Accuracy of Computed Tomography Attenuation Values in the Characterization of Pleural Fluid: An ROC Study[1]

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Rationale and Objectives. To assess the accuracy of computed tomography (CT) in characterizing pleural fluid based on attenuation values.

Materials and Methods. Protocol was approved by the local institutional review board and informed consent was waived. We retrospectively analyzed 145 pleural effusions of 145 patients (mean/standard deviation age: 60.7/15.9 years; 69 females) who underwent CT of the thorax and diagnostic thoracentesis within 7 days of each other. Effusions were classified as transudates or exudates using laboratory markers based on Light's criteria. The mean Hounsfield units (HU) of an effusion was determined by a region of interest on the three slices with the greatest anteroposterior diameter. A receiver operating characteristic curve was constructed to determine threshold values for classification on the basis of mean HU and to examine overall accuracy, using the area under the curve (A_z).

Results. Of the 101 exudates and 44 transudates, the mean attenuation of exudates (17.1 HU/standard deviation 4.4) was significantly higher than transudates (12.5 HU/6.3), ($P < .001$). There was a modest but significant positive relationship between mean HU and laboratory markers, with the strongest relationship with pleural/serum protein ($r = 0.57$, $P < .001$) and total pleural protein ($r = 0.56$, $P < .001$). The overall accuracy of attenuation values for identifying exudates was moderate, Az = 0.775, standard error = 0.039, with the largest limitation being the overlap with transudates in the 10–20 HU range, which constituted 66% (90/145) of the total effusions measured.

Conclusion. Although the mean attenuation of exudates is significantly higher than transudates, the clinical use of CT numbers to characterize pleural fluid is not recommended, as their accuracy is only moderate. Moreover, there is a notable overlap in attenuation values between transudates and exudates for a majority of effusions.

Key Words. Pleural Effusion; Tomography; X-Ray Computed; Exudates and Transudates.

The characterization of pleural fluid is important in the clinical management of various pathologies involving the thorax, because it often provides information regarding the underlying pathologic process. Although thoracentesis is routinely used to differentiate exudates from transudate, the procedure carries small but significant risks. Even under ultrasound guidance by an interventional radiologist, there is still an approximately 1% risk of pneumothorax requiring tube thoracostomy, along with a chance for many minor complications such as pain, shortness of breath, cough, and hematoma (1). A noninvasive method to characterize pleural fluid would be valuable in guiding therapy and avoiding the potential hazards associated with thoracentesis. In addition, such a technique could possibly also help patients with a contraindication to the procedure.

The mechanism for the formation of transudates is largely dependent on an imbalance of hydrostatic and osmotic forces, and transudates generally contain low levels

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of protein and demonstrate low specific gravity (2). Exudates are usually secondary to diseases of the pleura itself and often result from lymphatic obstruction or increased capillary permeability, leading to high levels of protein and lactate dehydrogenase and elevated specific gravity. Theoretically, given the greater degree of protein content in exudates, these type of effusions could potentially demonstrate greater attenuation values on computed tomography (CT) and consequently be noninvasively differentiated from transudates.

The purpose of our study was to assess the accuracy of CT in characterizing pleural fluid based on attenuation values.

METHODS AND MATERIALS

Patient Population

This research protocol was approved by the local institutional review board and informed consent was waived. Between November 2001 and November 2004, a total of 789 patients underwent diagnostic thoracentesis. A total of 145 patients were included in our retrospective analysis based the following criteria: CT and thoracentesis performed within 7 days of each other; sufficient laboratory data for diagnosis by Light's criteria: pleural fluid lactate dehydrogenase (LDH), pleural total protein, serum LDH, and serum total protein values (3); and no history of previous pleurodesis or placement of pleural drainage catheter. Of the 644 excluded patients, 577 did not undergo diagnostic thoracentesis within 7 days of CT, 37 had insufficient laboratory information, and 30 had a history of previous intervention.

In the patient population of 145 patients with 145 laboratory analyzed effusions, there were 76 males and 69 females with a mean/standard deviation age of 60.7/15.9 years (range 3–93 years). Thoracentesis was performed a mean/standard deviation of 2.8/2.1 days within undergoing CT. Pleural LDH (U/L), pleural total protein (g/dL), pleural specific gravity, serum LDH (U/L), and serum total protein (g/dL) values were obtained in all patients, and pleural albumin (42 patients) if performed. Pleural effusions were classified based on Light's criteria, which categorizes an effusion as an exudate if it demonstrates one or more of the following features: pleural fluid protein to serum protein ratio > 0.5, pleural fluid LDH to serum LDH ration > 0.6, and pleural fluid LDH greater than two thirds the upper limit of normal serum LDH (180 U/L at our institution) (3). In addition to Light's criteria markers, the most likely etiology of the pleural fluid, such as congestive heart failure or malignancy, was determined using clinical information and a combination of serum and pleural laboratory values, such as gram stain, and cultured for bacteria, total and differential cell counts, glucose level, hematocrit, and cytologic analysis based on previously published criteria (4).

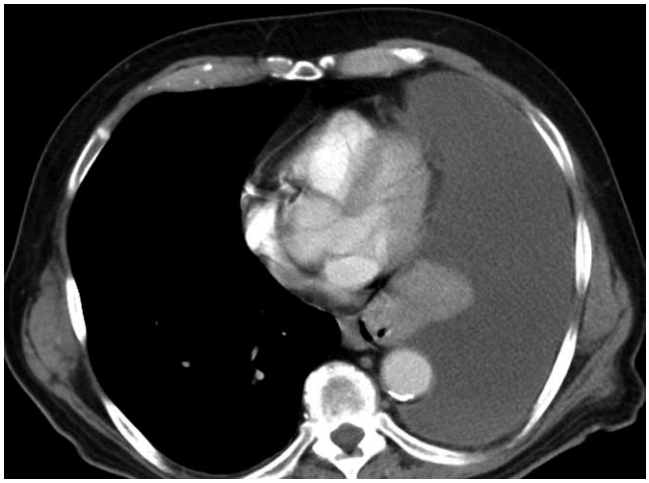

Figure 1. Contrast-enhanced axial computed tomography image of the thorax demonstrating a large left unilateral pleural effusion with a mean Hounsfield unit (HU) of 20.4 HU secondary to metastatic disease from neck squamous cell carcinoma.

Data Acquisition

CT scans were reviewed by a radiologist blinded to the clinical and laboratory information. The three slices with the greatest amount of fluid, determined by the largest anteroposterior distances of the effusion (mean for patients: 31 mm, range 11–210 mm), were used. A region of interest was placed encompassing the entire fluid on each slice and the mean Hounsfield unit (HU) value of the three slices was used (Figure 1). Care was taken not to include adjacent ribs, compressed or aerated lung parenchyma, and areas of pleural thickening. Reproducibility was assessed by an independent blinded radiologist measuring values in 50 random patients.

Scan Parameters

CT was performed on all patients on either an 8-slice scanner (LightSpeed Ultra, GE Medical Systems; Milwaukee, WI) ($n = 112$) or 16-slice scanner (LightSpeed 16, GE Medical Systems) ($n = 33$). All scans were obtained with one of the two following protocols. First, after a delay determined by an automated bolus timing program for