective (36, 45%), congestive cardiac failure (9, 11%), chronic kidney disease (5, 6%), acute pulmonary embolism (4, 5%), cirrhosis (2, 20%) and other causes (6, 8%) e.g. anaemia, dengue fever.

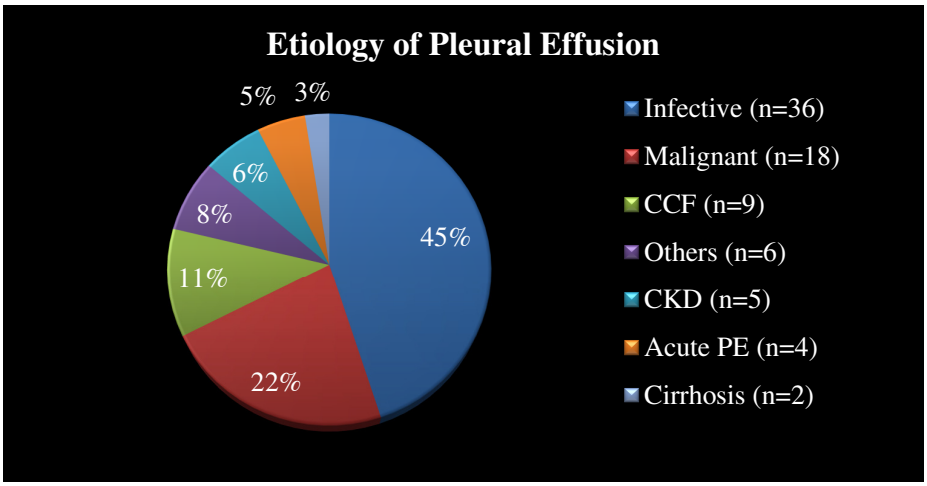

Figure 18: Etiology of pleural effusion

Of the infective effusion (n=36), 20 were parapneumonic effusions (56%), 12 complicated parapneumonic/empyema (33%), 2 hydropneumothorax (5.5%) and 2 pyopneumothorax (5.5%) (Figure 19).

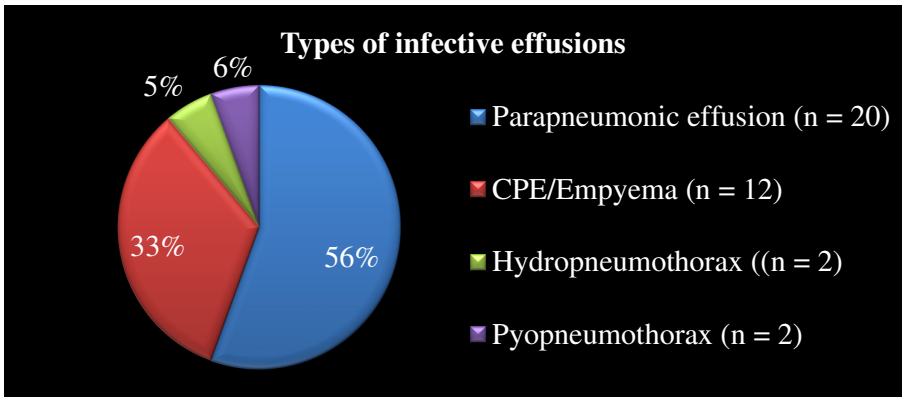

Figure 19: Distribution of infective pleural effusions

About 12 patients had tuberculosis as infective agent and in the remaining 24 patients it was non-tubercular in origin (Figure 20).

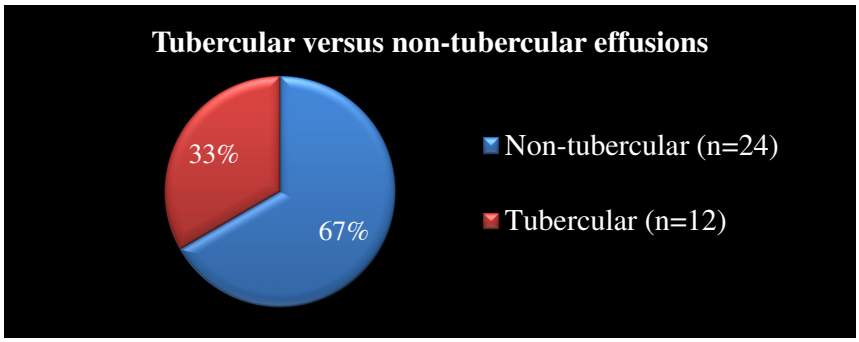

Figure 20: Infective versus non-infective pleural effusion

Of the 18 malignant effusions, 10 patients had carcinoma lung, 2 had gastric cancer, 1 had esophageal cancer, 1 malignant transformation of Phylloides tumor, 1 carcinoma thyroid, 1 carcinoma ovary and 2 cases of mesothelioma.

Most of the exudative effusions were complex septated (n=34, 62.5%), echogenic (n=14, 25%) or complex non-septated (n=5, 8.92%) on ultrasound with very few being anechoic (n=2, 3.5%). Transudative effusions were always anechoic (n=24, 100%) (Table 6).

Transudative effusions were commonly smaller (n=13, 54.1%) to moderate (n=10, 41.6%) in size in comparison to exudates which were moderate (n=31, 59.6%) to larger (n=16, 28%) in size both on USG and CT.

Pleural thickening, pleural nodules and loculations were seen only in exudative effusions (n=34, 60.7%; n=22, 39.2%; n= 8, 14.2%) and were not seen in any of the transudative effusions on USG.

Table 6: Demographic and USG findings of patients with exudative and transudative effusions

Parameter	**Patients with Transudates (n = 24)**	**Patients with exudates (n = 56)**
Age	49.5 (22 -77)	58 (18 -98)
Gender (M/F)	14/10	38/18
Anechoic	24 (100%)	2 (3.5%)
complex non-septated	0	5 (8.92%)
complex septated	0	34 (62.5%)
Echogenic	0	14 (25%)
Effusion size	l (1), m (10), s (13)	l (16), m (31), s (9)
Loculations	0	34
Pleural thickening	0	22
Pleural nodules	0	8

Table 7: CT findings of patients with exudative and transudative effusions

Parameter	Patients with Transudates (n = 24)	Patients with exudates (n = 56)
CT attenuation (HU)	4.6 (1.3 – 8.2)	14.6 (4.5 - 34)
Effusion size (mm)	37.1 (17.6 - 106)	75.9 (18.8 - 181)
Loculations	0	21
Pleural thickening	2	35
Pleural nodules	1	11

Loculations were better appreciated on ultrasound than CT. Pleural thickening and pleural nodules were better seen on CT compared to USG.

Pleural thickening were seen commonly in exudates than transudates with a sensitivity (62.5 %), specificity (91.6 %), PPV (94.5%), NPV (51.1%) with a *P* value <0.01. Pleural nodules were also more commonly seen in exudates than transudates with a sensitivity (19.6%), specificity (95.8%), PPV (91.6%), NPV (33.8%) with a *P* value <0.05. Loculations were seen only in exudates and were not seen any of the transudative effusions accounting for a sensitivity (35.5 %), specificity (100 %), PPV (100 %), NPV (40.6%) with a *P* value <0.01. These findings yielded low sensitivity but were more specific (Table 7 & Table 8).

Mean attenuation values were significantly higher in exudative (14.65 ± 6.07; mean ± SD, range: 4.5 to 34) effusions than transudates (4.66 ± 2.29; mean ± SD, range: 1.3 to 8.2) with a *P* value <.001. There is an overlap in the range of 4.5 to 8.2 (Figure 21 & Figure 22).

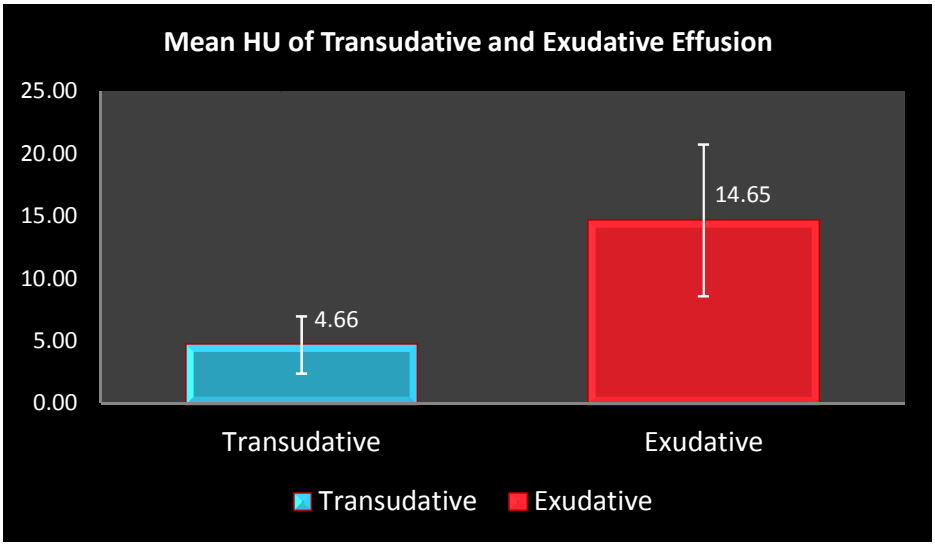

Figure 21: Mean attenuation values of transudative and exudative effusions

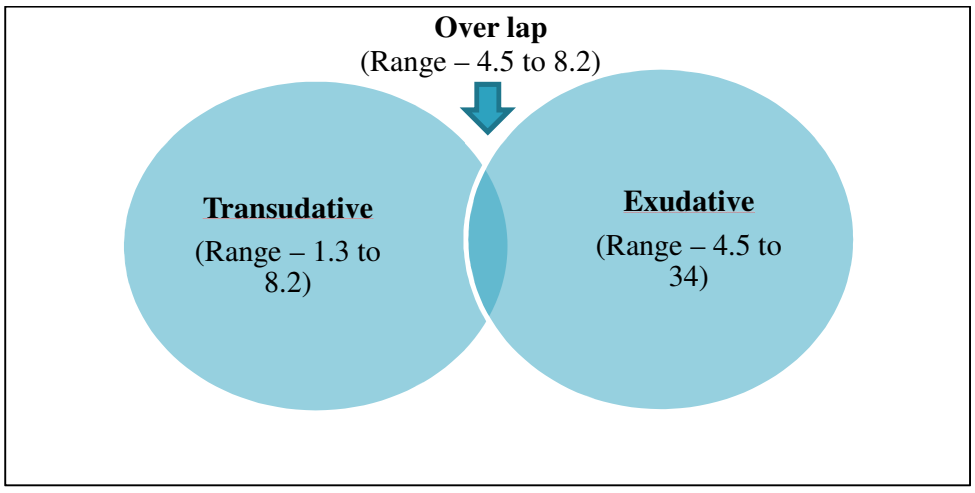

Figure 22: Demonstrates the overlap in mean attenuation values

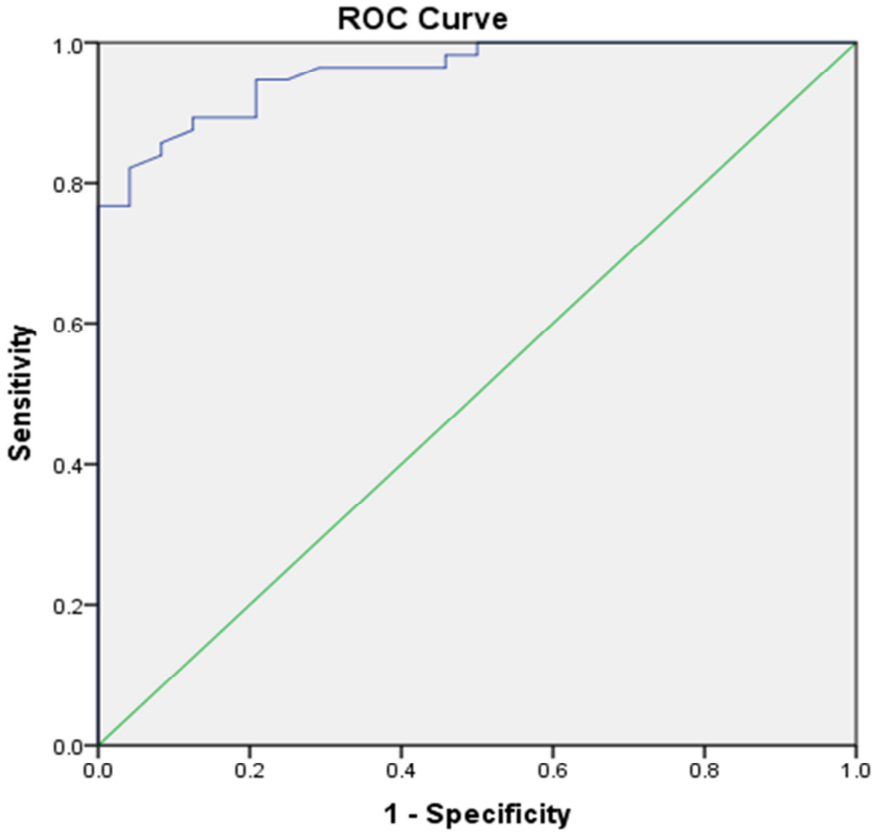

Figure 23: Graph shows receiver operating characteristic (ROC) curve plotting 1 – specificity (x axis) against sensitivity (y axis). Overall accuracy was excellent, with area under ROC curve of 0.958 and standard error of 0.019.

ROC curve was used to evaluate the accuracy of attenuation values in the identification of exudates with available attenuation values (Figure 23). Area under curve was 0.958 with 95% confidence interval 0.920-0.996. ROC curve showed a significant accuracy in differentiating exudates from transudates ($p<0.001$). Considering a cut-off point of 8 HU according to the ROC curve, we observed a sensitivity of 91.6%, specificity of 82.7%, PPV of 73.3% and NPV of 96%.

Table 8: Performance of CT parameters in differentiating exudates from transudates

CT parameters	CT attenuation values < 8 as cut off	Loculations	Pleural thickening	Pleural nodules
Sensitivity	91.6	37.5	62.5	19.6
Specificity	82.7	100	91.6	95.8
PPV	73.3	100	94.5	91.6
NPV	96	40.6	51.5	33.8
P value	<0.001	<0.001	<0.001	<0.05

Although CT attenuation values show good sensitivity and specificity in differentiating pleural effusion, presence of loculations, pleural nodules, and thickening are more specific (Table 8).

IMAGES

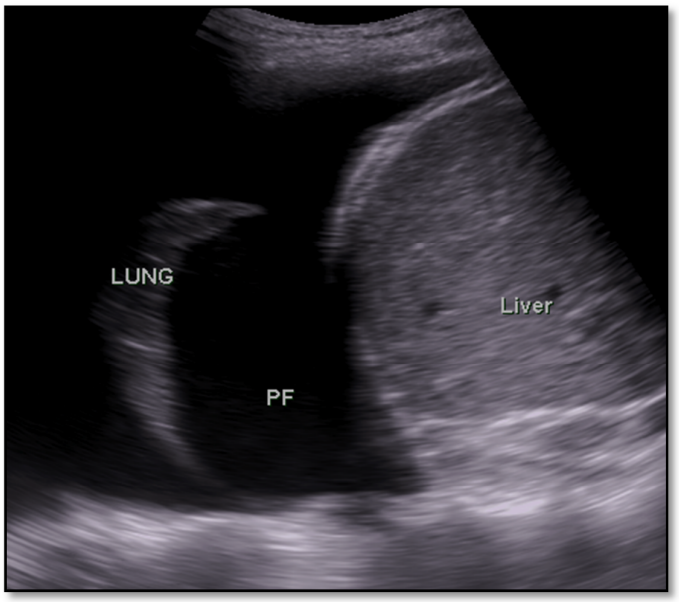

Figure 24: Ultrasound image showing anechoic effusion in a patient with alcoholic liver disease

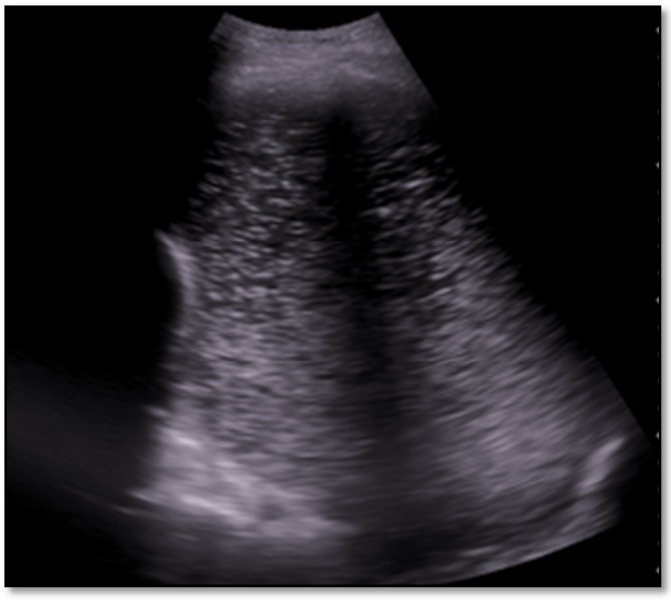

Figure 25: Ultrasound image showing complex non-septated effusion in a patient of tuberculosis.

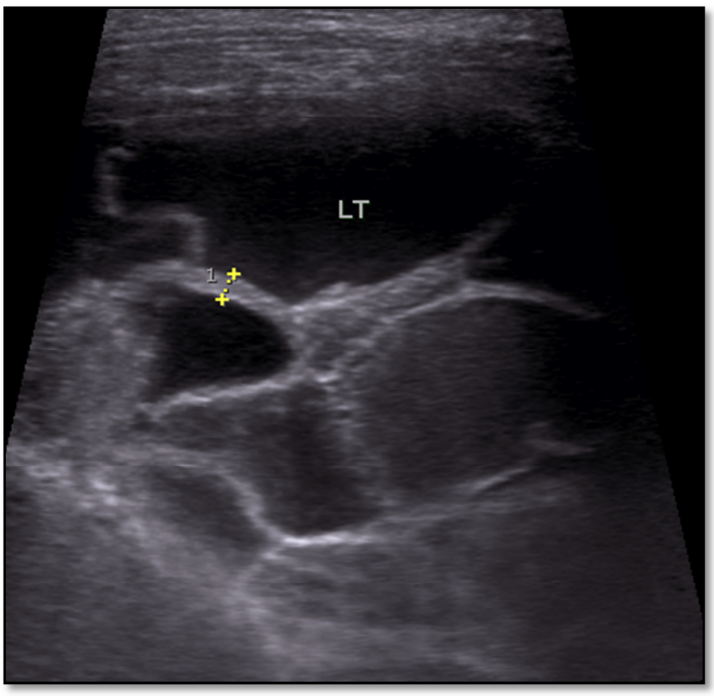

Figure 26: Ultrasound image showing complex septated effusion with thick septa in a case of malignant pleural effusion

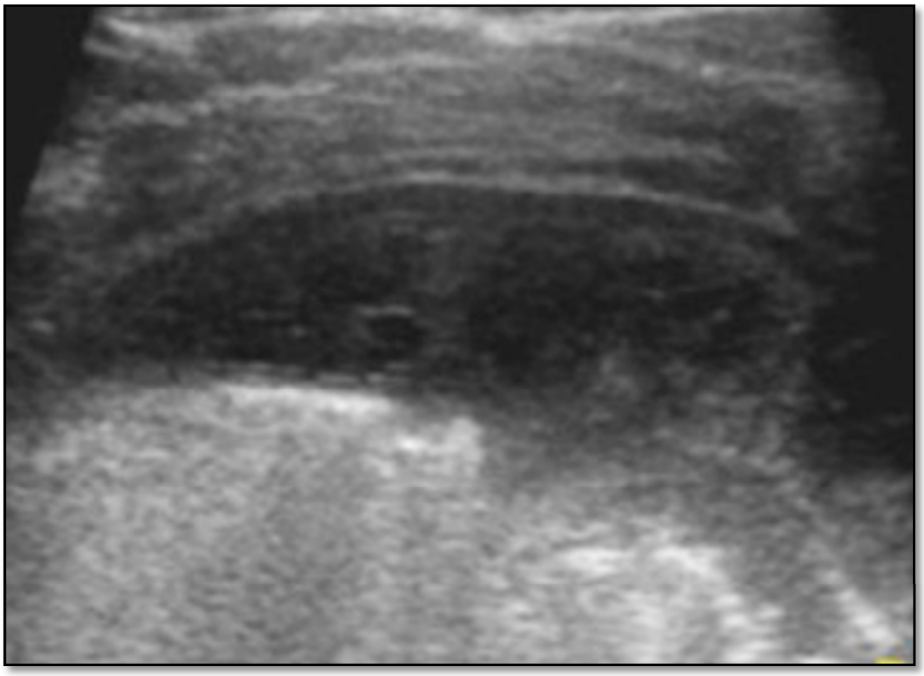

Figure 27: Ultrasound image showing echogenic effusion in a patient with empyema.

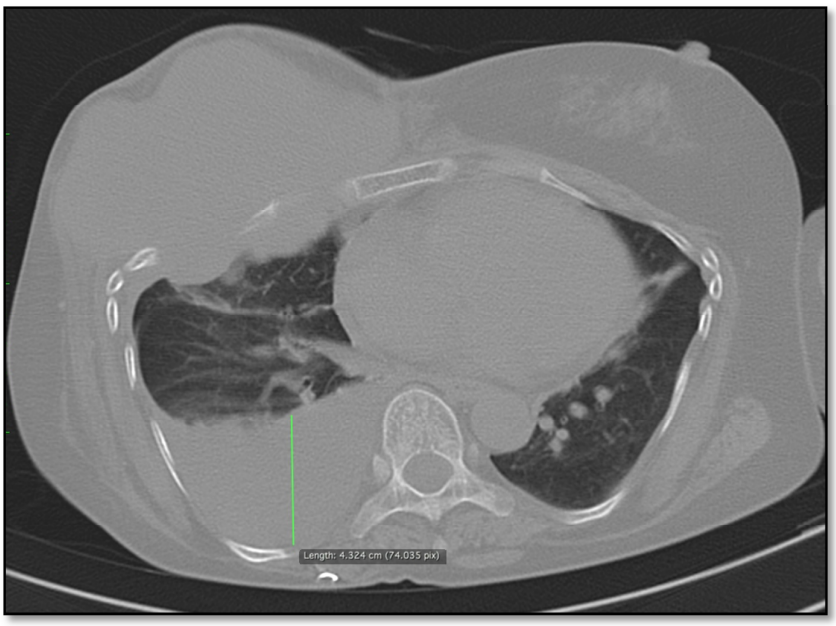

Figure 28: CT plain axial section depicting the measurement of pleural effusion in patient with malignant pleural effusion from phyllodes tumor of right breast

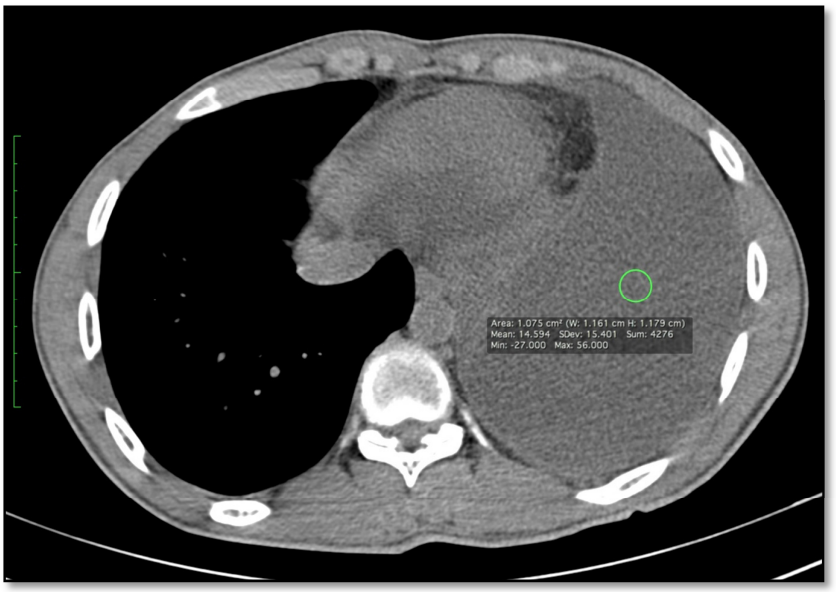

Figure 29: CT plain axial section depicting ROI measurement in patient with carcinoma lung

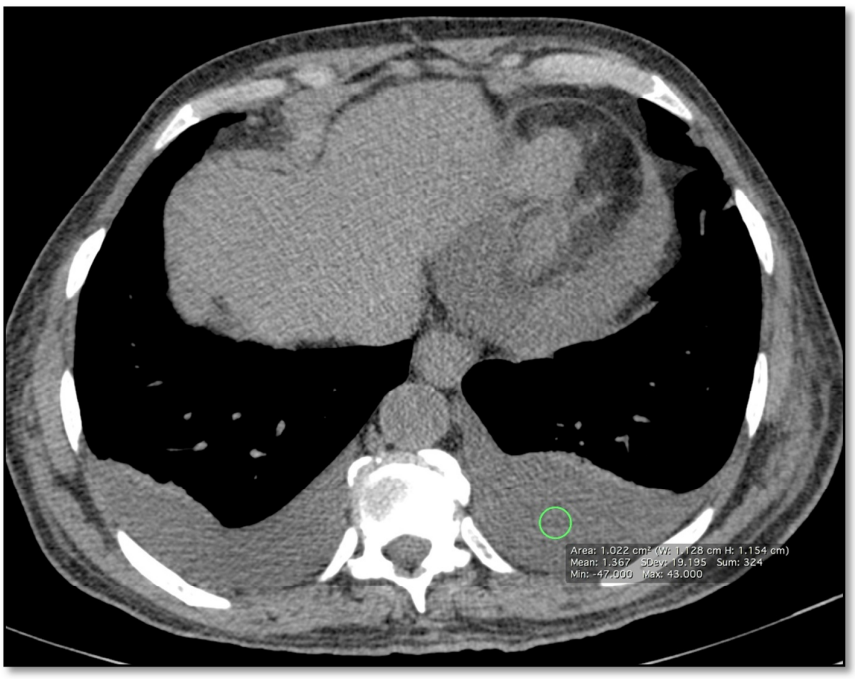

Figure 30: CT plain axial section showing mild bilateral pleural effusion with associated pericardial effusion in patient with congestive cardiac failure

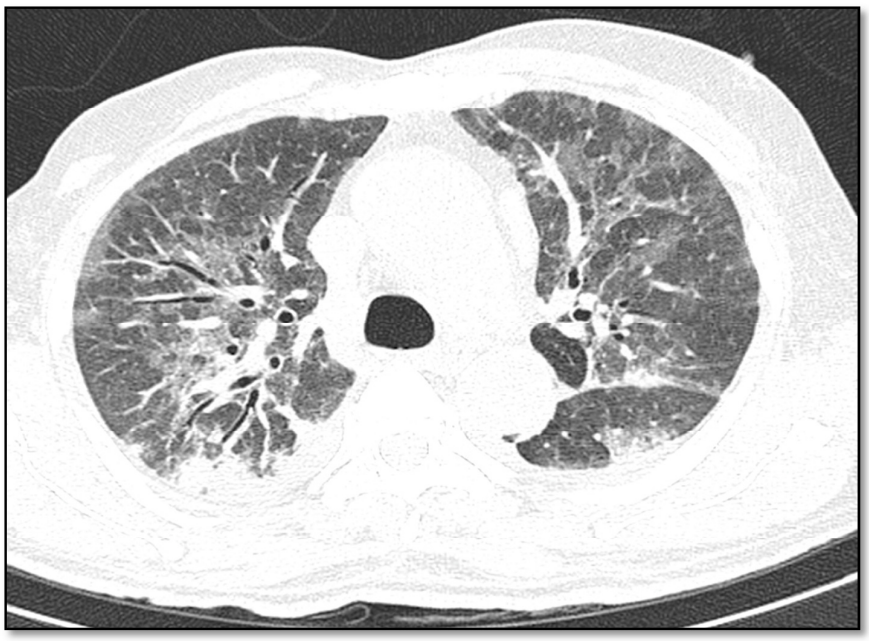

Figure 31: CT plain axial section showing mild bilateral pleural effusion with associated diffuse ground glass opacities in patient with congestive cardiac failure.

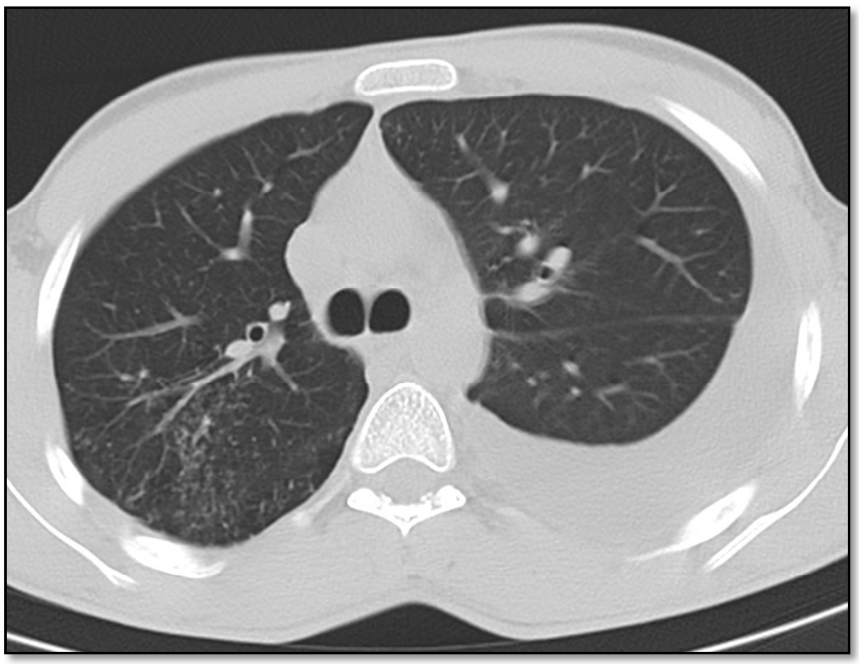

Figure 32: CT plain axial section showing moderate right sided pleural effusion with associated tree-in bud pattern in patient with tuberculosis

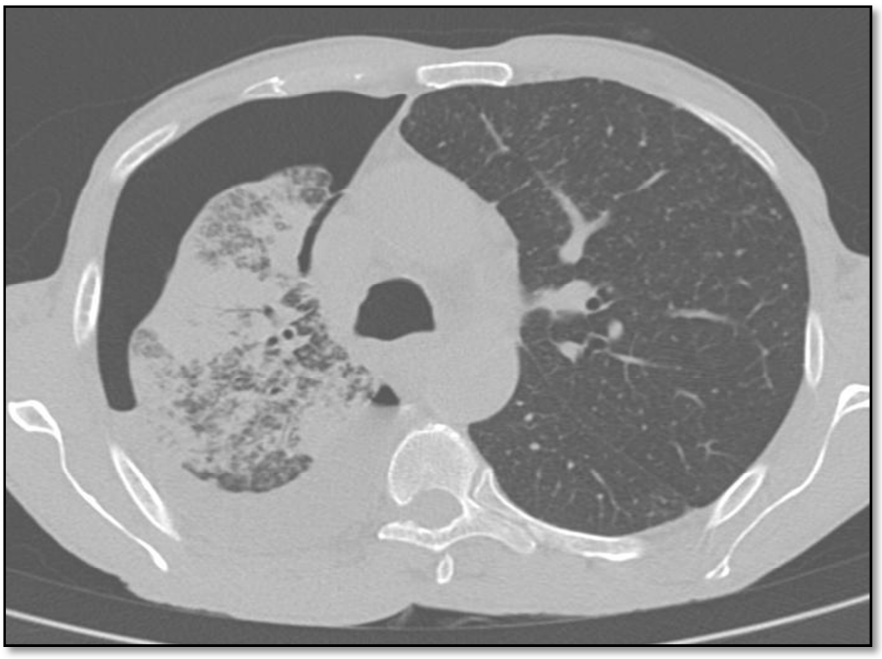

Figure 33: Plain CT axial section showing moderate right hydropneumothorax with suspicious broncho-pleural fistula in patient with tuberculosis

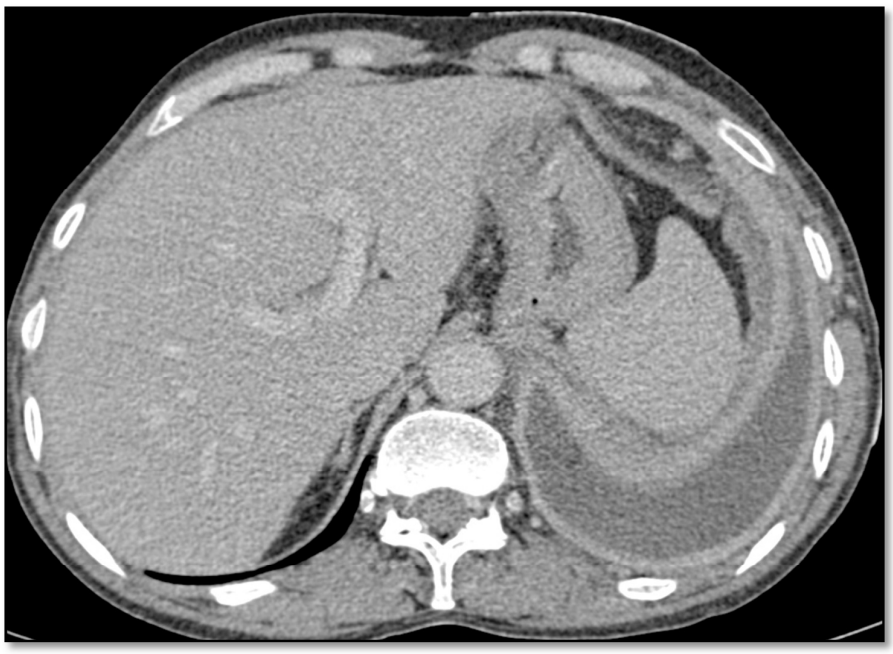

Figure 34: CECT axial section showing moderate left sided empyema demonstrating split pleura sign

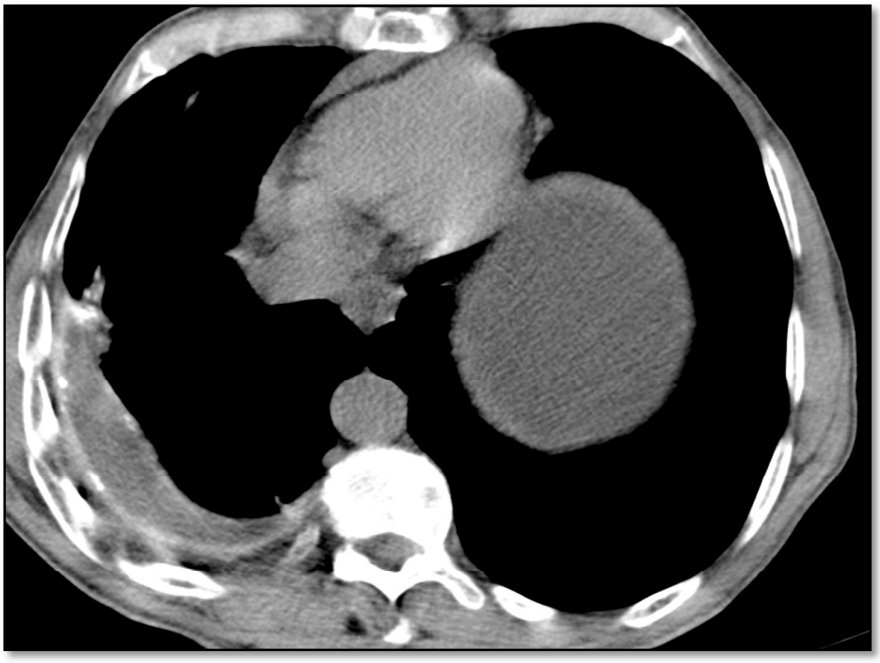

Figure 35: Plain CT axial section showing mild right sided chronic empyema with associated pleural calcifications

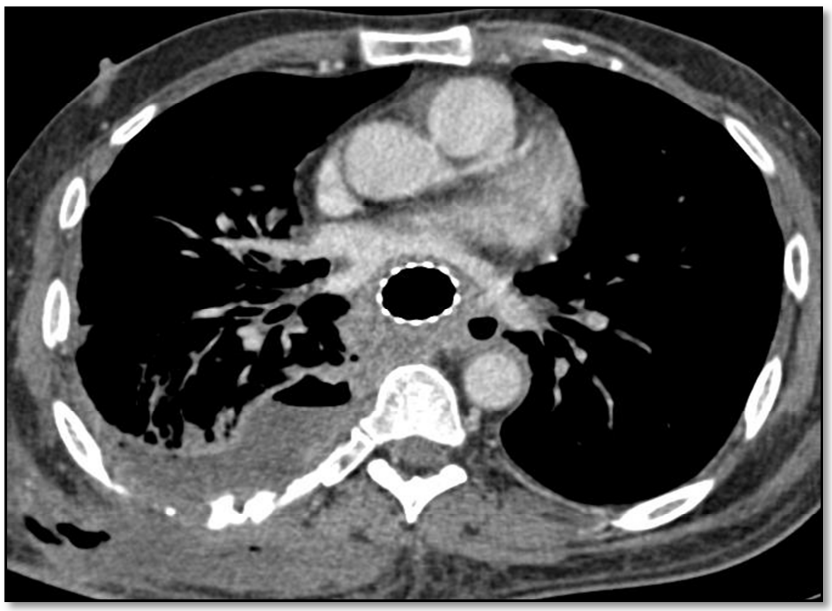

Figure 36: CECT axial section showing mild right sided empyema thoracis demonstrating split pleura sign and extension beyond extrapleural fat space into soft tissues with destruction of adjacent rib.

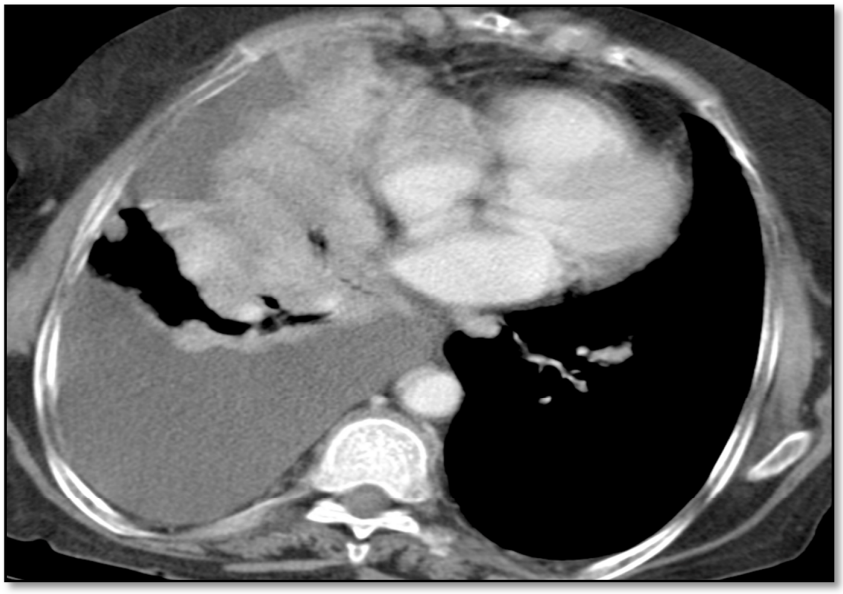

Figure 37: CECT axial section of a patient with carcinoma lung with associated pleural nodules

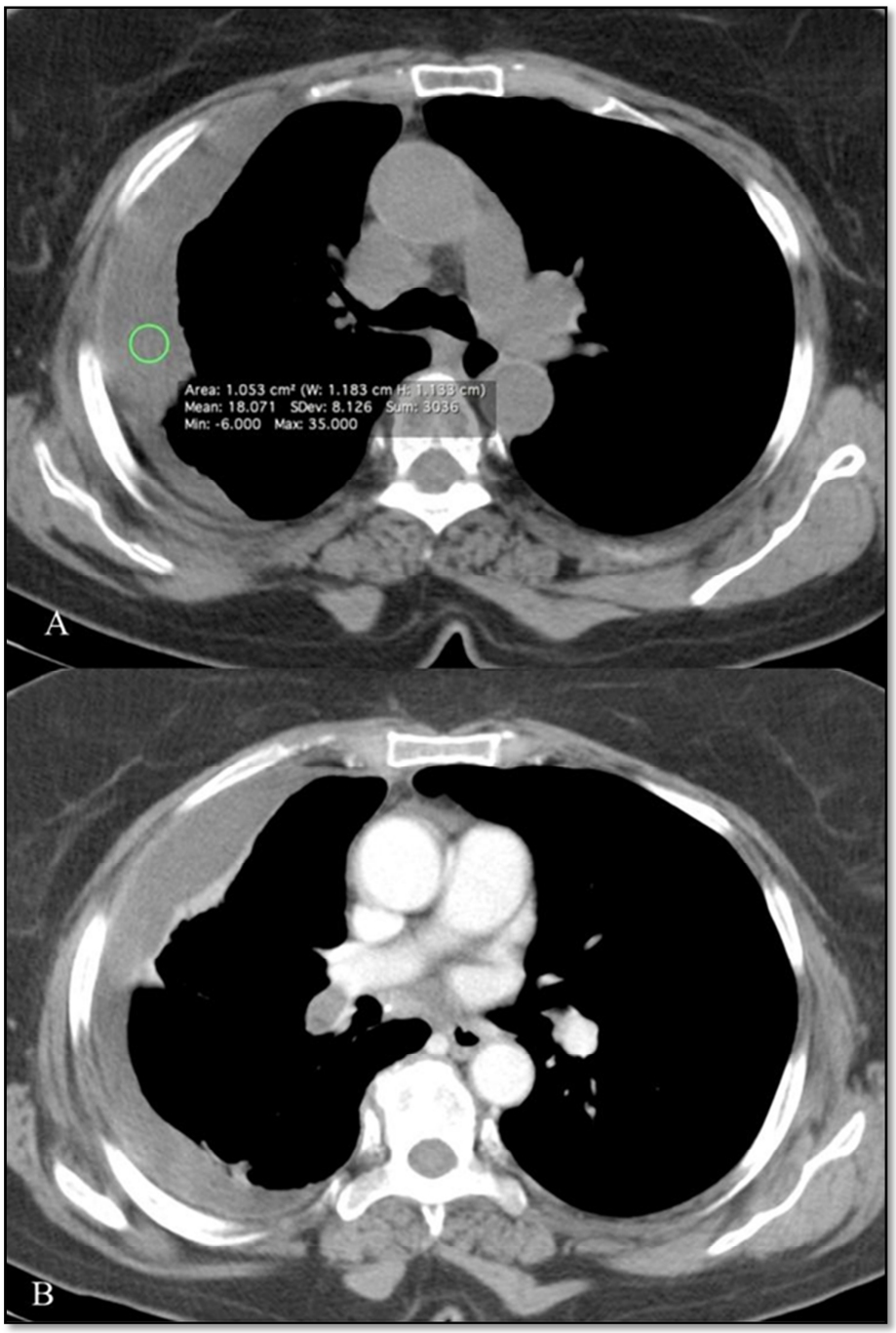

Figure 38: (A) Plain and (B) CECT axial section showing mild right sided pleural effusion in patient with pulmonary embolism demonstrating filling defect in right main pulmonary artery.

DISCUSSION

A distinction between transudative and exudative pleural effusion is crucial for establishing diagnosis and in management[2]. Both USG and CT have been indispensable tools in the diagnosis of pleural effusion.

Ultrasonography

The value of sonography for the detection of pleural lesions is well known[9,52]. Sonography is useful in localizing loculated or minimal effusion before thoracentesis[9,52,67].

As reported earlier, sonography is also helpful in determining the nature of pleural effusions[9,48,68]. Pleural effusion patterns can be sub-classified as anechoic, complex non-septated, complex septated and homogeneously echogenic. Transudates are usually anechoic, whereas an anechoic effusion could be either a transudate or an exudate. Pleural effusions with complex septated, complex nonseptated, or homogeneously echogenic patterns are always exudates ($p < .01$). Not only can the internal echogenicity of a pleural effusion be visualized in more detail but the associated pleural thickening, nodules and parenchymal changes can be clearly depicted[5,9]. We found similar results in our study, with 100% of transudates being anechoic while this finding being observed in only 3.5% of exudative effusion.

In our series, the homogeneously echogenic effusions are seen in empyema, few malignant effusions and acute pulmonary embolism, similar to previous study by yang et al[9]. The echogenic nature is probably due to the presence of a high content of tissue debris or blood in the pleural cavity[9,52].

As quoted earlier by yang et al[9], thickened pleura and lung parenchymal changes are also indicative of exudates. The pleural nodules were seen mostly in malignant effusions with only one case seen in a patient with cirrhosis which was a benign nodule in their study. Fibrin strands and septa within a hypoechoic space are useful signs serving to distinguish pleural fluid from a solid mass. The fibrin strands tend to occur in effusions that are rich in protein, sometimes the septa were so profuse that they had a honeycomb appearance[9,52].

In our study, fibrin strands and septa were also seen commonly in all kinds of exudates, including empyema, PPF/CPE, and malignant pleural effusions[9]. Adding to it, pleural nodules and thickening were observed only in exudative effusions similar to previous study.

In addition to the useful diagnostic information provided by the sonograms, chest USG also can be used to guide a percutaneous transthoracic needle aspiration/ biopsy of the associated pleural and lung parenchymal lesions with high diagnostic yield[9,69]. Hence, sonography is a useful diagnostic tool for determining the nature of pleural effusions which can further aid in the management.

Computed tomography

CT scan is not only a sensitive and specific tool for detecting pleural effusions, but it is also a useful tool for determining causes of effusions as well[2]. Several studies have attempted to evaluate the efficacy various computed tomographic parameters in differentiating transudative from exudative effusions which included mean attenuation values, presence of loculations, pleural thickening, and nodules. There was discrepancy in the results regarding the use of attenuation values between various studies[1,2,4,6,13,64,64,66].

Attenuation values

Previous studies[2,4,6,13,63] revealed significantly higher mean CT attenuation value of exudates (8.1-17.1 HU), compared to transudates (3.5-12.5 HU) and the authors determined that they were moderately helpful in differentiating transudates from exudates[2,4,6,13]. This fact is in accordance with the mechanism of formation of transudates, which reflects an imbalance in the hydrostatic and osmotic pressures leading to an excess of pleural fluid, without the associated pleural disease that is present in exudative effusions[66]. Study by Abramowitz et al found that the mean attenuation values of exudates (7.2 ± 9.4 HU) were lower than those of transudates (10.1 ± 6.9 HU; p = 0.24), however the results were not statistically significant[1]. Our results were similar to the prior studies[2,6,13,63] which showed significantly higher mean attenuation values of exudates (14.65 ± 6.07), compared with the transudates (4.66 ± 2.29), P value <0.001. When the cut-off value for exudative effusions was accepted as > 8, with a sensitivity of 91.6%, specificity of 82.7%, PPV of 73.3% and NPV of 96% with a significant *P* value < 0.001.

Although the mean attenuation values of exudates were significantly higher than those of transudates, there is an overlap in the values. Hence, it is essential to interpret them in addition to other CT findings to characterize pleural effusions.

Additional CT findings

Previous studies reported that presence of pleural thickening, pleural nodules and loculations were highly specific for exudates[2,4,64,66] with one study stating that they were seen only in exudates[66]. Cullu et al. reported that, compared to transudates, exudates had a significantly higher frequency of loculations and pleural thickening[4]. However, Abramowitz et al. found pleural thickening and loculated pleural effusion in more than one-third of patients with transudates, which is not in line previous studies and they stated that presence of pleural thickening, pleural nodules and loculations were not reliable findings for characterizing pleural effusions[1].

In our study, pleural thickening, pleural nodules and loculations were commonly seen in patients with exudative effusion with a high specificity (91.6 %, 95.8% and 100% respectively) keeping in line with the earlier studies.

Pleural thickening

Aquino et al reported that pleural thickening was seen commonly in exudative effusions with a high a high specificity of 96%[64]. They found pleural thickening in only one case of transudative effusion, concluding that parietal pleural thickening at contrast-enhanced CT almost always indicates the presence of a pleural exudate. Similar results were reported by Waite et al[70].

In our study, pleural thickening was seen commonly in exudates with a specificity of 91.6 % (*P* value <0.01), and only in 2 cases of transudates similar to earlier studies[4,64,66,70].

Pleural nodules

Earlier studies also stated that pleural nodules were seen commonly in exudates with high specificity[2,4,13]. The presence of pleural nodules or nodular pleural thickening were the most sensitive and specific findings for the diagnosis of malignant pleural effusions[66].

In our study, pleural nodules were found commonly in exudative group with only one patient with transudative effusion showing a benign nodule. We found that this finding is associated with high specificity of 95.8% (*P* value <0.01), similar to earlier studies[2,66].

Loculations

Compared with transudative effusions, exudative effusions had significantly higher loculation[4,64]. Few studies found that loculations were seen only in exudates[66]. Other studies stated that this finding was associated with both exudates and transudates with equal distribution or with lower sensitivity and specificity[1,13].

We found 100% specificity with respect to presence of loculations in exudative effusions, similar to an earlier study[64]. Patients with transudative effusions had no septations and none of them demonstrated septations on USG as well, supporting earlier studies[9,66].

Our study had few limitations. First, the radiologists were aware of the clinical history and probable diagnosis. Second, this study contained small sample size of transudate effusions. Third, not all patients underwent contrast study which could have affected the evaluation of additional CT findings.

CONCLUSION

We conclude that ultrasonographic appearance of pleural effusion is very much helpful in distinguishing transudate from exudate, with transudative effusion being always anechoic (100%) contrary to exudates, which is seen only in minimal number of cases (3.5%). Other appearances, complex non-septated, complex septated and echogenic effusions are seen in only exudates.

Mean attenuation values play a useful role in differentiating the nature of pleural effusions. According to our study, transudative effusions can be considered when HU values are less than 8 with sensitivity is with a sensitivity of 91.6%, specificity of 82.7%, PPV of 73.3% and NPV of 96%. Hence, diagnostic thoracocentesis which is associated with potential complications could be avoided in patients having pleural effusion with CT attenuation value < 8.

Since there is overlap in HU values, correlation with additional CT findings like pleural thickening, pleural nodules and loculations which are more specific and show higher prevalence among exudative effusions is necessary.

SUMMARY

Pleural effusion is a commonly encountered clinical problem. The first step in assessing pleural effusion is to decide whether the pleural fluid is a transudate or an exudate. Although clinical and radiological findings may provide significant evidence about the cause of pleural effusion, diagnostic thoracocentesis may still be necessary to evaluate the nature of pleural effusion which is associated with certain complications and has some relative contradictions.

We evaluated the efficacy of USG & CT in distinguishing the nature of pleural effusion which could act as a non-invasive tool and would be beneficial in patient management.

80 patients who underwent USG, CT and diagnostic thoracocentesis were studied. Pleural effusions were classified as exudates or transudates according to the Light's criteria. USG appearances and CT attenuation values along with additional findings like presence of pleural thickening, pleural nodules and loculations were evaluated.

Twenty four (30%) of the 80 pleural effusions were transudates and 56 (70%) were exudates. Transudative effusions were more often bilateral (87.5 %) in comparison to exudative effusions which were unilateral (89.2 %) with a significant $p < .001$ and were small to moderate in size.

Transudative effusions were always anechoic (100%). Most of the exudative effusions were complex septated (62.5%), echogenic (25%) or complex non-septated (8.9%) on ultrasound with very few being anechoic (3.5%).

Loculations were better appreciated on ultrasound than CT. Pleural thickening and pleural nodules were better seen on CT compared to USG.

Mean attenuation values were significantly higher in exudative (14.65 ± 6.07; mean ± SD, range: 4.5 to 34) effusions than transudates (4.66 ± 2.29; mean ± SD, range: 1.3 to 8.2) with a *P* value <.001. Effusions can be considered as transudative if the CT attenuation value is < 8, with a sensitivity of 91.6%, specificity of 82.7%, PPV of 73.3% and NPV of 96% with a significant *P* value < 0.001.

Pleural thickening, nodules and loculations were seen commonly in exudates than transudates with a high specificity (91.6 %, 95.8% and 100% respectively), although they are less sensitive.

We conclude that ultrasonography is a very helpful non-invasive and bedside tool in determining the nature of pleural effusion. CT attenuation values play a useful role in differentiating the nature of pleural effusion. Transudative effusions can be considered when HU values are < 8, where diagnostic thoracocentesis associated with potential complications could be avoided. As there is an overlap in HU values, correlation with additional CT findings like pleural thickening, pleural nodules and loculations which show higher prevalence among exudative effusions is necessary.

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PROFORMA

EFFICACY OF ULTRASONOGRAPHY AND COMPUTED TOMOGRAPHY IN DIFFERENTIATING TRANSUDATE FROM EXUDATE IN PATIENTS WITH PLEURAL EFFUSION

1. Name
2. Age/sex
3. Hospital ID
4. Brief present history
5. Past history : TB, Cardiac disease, Chronic kidney disease, malignancy
6. USG FINDINGS:
    I. Quantity (volume) - Small/ moderate/ large.
    II. Type of fluid – anechoic/complex non-septated/complex septated/echogenic.
7. CT FINDINGS:
    i. CT attenuation (HU)
    ii. Effusion size (mm)
    iii. Loculations
    iv. Additional findings
8. Laboratory markers
    i. PF albumin: serum albumin
    ii. PF LDH: serum LDH
    iii. Cell type
    iv. Culture, if available
9. Probable diagnosis:
    I. By USG:
    II. By CT:
    III. By Light's criteria:
10. Final diagnosis:

INFORMED CONSENT FORM

I, the undersigned, agree to participate in this study and authorize the collection and disclosure of my personal information as outlined in this consent form.

I understand the purpose of this study, the risks and benefits of the procedure and the confidential nature of the information that will be collected and disclosed during the study.

The information collected will be used only for research.

I have had the opportunity to ask questions regarding the various aspects of this study and my questions have been answered to my satisfaction.

I understand that I remain free to withdraw from this study at any time and this will not change my future care.

Participation in this study does not involve any extra cost to me.

Subject's name and signature /thumb impression Date:

Name and signature of witness Date:

Name and signature of person obtaining consent Date:

PATIENT INFORMATION SHEET

TITLE: EFFICACY OF ULTRASONOGRAPHY AND COMPUTED TOMOGRAPHY IN DIFFERENTIATING TRANSUDATE FROM EXUDATE IN PATIENTS WITH PLEURAL EFFUSION

Principal Investigator: Dr. Ramya Chandra Bandaru/ Dr. N. Rache Gowda

I, Dr. RAMYA CHANDRA BANDARU, post-graduate student in Department of Radio-Diagnosis at Sri Devaraj Urs Medical College. I will be conducting a study titled "Efficacy of ultrasonography and computed tomography in differentiating transudate from exudate in patients with pleural effusion" for my dissertation under the guidance of DR. N. RACHEGOWDA, Prof., Department of Radio-Diagnosis. Pleural effusion is a common clinical problem and can arise from many diseases. The first step in assessing a pleural effusion is to decide whether the pleural fluid is a transudate or an exudate. Although clinical and radiological findings may provide significant evidence about the cause of pleural effusion, it may still be necessary to evaluate some cases with diagnostic thoracentesis which is associated with certain complications and contraindications.

Thus, I am doing this study, which might act as an alternative diagnostic tool and help in further management in such situations.

If you agree to participate in the study, we will collect the relevant details about you from your hospital records. The information collected will be used only for research purpose. This study will be reviewed by local ethical board and will be started only after their formal approval. The care you will get will not change if you do not wish to participate. You are required to sign/thumb impression only if you voluntarily agree to participate in this study. Participation in this study will not involve any cost for you. This also does not affect the care you will receive in the hospital.

CONTACT DETAILS:

Dr. RAMYA CHANDRA. B Phone number - 7022063685

Dr. N. RACHEGOWDA Phone number- 9448101418

ಮಾಹಿತಿಯುಕ್ತ ಸಮ್ಮತಿಯ ನಮೂನೆ

ನಾನು ರುಜುಮಾಡಿರುವ, ಈ ಅಧ್ಯಯನದಲ್ಲಿ ಭಾಗವಹಿಸಲು ಈ ಸಮ್ಮತಿಯ ರೂಪ ಅಂಶಗಳಂತೆ ನನ್ನ ವೈಯಕ್ತಿಕ ಮಾಹಿತಿಯ ಸಂಗ್ರಹಣೆ ಮತ್ತು ಬಹಿರಂಗಪಡಿಸುವಿಕೆಯ ಅಧಿಕೃತಗೊಳಿಸಲು ಒಪ್ಪುತ್ತೇನೆ.

ನಾನು ವಿಧಾನ ಮತ್ತು ಸಂಗ್ರಹಿಸಿ ಅಧ್ಯಯನ ಮಾಡುವ ಸಂದರ್ಭದಲ್ಲಿ ಬಹಿರಂಗಪಡಿಸಲಾಗುತ್ತದೆ ಮಾಹಿತಿಯನ್ನು ಗೌಪ್ಯ ಪ್ರಕೃತಿಯ ಅಪಾಯಗಳು ಮತ್ತು ಲಾಭಗಳ ಈ ಅಧ್ಯಯನದ ಉದ್ದೇಶ ಅರ್ಥ. ಸಂಗ್ರಹಿಸಿದ ಮಾಹಿತಿಯನ್ನು ಮಾತ್ರ ಸಂಶೋಧನೆಗೆ ಬಳಸಲಾಗುತ್ತದೆ.

ನಾನು ಈ ಅಧ್ಯಯನದಲ್ಲಿ ವಿವಿಧ ಅಂಶಗಳನ್ನು ಕುರಿತು ಪ್ರಶ್ನೆಗಳನ್ನು ಕೇಳಲು ಅವಕಾಶ ಹೊಂದಿದ್ದರು ಮತ್ತು ನನ್ನ ಪ್ರಶ್ನೆಗಳಿಗೆ ನನ್ನ ತೃಪ್ತಿ ಉತ್ತರಗಳನ್ನು ನೀಡಲಾಗಿದೆ.

ನಾನು ಯಾವುದೇ ಸಮಯದಲ್ಲಿ ಈ ಅಧ್ಯಯನದಿಂದ ಹಿಂಪಡೆಯಬಹುದು ಉಚಿತ ಉಳಿದು ಈ ನನ್ನ ಭವಿಷ್ಯದ ಕಾಳಜಿ ಬದಲಾಗುವುದಿಲ್ಲ ಎಂದು ಅರ್ಥ.

ಈ ಅಧ್ಯಯನದಲ್ಲಿ ಭಾಗವಹಿಸುವಿಕೆ ನನಗೆ ಯಾವುದೇ ಹೆಚ್ಚುವರಿ ವೆಚ್ಚವಿಲ್ಲದೆ ಒಳಗೊಳ್ಳುವುದಿಲ್ಲ.

ವಿಷಯದ ಹೆಸರು ಮತ್ತು ಅರ್ಜಿದಾರರ ಸಹಿ ದಿನಾಂಕ:

ಹೆಸರು ಮತ್ತು ಸಾಕ್ಷಿ ಸಹಿ: ದಿನಾಂಕ

ಹೆಸರು ಮತ್ತು ವ್ಯಕ್ತಿ ಪಡೆಯುವ ಒಪ್ಪಿಗೆ ಸಹಿ: ದಿನಾಂಕ

KEY TO MASTER CHART

A - Anechoic

B - Bilateral

CCF – Congestive cardiac failure

CKD – Chronic kidney disease

CNS – Complex non-septated

CS – Complex septated

CT – Computed tomography

E - Echogenic

F - Female

HU – Hounsfield unit

l - Large

L - Left

M - Male

m - Moderate

PE – Pulmonary embolism

R – Right

s - Small

TB - Tuberculosis

Sl No	Trial ID	AGE	SEX	LATERALITY	ULTRASOUND		EXUDATIVE		TRANSUDATIVE		DIAGNOSIS	Additional CT Findings		
					Size	Type	CT mean HU	Size (mm)	CT mean HU	Size (mm)		loculations	Pleural thickening	Pleural nodules
1	544401.9	45	F	R	l	CS	18.4	133			Carcinoma lung	P	P	P
2	5509884	60	F	L	l	CS	9.6	163			Parapneumonic effusion (TB)	A	A	A
3	8801245	22	F	R	m	CS	16.2	64.2			Parapneumonic effusion	A	A	A
4	4553399	65	F	R	l	E	13	181			Malignancy (ovarian)	A	A	A
5	4043568	65	F	R	s	E	18	27.6			Acute PE	A	A	A
6	7644183	48	F	R	m	E	17	43.2			Malignancy (breast)	A	A	A
7	5615154	73	F	R	l	E	16	153			Carcinoma lung	A	P	A
8	5139497	25	M	R	m	CS	13.8	61.3			Parapneumonic effusion	P	A	A
9	7531109	76	M	R	m	CS	15.3	56.3			Carcinoma lung	A	P	P
10	2926933	18	M	L	l	CS	14.5	137			Parapneumonic effusion (TB)	A	A	A
11	839535.7	75	M	R	m	CS	10	57.7			Carcinoma lung	A	A	A
12	9423679	56	M	R	l	CS	16.2	164			Parapneumonic effusion	A	A	A
13	11028.38	28	M	R	m	CS	19.2	64.1			Empyema	P	P	A
14	813855.7	45	M	R	m	CS	20	36.3			Parapneumonic effusion	P	P	A
15	9530834	45	M	B	l	CS	8	154			Malignancy (stomach)	A	P	P
16	2906315	50	M	B	l	A			3	106	Cirrhosis of liver	A	A	A
17	275708.9	76	M	B	m	A			1.3	68.8	CKD	A	A	A
18	5132990	68	M	B	m	A			6	57	CCF	A	A	A
19	8378747	58	F	B	m	A			2.7	36.5	CCF	A	A	P
20	4874783	32	M	B	s	A			6.3	30	Cirrhosis of liver	A	A	A
21	6346053	70	F	R	l	E	15.2	164			Carcinoma lung	A	P	P
22	5153127	46	M	L	l	CS	14	132			Pyopneumothorax	P	P	A
23	3653808	24	M	B	m	A			5.2	64	CKD	A	A	A
24	9825799	80	F	R	m	E	14.2	99.8			Carcinoma lung	A	P	P
25	4342963	55	F	R	m	CS	12.6	74.6			Parapneumonic effusion (TB)	P	P	A
26	9634259	42	M	R	m	CS	22	98			Empyema	A	P	A
27	231198.5	65	M	B	m	CS	8.9	56.3			Parapneumonic effusion	P	P	A

Sl No	Trial ID	AGE	SEX	LATERALITY	ULTRASOUND		EXUDATIVE		TRANSUDATIVE		DIAGNOSIS	Additional CT Findings		
					Size	Type	CT mean HU	Size (mm)	CT mean HU	Size (mm)		loculations	Pleural thickening	Pleural nodules
28	5496275	70	F	R	m	E	12.8	92.3			Carcinoma lung	A	A	A
29	7482933	64	M	R	m	CS	17.5	80.4			Empyema	P	P	A
30	5257253	88	M	R	m	CS	5	52.7			Carcinoma lung	P	P	P
31	5337231	58	M	R	l	CS	12.6	114			Parapneumonic effusion (TB)	A	P	A
32	4803840	45	M	R	l	CS	25	108.8			Empyema	P	P	A
33	445224.4	65	M	R	m	E	17	82.5			Carcinoma lung	A	A	A
34	5552561	30	M	R	m	CS	24	42.2			Pyopneumothorax (TB)	P	P	A
35	5590471	40	M	L	m	CNS	15.3	72			Hydropneumothorax (TB)	P	A	A
36	3737789	35	F	B	m	A			4.8	43	Anemia	A	A	A
37	2280767	60	F	L	s	A			5.85	30	Acute PE	A	P	A
38	1875545	25	F	R	s	A			7.9	29.2	Acute PE	A	A	A
39	4317706	75	F	B	s	A			2.8	27.8	CCF	A	A	A
40	9903159	52	F	B	m	A			8.2	52.3	CCF	A	A	A
41	8169888	67	M	R	l	CS	12.2	32			Hydropneumothorax (TB)	P	P	A
42	1543605	45	M	R	s	CS	4.5	29			Parapneumonic effusion (TB)	A	A	A
43	121533	60	F	B	m	CNS	6.3	46.5			Parapneumonic effusion	P	P	A
44	3550445	40	M	B	m	A			4.1	32	CKD	A	A	A
45	3356275	50	M	R	l	CNS	13.1	197			Parapneumonic effusion (TB)	A	A	A
46	5872042	66	M	L	m	CS	6.9	37.5			Parapneumonic effusion (TB)	A	P	A
47	8266070	35	M	R	s	A			9.5	17.6	CKD	A	A	A
48	7336563	52	M	R	s	CS	17.9	25			Empyema	A	P	A
49	3538058	72	M	R	s	E	19.5	28.2			Empyema	A	P	A
50	3720302	55	F	L	m	E	8.2	39.2			Parapneumonic effusion	A	A	A
51	1391915	60	M	L	l	CS	23.5	124.9			Carcinoma lung	A	P	P
52	7783926	65	M	L	l	CS	17.2	139.1			Empyema	P	P	A
53	1475475	77	M	B	m	A			1.3	42.1	CCF	A	A	A
54	830092.8	80	M	L	s	E	6.9	29.2			Acute PE	A	A	P

Sl No	Trial ID	AGE	SEX	LATERALITY	ultrasound		EXUDATIVE		TRANSUDATIVE		DIAGNOSIS	Additional CT Findings		
					size	Type	CT mean HU	Size (mm)	CT mean HU	Size (mm)		loculations	Pleural thickening	Pleural nodules
55	4545244	48	M	R	m	CS	7.9	73.8			Mesothelioma	P	P	P
56	4239342	33	M	R	m	CS	14.6	76.9			Parapneumonic effusion	P	P	A
57	7453673	98	F	B	m	CNS	7.8	49			Parapneumonic effusion	A	A	A
58	9764445	49	F	R	m	E	14.32	33			Empyema	A	P	A
59	8853689	40	M	B	s	A			3.5	23.5	CCF	A	P	A
60	8673148	38	M	R	l	CS	8.7	162			Parapneumonic effusion	P	P	A
61	6796299	61	M	R	m	A	14.5	52.3			Malignancy (stomach)	A	A	A
62	8333371	50	M	B	m	CS	6.7	22.5			Malignancy (oesophagus)	A	P	P
63	5650549	72	M	R	s	E	24.2	22.8			Empyema	A	P	A
64	8347223	81	F	B	s	A	8.9	20.2			Malignancy (thyroid)	A	A	A
65	3401972	22	M	B	s	A			6.6	19.6	CCF	A	A	A
66	842953.7	25	F	B	s	A			7	24.2	Dengue fever	A	A	A
67	5469399	40	F	B	m	A			3.2	41	Dengue fever	A	A	A
68	9605645	27	F	B	s	A			2.9	20.1	Dengue fever	A	A	A
69	5266390	43	F	B	m	A			1.6	35.7	Dengue fever	A	A	A
70	6499212	39	M	B	s	A			5.3	26	Dengue fever	A	A	A
71	1930163	55	M	L	m	CS	30	24.2			Empyema	P	P	A
72	96719.49	55	M	L	s	CS	12	65.5			Parapneumonic effusion	P	A	A
73	335433	52	M	R	m	CS	14.6	31.5			Empyema thoracis	P	P	A
74	5865332	37	F	R	m	CNS	17.4	30.4			Parapneumonic effusion (TB)	A	A	A
75	953941	50	M	R	m	CS	34	33.3			Empyema	A	P	A
76	2532007	60	M	B	s	A			2.5	22.8	CKD	A	A	A
77	5671449	65	M	B	s	A			7.3	24.5	CCF	A	A	A
78	3402313	60	M	B	s	A			2.9	18.9	CCF	A	A	A
79	1943776	70	F	L	s	E	12.6	18.8			Mesothelioma	A	P	P
80	5992957	48	M	R	m	CS	14.6	45.9			Parapneumonic effusion (TB)	A	P	A