

COMPUTERIZED TOMOGRAPHY (CT) IN COAL WORKERS' PNEUMOCONIOSIS

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CWP is a common occupational disease and there have been many publications on the use of X-ray examination in this condition. But we have been unable to trace any publication on CT diagnosis of CWP. In order to investigate the diagnostic value of CT for CWP, 100 coal workers were examined by CT scanning and results compared with that of standard chest radiographs and pulmonary function tests.

SUBJECTS AND METHODS

The 100 male underground coal workers were selected at random. The age range was 40 to 75 years (mean 62) and coal dust exposure range was from 11 to 40 years (mean 20.15).

CT Scanning Examination

CT scans were obtained using a Toshiba TCT80A scanner at 1 cm intervals from the apex to the diaphragm at full inspiration appropriate for the lung (level -800, width 1000 HU) and mediastinum (level 40, width 400 HU).

Visual analysis

1. *Small opacity.* According to the principle of ILO Classification, the profusion of small opacities on each slice of CT was classified into four categories. A scoring system for the CT scans was devised. The two lungs were divided into six zones and CT score for small opacities for any zone was counted as the product of profusion of small opacities and the percentage ratio of the small opacity slices to whole slices on that zone. Then the scores of the left, right and two lungs might be counted. The starting point for diagnosing pneumoconiosis was considered to be the score '2' i.e., at least two lung zones were full of small opacities with category 1.
2. *Large opacity.* If a dense opacity with a diameter than 10 mm appeared in the lung fields of two adjacent slices, and was still observed at the mediastinum level then a large opacity was recorded.
3. *Emphysema.* Following Goddard's standard we considered areas of low attenuation and vascular disruption to be suggestive of emphysema. The emphysema was classified into four grades according to its extent on the CT films.¹ The scoring system for CT emphysema was counted as the product of the emphysema grade and percentage ratio of emphysema slices appear-

ing to the whole slices on that zone. Emphysema might be diagnosed if there were characteristic appearances of emphysema on at least half slices on one lung zone.

Numerical analysis

The mean attenuation of the whole lung field density was measured at the three slices of the apex of the lung, carina and immediately above the dome of the right hemidiaphragm corresponding to the upper, middle and lower zones of the right lung for every subject. The mean attenuation values of the above three slices was also calculated.

X-ray Examination

Standard PA and lateral chest X-ray films were obtained on all subjects at the same time as CT scanning was carried out. The films were read using the 1980 ILO Classification and also according to the routine standard² did the diagnosis of emphysema.

Pulmonary Function Tests

The following tests were carried out for 80 subjects while having CT examination: VC%, FEV₁%, FEV₁/VC%, MBC%, RV/TLC. Loss of lung function was considered to be present if the FEV₁% was less than 60, FEV₁/VC% less than 60, MBC% less than 80 and RV/TLC more than 40%.

RESULTS

Visual Analysis

2175 slices of CT scanning were taken from 100 coal workers. Three had no small or large opacities present. 45 had small opacities present. Of these 34 might be diagnosed as simple pneumoconiosis with the CT score 2. 42 had complicated pneumoconiosis with large opacities present. 96 had changes with emphysema. Of these 87 could be diagnosed as having emphysema according to the CT criterion given above.

Small opacity

995 slices of scanning were taken from 48 subjects without large opacities. At any zone category 1 profusion was the most common (69.14%). Category 3 profusion was the least common (2.97%). Among the 497 slices showing small opacities were observed, mostly in the middle and lower zones. For the distribution of small opacities at anterior or posterior parts of the lung small opacities were observed at

the posterior part of the lung for 459 slices (92.35%) and at the anterior part of the lung for 324 slices (65.19%).

Large opacity

There were large opacities present on CT for 52 subjects. 88.3% of large opacities appeared at the posterior part of the lung. Only 11.7% at the anterior part of the lung. 84.1% of large opacities were mainly distributed at the medulla of the lung with a distance of 1–2 cm from the outer margin of lung amongst large small opacities distributed obviously at the medulla of the lung.

Emphysema

For all scanning slices 932 (42.38%) of the right lung, and 972 (40.09%) for the left lung showed appearances characteristic of emphysema. Emphysema appeared mostly in the lower lung zones (65.8%) and least at the upper zone (19.4%). Grade 1 was the most common (23.84%) with grade 4 accounting for only 0.54%. For most CT films (96.57%) emphysema was observed at the anterior part of the lung. 34 bullae were observed in 14 subjects. Most of the bullae were located in the upper lung zone and in the posterior part of the lung.

Numerical Analysis

The mean attenuation value of lungs for 48 subjects, without large opacities, was -854.95 ± 47.92 HU. That for the upper, middle and lower zones were -846.49 ± 60.62 , -871.7 ± 48.97 and -846.6 ± 49.33 HU respectively. No definite trends were discoverable. These values were calculated statistically for 0, ≤ 2 and > 2 of the CT score for the profusion of small opacities and were -874.43 ± 45.11 , -855.27 ± 34.45 and -856.11 ± 48.44 HU respectively. Again no definite rule was found. The mean attenuation value for the upper, middle and lower zones for the 100 coal workers were -839.43 ± 63.14 , -857.47 ± 48.31 and -860.36 ± 47.79 HU respectively, all lower than the normal value. The mean value of the sum of attenuation values of three slices of the right lung for all subjects calculated statistically for ≤ 3 and > 3 of CT score for emphysema were -849 ± 44.09 and -863.9 ± 39.73 HU respectively. There was a significant difference between the attenuation values of ≤ 3 score and > 3 score ($t = 2.18$, $P < 0.005$).

Comparison of CT and Chest Radiograph

Small opacity

For diagnosing pneumoconiosis either positively or negatively by CT and ILO Classification 41 subjects (85.4%) were agreed, 7 (14.6%) were not. This was within the acceptable extent of the difference of film examination. CT score for small opacities was also closely related to the complete twelve-point scale of profusion of the ILO Classification 1980 ($r = 0.7357$, $P < 0.01$).

Large opacity

For 52 subjects with CT showing large opacities, large opacities could be diagnosed on chest radiographs for 37. None of the subjects showed a large opacity on his chest radiograph, but not on CT. Thus the detectable rate of large opacity with CT was increased by 15% over that by chest

radiography. For 30 subjects diagnosed as simple pneumoconiosis by their chest radiographs, according to the ILO Classification 1980, 12 (40%) had large opacities in their CT. CT was also to demonstrate calcification and cavitation in large opacities much more readily than chest radiography. For 52 subjects showing large opacity 28 of them (53.9%) had calcification on CT examination, with the mediastinum window level, but only 2 (5.4%) had calcification areas on chest radiograph. 18 (34.62%) of the subjects showed cavitation on CT but only 2 subjects showed cavitation on chest radiography.

Emphysema

Emphysema was diagnosed for 87 subjects by CT but only for 49 subjects by chest radiography. There were very significant difference between these two methods ($u = 5.8$, $P < 0.001$). The use of CT increased the rate of detection of emphysema by 38%. Bullae were shown by CT for 14 subjects but on chest radiography only 4 of them had typical bullae.

Comparison of CT and Pulmonary Tests

CT score for small opacities was not definitely related to lung function. The comparison of CT score of emphysema and the number of lung function tests showing decrements demonstrated: For 60 subjects with a score of ≤ 6 the mean number of positive items was 2.65. For 20 subjects with a score of > 6 the mean number of positive items was 3.75. There was a very significant difference between the two cases ($t = 2.77$, $P < 0.01$).

DISCUSSION

Using standard radiography pneumoconiosis could be diagnosed with confidence by X-ray, and the ILO Classification was the generally accepted "gold standard" for the categorization of pneumoconiosis. In this paper it has been shown that there was an equal ability to diagnose simple pneumoconiosis using CT. The CT score of small opacities designed by us was very closely related to the ILO Classification and showed that CT might be used to diagnose pneumoconiosis reliably on chest radiographs. Although CT was better than chest radiography in detecting small opacities distributed at the anterior/posterior context or medulla part of the lung the additional cost involved in using CT did not justify the slightly superior advantage over chest radiography for diagnosing simple pneumoconiosis.

CT was significantly superior to the chest radiograph for diagnosing complicated pneumoconiosis. In this paper it has been shown that 15% more large opacity might be detected by CT than by chest radiography. It has been shown that in films showing simple pneumoconiosis by chest radiography large opacities could also be detected by CT for 40% of them. In addition it has been shown that CT is capable of detecting emphysema much more easily than chest radiography, and that the detection rate for emphysema is 38% greater for CT than chest radiography. It is common knowledge that the large opacity and emphysema were the important causes of deteriorating for patients of pneumoconiosis. Thus it was important to detect large opacities and emphysema early. In our opinion the main in-

dication for CT in coal workers is to detect these large opacities and emphysema undetectable by chest radiographs.

In recent years there has been a great deal of interest in diagnosing diffuse disease and emphysema of the lung by use of CT attenuation values.^{1,3} Rosenblum reported that the mean attenuation value for whole lung for normal persons was -743 ± 58 HU.³ Attenuation of the 100 coal workers described in this paper was lower than the above mentioned normal value and tended to decrease with increase of the CT score for emphysema. This appeared to be related to the fact that most of the coal workers had emphysema. Diagnosis of emphysema by measuring the attenuation value of lung was possible. On the other hand the attenuation value of lung had no definite relation to the CT score for small opacities. In our opinion this might be the result of mutual influence between pneumoconiosis with differing degrees of profusion

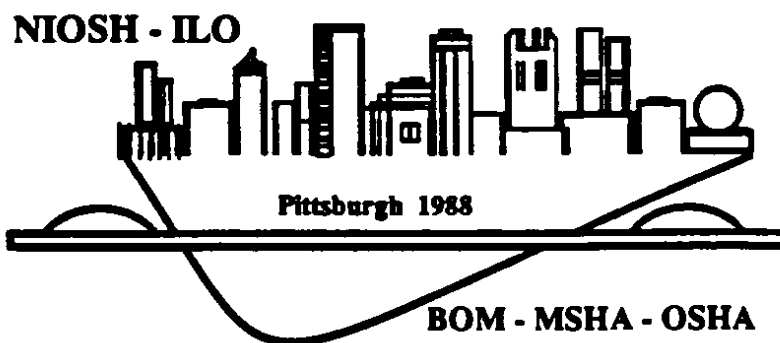
and emphysema with varying degrees of severity. In the situation where there might be simultaneous co-existence of disease with decreasing and increasing density of lung, as is shown by the coal workers in this paper, precisely how to evaluate the mean attenuation values of lung measured also needs further study. For this reason we do not, at present, recommend diagnosing pneumoconiosis by measuring the attenuation value of lung. This is best done mainly by visual analysis.

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