CT of Pleural Abnormalities

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The pleural surface of the lung and adjacent chest wall are made up of a number of tissue layers. On CT in normal patients, a 1 to 2 mm thick stripe of soft tissue density (the "intercostal stripe") is often visible in the anterolateral and posterolateral intercostal spaces, at the point of contact of lung with chest wall.[1] This stripe primarily represents the innermost intercostal muscle. Although the parietal pleura, a thin layer of extrapleural fat, and the endothoracic fascia lie internal to the innermost intercostal muscle and rib segments, they are not normally visible on CT or HRCT.

In the paravertebral regions, the innermost intercostal muscle is anatomically absent. In this location, a very thin line (the "paravertebral line") is sometimes visible on CT at the lung-chest wall interface; this line represents the combined thicknesses of the visceral and parietal pleura and the endothoracic fascia.[1]

CT Diagnosis of Pleural Thickening

Asbestos exposure is known to result in thickening of the parietal pleura.[1-3] Thus, patients with asbestos exposure serve as an excellent model of parietal pleural thickening for the purpose of understanding the CT appearances of pleural disease. In patients with asbestos exposure, parietal pleural thickening can result in 3 findings:

1) A stripe of soft tissue density, 1 mm or more in thickness, can be seen internal to rib segments. Since parietal pleural thickening is often associated with thickening of the normal extrapleural fat layer, the thickened pleura may be separated from the rib by several mm.

2) Thickening of the extrapleural fat layer can also allow the thickened parietal pleura to be seen as distinct from the innermost intercostal muscle. This results in the "sandwich sign", in which the soft-tissue opacity parietal pleura and innermost intercostal muscle are separated by a layer of low attenuation fat.

3) In the paravertebral regions, a distinct stripe of density, 1 or 2 mm in thickness. indicates the presence of pleural thickening.

CT Technique for Examining the Pleura or Pleuro-Pulmonary Disease

Usually contiguous 1 cm collimation, or spiral CT with 7 mm collimation is sufficient for imaging pleural abnormalities. Contrast enhancement at an injection rate of 1-2 ml/sec is essentia]; following contrast opacification thickened pleura, fluid collections, and collapsed or consolidated lung can be distinguished [4]. This is not always possible without contrast infusion.

Diagnosis of Pleural Fluid Collections

Is it an exudate or a transudate?

Distinguishing an exudate from a transudate can be important in differential diagnosis and clinical management. Exudative effusions can have a variety of causes, but often reflect the presence of a pleural abnormality associated with increased permeability of pleural capillaries.[5,6] Common causes of an exudate include pneumonia, empyema, and neoplasm. Transudative effusions are unassociated with pleural disease, and are usually the result of systemic abnormalities which cause an imbalance in the hydrostatic and osmotic forces leading to pleural fluid formation. Common causes of a transudative effusion include congestive heart failure, cirrhosis, overhydration, and nephrotic syndrome.

Most effusions appear to be near water in attenuation on CT. CT numbers cannot be used to reliably predict the protein content or specific gravity of the fluid, and whether it is a transudate or an exudate. Acute or subacute hemothorax can sometimes appear inhomogeneous in attenuation with some regions, particulary dependent regions, having a CT attenuation value greater than that of water.

The appearance of the parietal pleura on contrast enhanced CT can be of value in predicting the nature of a pleural fluid collection [4]. The presence of

thickened parietal pleura on contrast enhanced CT, in association with a pleural effusion, indicates that the fluid collection is an exudate, with only rare exceptions. Such an effusion should be tapped for diagnosis. The absence of pleural thickening in a patient with pleural effusion indicates that the effusion is either a transudate or exudate.[4,7] In a study we have performed,[4] pleural thickening is present in only 61% of consecutive patients with an exudate; this finding had a specificity of 96% in diagnosing exudate and a positive predictive value of 97%.

Pleural thickening on CT is least sensitive (27-48%) in patients with an exudate associated with neoplasm. On the other hand, CT shows pleural thickening and enhancement in nearly all patients with empyema. In a study by Waite et al.,[7] 23 of 24 empyemas demonstrated pleural thickening and enhancement on CT. In our study, all 10 empyemas showed pleural thickening; pleural thickening was less frequently (56%) seen in association with uninfected parapneumonic effusions.

Thus, in a patient with symptoms of infection and a pleural effusion, the presence of parietal pleural thickening on CT indicates the presence of an exudate, and thoracentesis is necessary. If pleural thickening is absent, empyema or complicated parapneumonic effusion (one needing drainage for treatment) is highly unlikely. In a patient with malignancy, CT does not help in assessing the presence or absence of a malignant effusion, and thoracentesis is usually required regardless of what CT shows.

Sonography is also useful in diagnosing the presence of an exudate, with an accuracy nearly identical to that of CT. Yang et al[8] found that all effusions having the sonographic appearances of septation, complex nonseptation, or homogeneous echogenicity were exudative. Anechoic effusions, however could be either transudative or exudative. The sensitivity of sonography in this study was 66%, with a specificity of 100% and a positive predictive value was 100%.

Diagnosis of Pleural Fluid Abnormalities in Patients with Pneumonia

Pleural fluid accumulates in approximately 40% of patients with pneumonia, and the term parapneumonic effusion is used to describe this occurrence. Parapneumonic effusions are usually classified in 3 stages (these are also known as the 3 stages of an empyema).

Stage 1 (Exudative Stage)

An exudative parapneumonic effusion probably results from increased permeability of the visceral pleura. Effusions in this stage are commonly exudates, as the name implies, and are typically small, sterile, and have normal glucose (> 40 - 60 mg/dL) and pH values (> 7.2). They will usually resolve with appropriate antibiotic treatment. Stage 1 effusions may not show pleural thickening on CT. As indicated above, about 50% of exudative parapneumonic effusions will show pleural thickening; these are usually crescentic, without evidence of loculation.

Stage 2 (Fibropurulent or Acute Empyema Stage)

The term "empyema" is generally used when a pleural effusion is infected, although its true definition necessitates the presence of "pus" in the pleural space. Although most empyemas occur in association with pneumonia, approximately 10% are unassociated with obvious lung disease. The term "empyema" is synonymous with "fibropurulent parapneumonic effusion".

The fibropurulent stage of a parapneumonic effusion is characterized by the presence of organisms in the pleural fluid, increased effusion, increased WBC and PMN in the fluid, fibrin deposition along the pleural surfaces, a tendency for loculation, decreased glucose and pH levels, and increased LDH (>1000 IU/L).

In a patient who has a pneumonia, the presence of a localized or loculated pleural effusion strongly suggests the presence of an empyema. On plain radiographs, empyemas or loculated fluid collections will often have a somewhat lenticular configuration, appearing much larger in one dimension (i.e. as seen on the PA radiography) than the other (i.e. on the lateral radiography). Furthermore, because the collection may have a obtuse angles at the point it contacts the chest wall, it may appear much more sharply defined in one projection than the other. In the presence of a bronchopleural fistula (BPF), an empyema cavity can contain air. Gas within an empyema is presumptive evidence of a BPF, although the presence of a gas-forming organism is occasionally associated with this finding.

With conventional radiographic techniques, an empyema containing air may be difficult or impossible to differentiate from a peripheral lung abscess abutting the chest wall. This distinction can be an important

one to make because empyemas are often treated by tube thoracostomy in addition to systemic antibiotics, whereas most lung abscesses require antibiotics only. On CT, empyemas typically have a regular shape and are round, elliptical, or lenticular in cross section, although crescentic collections can also be seen;[9,10] they tend to be sharply demarcated from the adjacent lung. Parietal pleural thickening is almost always seen on CT, while visceral pleural enhancement is somewhat less common. With contrast infusion, a "split-pleura" sign is commonly visible, with the enhancing visceral and parietal pleural surfaces split apart by the fluid collection, but this sign need not be present. The pleural layers usually appear smooth and of uniform thickness.[7] Lung abscesses tend to be rounded in shape, ill-defined, and have walls of irregular thickness. Empyemas also compress and displace lung and vessels, acting like a space-occupying mass, while lung abscesses usually destroy lung without displacing it.

In some patients with lung abscess and an air-containing empyema indicating the presence of a bronchopleural fistula, the site of the BPF can be demonstrated on CT. Absence or interruption of the enhancing visceral pleura adjacent to an air-filled abscess cavity (the "interrupted pleura sign") implies that this is the site of perforation. It should be noted, however, that an interrupted pleura does not always indicate the presence of a bronchopleural fistula.

In patients with uninfected parapneumonic effusion or empyema, it is common (60-80 % of cases) to see extrapleural fat thickening when parietal pleural thickening is present. Increased attenuation of extrapleural fat representing edema is less common (30% of cases).[7]

Several pulmonary infections can involve the chest wall by direct extension ("empyema necessitatis"). Tuberculosis accounts for about 70% of cases of empyema necessitatis, but other organisms such as actinomycosis, nocardiosis, and other bacteria can be responsible. In this setting, extensive extrapleural fat thickening, edema, and subcutaneous collections can be seen on CT.[11]

As tube thoracostomy is commonly used to treat empyema, it is important to consider the indications for tube placement in patients with a fibropurulent effusion. These will vary depending on the clinician involved and the clinical setting, but Light suggests the following criteria: 1) thick pus present on thoracentesis, 2) positive gram stain, 3) pH < 7.0, 4) glucose < 40 mg/dL. Although pleural thickening seen on CT is common in an acute empyema, this does not constitute a "pleural peel", and surgery is rarely required. Follow tube drainage, the pleural thickening usually resolves within a period of days or weeks,[12] although focal pleural abnormalities can remain. Tube thoracostomy is generally avoided in patients with a tuberculous empyema.

Stage 3 (Organization Stage)

In patients with chronic empyema, especially empyema which is tuberculous in origin, organization of the empyema, with ingrowth of fibroblasts, can result in extensive pleural fibrosis and the development of an inelastic fibrotic "pleural peel". This can cause lung restriction and decreased lung volume ("trapped lung"). On CT, a thickened layer of extrapleural fat is frequently visible, separating the thickened parietal pleura from the intercostal muscle or rib. Calcification, which usually is focal in its early stages, may become extensive.[13]

Dense pleural thickening, even with calcification, does not indicate that the pleural disease is inactive. Loculated fluid collections resulting from active infection may be seen on CT within the thickened pleura [14]. Similar pleural thickening can be the result of chronic or prior infection, chronic inflammatory disease, hemothorax occurring because of trauma, neoplasm, or radiation. Except in patients with neoplasm, calcification can occur.

Pleural Neoplasms

CT findings which are most helpful in distinguishing malignant and benign pleural diseases include 1) circumferential pleural thickening, 2) nodular pleural thickening, 3) parietal pleural thickening greater than 1 cm, and 4) mediastinal pleural involvement.[15] The specificities of these findings for diagnosing malignant pleural disease were determined to be 100%, 94%, 94%, and 88% respectively, while their sensitivities were 41%, 51%, 36%, and 56%.[15] If one or more of these findings are considered to indicate malignancy, overall diagnostic accuracy is about 75%.

Malignant (Diffuse) Mesothelioma

Diffuse mesothelioma is a highly malignant, progressive neoplasm with an extremely poor prognosis.[16] In most patients, malignant mesothelioma is related to asbestos exposure, and although it is rare in the general population, the incidence in asbestos workers

is up to 5%. It is characterized morphologically by gross and nodular pleural thickening, which can involve the fissures. Hemorrhagic pleural effusion often occurs. Malignant mesothelioma spreads most commonly by local infiltration of the pleura. CT is very helpful in diagnosis, and the frequency of various CT findings have been described.[16]

Pleural thickening is common (90%), and is often irregular or nodular in contour-, focal pleural masses can sometimes be seen. Pleural fluid collections are visible on CT in 75%. Fluid can be difficult to distinguish from tumor, even on CT, since tumor nodules can sometimes appear low in density. However, CT scans with the patient prone or decubitus can help to distinguish underlying tumor from free fluid. Also, enhancement of the pleura after contrast infusion can also help differentiate tumor from adjacent fluid collections on CT.[16-20]

Although pleural mesothelioma is visible most frequently along the lateral chest wall, mediastinal pleural thickening or concentric pleural thickening is seen with extensive disease. The abnormal hemithorax can appear contracted and fixed (40%), with little change in size during inspiration. Thickening of the fissures, particularly the lower part of the major fissures, can reflect tumor infiltration of the fissures or associated pleural effusion; involvement of the fissures is seen on CT in 85%. Malignant mesothelioma typically spreads by local invasion, involving the mediastinum and sometimes the chest wall (15%), but hematogenous pulmonary metastases, and distant metastases do occur.

Metastases

Pleural metastases usually result in pleural effusion without visible pleura thickening. However, pleural metastases can result in nodular pleural thickening or masses visible on CT. In some patients with pleural metastases, particularly those with a malignant thymoma, can show pleural metastases unassociated with effusion. Metastatic adenocarcinoma can infiltrate the pleura and may be indistinguishable from malignant mesothelioma.[15]

In a patient with bronchogenic carcinoma, pleural effusion can occur for a variety of reasons, including obstructive pneumonia, and lymphatic or pulmonary venous obstruction by tumor. Only those patients with demonstration of tumor cells in the pleural fluid are considered unresectable.

Pleural effusions are found in 15% of patients with Hodgkin's disease, and usually reflect lymphatic or venous destruction rather than pleural involvement, because they tend to resolve following local mediastinal or hilar radiation. Pericardial effusions, on the other hand, present in 5%, usually indicate direct involvement of the pericardium.

Local Fibrous Tumor of the Pleura (Benign Mesothelioma)

Localized fibrous tumor of the pleura is the new name of an uncommon tumor, formerly known as benign mesothelioma. This lesion is usually detected incidentally on chest radiographs. However, it can be associate with hypoglycemia and hypertrophic pulmonary osteoarthropathy. It usually arises from the visceral pleura and therefore can be within a fissure, but more commonly involves the costal pleural surface. They appear as solitary, smooth, sharply defined, often large lesions, contacting a pleural surface.

On CT, necrosis can result in a multicystic appearance with or without contrast infusion. Although it is generally believed that pleural abnormalities result in obtuse angles at the point of contact of the lesion and chest wall, benign mesothelionas typically show acute angles with slightly tapered pleural thickening adjacent to the mass.[21] This thickening may reflect a small amount of fluid accumulating in the pleural space at the point where the visceral and parietal pleural surfaces are separated by the mass. A similar "beak" or "thorn" sign is often visible on plain radiographs in patients with a benign fissural meshotheolioma.

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