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# Roentgenologic Manifestations

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For the purposes of this presentation it is agreed that pneumoconiosis should be defined in anatomical terms: Pneumoconiosis is the accumulation of dust in the lungs and the tissue reaction to its presence; the inhalation of coal mine dust is the cause of *coal workers'* pneumoconiosis, and it can be detected in life by means of an abnormal roentgenographic pattern and a positive history of dust exposure while working in soft-coal mines (1).

Pneumoconiosis is a disease in which the radiologist should play the dominant role in diagnosis and elucidation of the natural history (2). That opportunity has been enhanced as a result of suggested changes in recording the manifestations of the various patterns of anatomic changes in the chest (Figs. 17 and 18).

## ESSENTIALS OF CHEST RADIOGRAPHY (3)

The most desirable chest radiograph for the study of the pneumoconioses or other pulmonary disease is one in which the lung is shown in greatest detail. Although it is important to visualize the mediastinal structures, it is most difficult to obtain a chest radiograph in which both the lungs and mediastinum are seen equally well. A film in which the vertebral bodies are faintly visible through the heart shadow will ordinarily be adequate for the study of pulmonary detail and also will provide acceptable visualization of the mediastinum.

The maximum information can be obtained from radiographs which have a broad range of contrast, i.e., a long grey scale. High-contrast radiographs should be avoided.

## Equipment

The installation and maintenance of the radiographic equipment is of the greatest importance. The electric power source should be independent of other users. It must be of adequate capacity and should be subject to no more than a 5% fluctuation. The radiographic unit must be carefully calibrated at the time of installation and should be recalibrated periodically. Preventive maintenance at regular intervals, preferably by factory trained personnel, is strongly recommended.

The generator should have a minimum capacity of 300 mA at 125 kV(peak). A generator with a capacity of 150 kV(peak) is strongly recommended. The generator must be full-wave rectified. It should be equipped with an accurate timer ($\pm 1\%$) capable of minimum exposure of no more than 10 mseconds.

A rotating anode tube is essential. It should have as small a focal spot as feasible for the anticipated load, but in no instance should this exceed 2 mm in diameter.

A total filtration, inherent and added, of the primary X-ray beam should be the equivalent of at least 2.5 mm of aluminum.

The radiation should be confined by means of a collimator to the portion of the subject to be examined. This will not only decrease radiation hazard, but will improve detail by reducing scattered radiation. The collimator should have an adjustable diaphragm and a light beam for centering, and it should be designed so the projected field cannot exceed the size of the film. Evidence of collimation should be visible at the edges of the film as "cone cuts."

Medium speed (par speed) intensifying screens should be used. They provide the best compromise between sharp definition and short exposure. The cassettes in use must all contain screens of the same speed and must be checked periodically for screen cleanliness, contact, and defects.

The X-ray film should be of a general purpose type and of medium sensitivity. High-speed film is not recommended. The film should be no larger than needed to cover both lungs, including the costophrenic angles.

When using kilovoltages of 80 and above, reduction of secondary radiation by a grid or other means is essential. A 10:1, 100 line/in. fixed grid or an air-gap of 8 in. with an 8-ft focal-spot–film distance may be used.

Automatic processing should be employed whenever possible. If only manual processing is available, a constant time–temperature technique must be followed meticulously. An improper exposure cannot be corrected by improper processing.

Further improvement in radiographic quality may be expected with the use of a three-phase generator or other means of increasing the effective photon energy, high-speed rotating anode tubes, smaller focal spots, finer grain film, etc.

## Technique

Correct centering of the X-ray tube and careful positioning of the subject are of great importance for the proper visualization of anatomic structures and comparison of serial examinations. For the P-A projection, the X-ray tube should be centered to the center of the film and the beam directed horizontally. The shoulders should be positioned so the scapulae are outside the lungs. The exposure should be made at

full inspiration and made immediately after this has been reached to avoid the Valsalva effect. It is desirable, but not essential, that all the clothes above the waist be removed.

The focal-spot–film distance should be fixed between 5 and 6 ft (approximately 1.5 and 2.0 m).

For the reasons given above, a variable high kilovoltage, constant mA-second technique is recommended. Exposure factors employed may vary somewhat with each generator and tube. The highest range of kilovoltage and shortest range of mA-second obtainable should be used. For the average subject, with an A-P chest diameter between 21 and 23 cm, the usual exposure factors will be 5 mA-second at approxi-

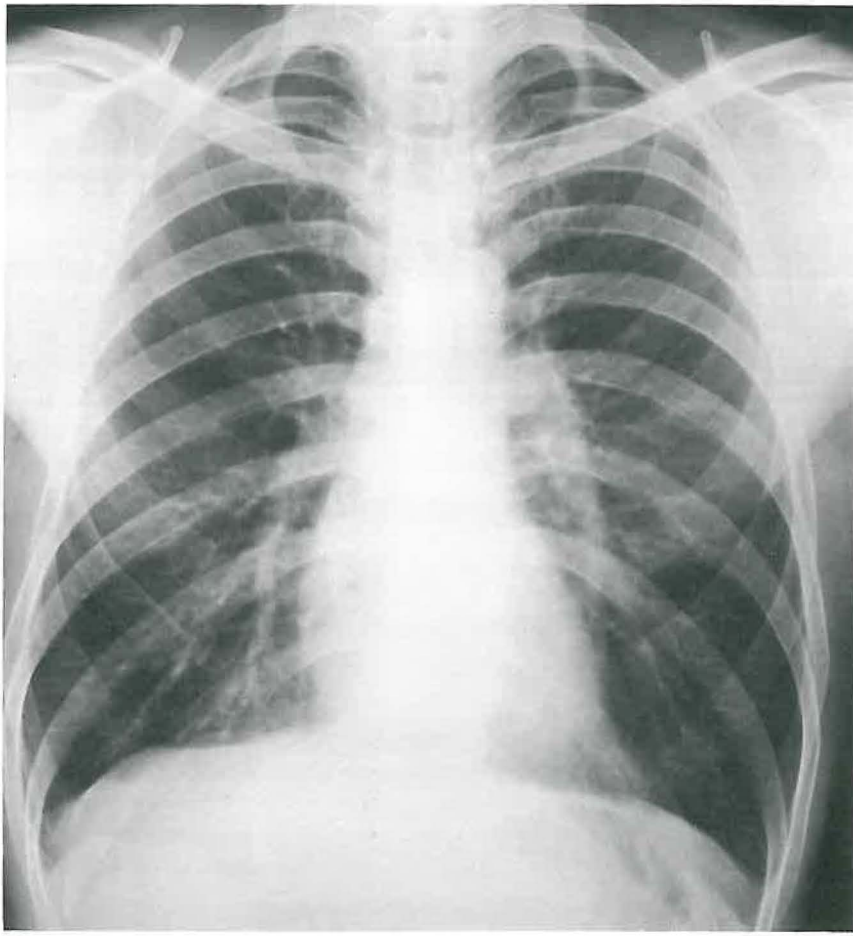

FIG. 1. Soft-coal miner in whom there was no clinical or roentgenographic evidence of pneumoconiosis. Note the pattern of the major vascular components, arteries and veins. Many of the small vessels do not produce a pattern that can be seen. This chest study is characterized as Category 0.

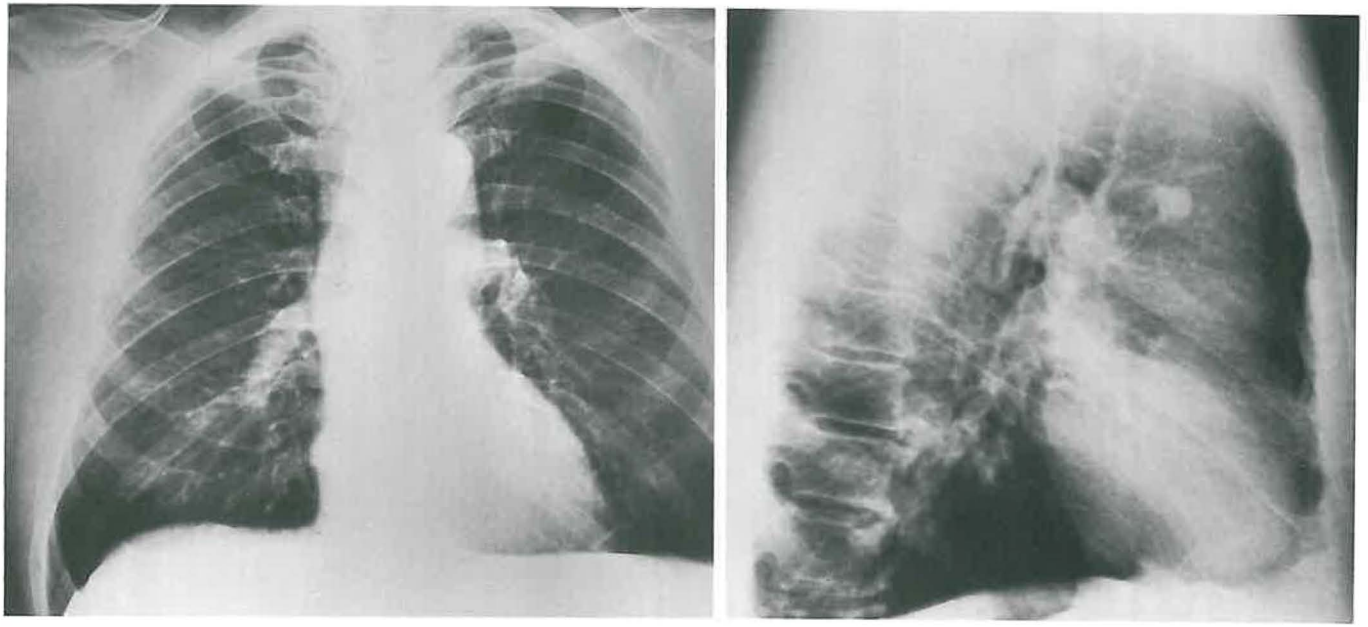

**FIG. 2.** Adenosquamous carcinoma of the left upper lobe in a 65-year-old white man. There were no symptoms, and the lesion was found in a routine chest examination which fortunately included posteroanterior and left lateral views. In the P-A roentgenogram, the lesion was not seen because its shadow was superimposed on the shadow of the left hilum. The shadow of the lesion is readily seen in the lateral view.

mately 125 kV(peak). The recommended exposure time is 1/60 (0.017) second.* It should not exceed 1/30 (0.032) second. With chests of larger diameter, additional exposure is obtained by increasing the kilovoltage. The mA-second is increased only when the kilovoltage required to give a proper exposure exceeds the capability of the generator or X-ray tube. With focal-spot–film distances of less than 6 ft (2.0 m) the technique should be adjusted by decreasing the mA-second.

With the low-kilovoltage technique, the exposure factors for the average subject are approximately 300 mA × 0.05 second (15 mA-second) at 75 kV. For larger subjects, either the mA-second or the kilovoltage are increased.

Phototimers are inaccurate with exposures of less than 0.03 second and are not recommended with the technique suggested above. However, phototiming can be very useful with exposure of longer duration.

### What Roentgenograms Should be Made?

Survey radiographic examinations oftentimes are limited to a single posteroanterior (P-A) roentgenogram made in the erect posture (Fig. 1). On occasion, other exposures may be used; P-A view in expiration and inspiration; anteroposterior (A-P) view in inspiration; and right and left lateral views. Each view provides additional and sometimes very important information. One real value of stereoscopic P-A views is that one has two views made within a few seconds of each other. If one places the films side by side one may note the variation in the vascular pattern and one may find small opacities that resemble a pattern of pneumoconiosis on one roentgenogram and not in the other. In many instances, especially when emphysema is present, P-A views made in inspiration and expiration are helpful in demonstrating small opacities which are less prominent in the inspiratory roentgenogram. With pleural calcification and thickening, the lateral view provides important information in addition to that found in the P-A roentgenogram. Small parenchymal lesions 1–3 cm in size may not be recognized in P-A roentgenograms when their shadows are superimposed upon those of the hila, but they are readily detected in the lateral view (Fig. 2).

## ROENTGENOGRAPHIC PATTERNS OF COAL WORKERS' PNEUMOCONIOSIS

The roentgenographic changes in coal workers' pneumoconiosis seen in the United States involves the lungs, the pleura, and their supporting structures. My own experience has largely been with coal miners in Alabama, Appalachia, Illinois, Indiana, Pennsylvania, and Utah (4–6).

* Based on 60-cps current. For 50-cps current, exposure times are 1/50 (0.02) and 1/25 (0.04) second.

Cardiac abnormalities may occur, but the roentgen examination without elaborate contrast studies does not contribute very much.

The patterns of small and large opacities in coal workers' pneumoconiosis in many instances are similar to those seen in anthracosilicosis. In others, the shadow pattern of abnormal changes, largely, are seen in the lower two-thirds of the lung fields (5).

Emphysema, as a rule, is not well portrayed in P-A roentgenograms of coal workers' pneumoconiosis.

Pleural thickening is often seen. It occurs along the periphery and in the interlobar fissures. In most instances it is a generalized thickening and not plaque-like. Calcification of the pleura occurs, and it may be very slight or extensive. As far as we have been able to discover, there has not been an exposure to asbestos dust in those instances where calcified pleura was found in coal workers' pneumoconiosis (7, 8).

## Aims and Principles of the UICC (U/C) Classification (Table I)

This classification is a modification of the ILO 1958 scheme and others (9). Quoting freely from the original manuscript (10), this classification:

as far as possible is purely descriptive of radiographic appearances and does not use interpretive words such as "fibrosis" or "infection" which already have definitions in terms of pathology;

describes the natural history of the changes produced by all dusts as far as is known, but it avoids the use of terms such as "early stages," "progressive," or "final";

provides a system of recording qualitatively and semiqualitatively (with the help of verbal descriptions and standard films) different features of the film which can be separately assessed and graded. It provides a code that permits a brief description of the important radiographic features of the pneumoconioses.

## General Description of the Classification

The ILO 1958 scheme divided the opacities in the lung fields (lung parenchyma) into "small" and "large." The U/C scheme retains that main subdivision but further divides the small opacities into "rounded" and "irregular," and the large opacities into "well defined" and "ill defined." The ILO scheme recorded pleural changes with a symbol "pl." The U/C scheme brings the pleural changes into the main classification, with a subdivision "calcified" and "noncalcified."* It also records the presence of a poorly defined cardiac outline and diaphragm within the main

scheme but retains the symbol "co" (abnormal cardiac shape) as defined in the ILO scheme and its later modification by the U. S. Public Health Service (9) (See Chapter 3, Fig. 1).

Provision has been made for the separate recording of three features for each variable (Figs. 14 and 15):

1. *Type:* for example, small or large, rounded or irregular, calcified,* etc.;
2. *Profusion:* the number of opacities (rounded or irregular) per unit area, e.g., per zone (see below). The word *profusion* is used in preference to density because this latter word is also used radiologically to describe the radiopacity of a shadow. The profusion is graded on a basic four-point scale—0, 1, 2, 3—with a means of increasing this to a twelve-point scale when greater precision is required.
3. *Extent:* the area (number of zones) of the lung field affected or length, as in the case of cardiac border involvement. This also provides information about the site of abnormality, which may later be of value.

In the ILO 1958 scheme, category 1 of small opacities was defined in terms of the number of rib spaces involved—a measure of extent. Categories 2 and 3 included factors of both extent and of profusion. One of the criticisms of the ILO 1958 scheme was that it failed to provide for the classification of a film with definite but very sparse rounded opacities seen in more than two rib spaces. That criticism is met in the U/C scheme.

The classification recognizes the existence of a continuum of change from complete normality to the most advanced category or grade in the recorded features. For example, with regard to small opacities a film may be correctly classified as category 0 if there are no opacities seen or if it is thought to show a few which are not sufficiently definite or numerous to reach the definition of category 1 (Table I). No sudden step from normality to abnormality is implied at the 0–1 boundary.

## Details of the Classification (10)

### Small Opacities

These are classified as in the ILO 1958 scheme modified by the U. S. Public Health Service, with some further alteration of the verbal definitions.

* The use of the word "calcified" is at variance with the general principle of not using interpretive words, but it was accepted because of its wide utilization in radiology.

TABLE I

UICC/Cincinnati Classification of Radiographic Appearances of Pneumoconioses[a]

| | | Codes | Definitions |
|---|---|---|---|
| Small opacities | Rounded profusion | | The category of profusion is based on assessment of the concentration of opacities in the affected zones. The standard films define the mid-categories. |
| | | 0/– 0/0 0/1 | Category 0—small rounded opacities absent or less profuse than in category 1 |
| | | 1/0 1/1 1/2 | Category 1—small rounded opacities definitely present but relatively few in number |
| | | 2/1 2/2 2/3 | Category 2—small rounded opacities numerous<br>The normal lung markings are usually still visible. |
| | | 3/2 3/3 3/4 | Category 3—small rounded opacities very numerous<br>The normal lung markings are partly or totally obscured. |
| | Type | *p q r* | The nodules are classified according to the approximate diameter of the predominant opacities.<br>*p*—rounded opacities up to about 1.5 mm diameter<br>*q*—rounded opacities exceeding about 1.5 mm and up to about 3 mm diameter<br>*r*—rounded opacities exceeding about 3 mm and up to about 10 mm diameter |
| | Extent | Lung zones | The zones in which the opacities are seen are recorded. Each lung is divided into thirds—upper, middle, lower zones. Thus a maximum of six zones can be affected. |
| | Irregular profusion | | The category of profusion is based on assessment of the concentration of opacities in the affected zones. The standard films define the mid-categories. |
| | | 0/– 0/0 0/1 | Category 0—small irregular opacities absent or less profuse than in category 1 |

| | | | |
|---|---|---|---|
| | | 1/0 1/1 1/2 | Category 1—small irregular opacities definitely present but relatively few in number<br>The normal lung markings are usually visible. |
| | | 2/1 2/2 2/3 | Category 2—small irregular opacities numerous<br>The normal lung markings are usually partly obscured. |
| | | 3/2 3/3 3/4 | Category 3—small irregular opacities very numerous<br>The normal lung markings are usually totally obscured. |
| | Type | *s t u* | Since the opacities are irregular, the dimensions used for rounded opacities cannot be used, but they can be roughly divided into three types.<br>*s*—fine irregular or linear opacities<br>*t*—medium irregular opacities<br>*u*—coarse (blotchy) irregular opacities |
| | Extent | Lung zones | The zones in which the opacities are seen are recorded. Each lung is divided into thirds—upper, middle, lower zones—as for rounded opacities. |
| Large opacities | Size | A B C | Category A—an opacity with greatest diameter between 1 cm and 5 cm, or several such opacities the sum of whose greatest diameters does not exceed 5 cm<br>Category B—one or more opacities larger or more numerous than those in category A, whose combined area does not exceed one-third of the area of the right lung<br>Category C—one or more large opacities whose combined area exceeds one-third of the area of the right lung |
| | Type | wd id | As well as the letter "A," "B," or "C," the abbreviation "wd" or "id" should be used to indicate whether the opacities are well defined or ill defined. |

(*Continued*)

TABLE I (*Continued*)

| | | Codes | Definitions |
|---|---|---|---|
| Other features | Pleural thickening | | |
| | Costophrenic angle | Right Left | Obliteration of the costophrenic angle is recorded separately from thickening over other sites. A lower limit standard film is provided. |
| | Other sites | 1 2 3 | Grade 0—not present or less than grade 1<br>Grade 1—up to 5 mm thick and not exceeding one-half of the projection of one lateral chest wall. A lower limit standard film is provided.<br>Grade 2—more than 5 mm thick and up to one-half of the projection of one lateral chest wall or up to 5 mm thick and exceeding one-half of the projection of one lateral chest wall<br>Grade 3—more than 5 mm thick and exceeding more than one-half of the projection of one lateral chest wall |
| | Diaphragm | | |
| | Ill defined | Right Left | The lower limit is one-third of the affected hemidiaphragm. A lower limit standard film is provided. |
| | Cardiac outline | | |
| | Ill defined (shagginess) | 1 2 3 | Grade 0—up to one-third of the length of the left cardiac border or equivalent<br>Grade 1—above one-third and up to two-thirds of the length of the left cardiac border or equivalent<br>Grade 2—above two-thirds and up to the whole length of the left cardiac border or equivalent |

Grade 3—more than the whole length of the left cardiac border or equivalent

Pleural calcification

| | | | |
|---|---|---|---|
| Diaphragm | 1 | 2 | 3 |
| Walls | | | |
| Other sites | | | |

Grade 0—no pleural calcification seen
Grade 1—one or more areas of pleural calcification, the sum of whose greatest diameters does not exceed 2 cm
Grade 2—one or more areas of pleural calcification, the sum of whose greatest diameters exceeds 2 cm but does not exceed 10 cm
Grade 3—one or more areas of pleural calcification, the sum of whose greatest diameters exceeds 10 cm

Other symbols:

Obligatory

ca—suspect cancer of lung or pleura
co—abnormality of cardiac size or shape
cp—suspect cor pulmonale
es—eggshell calcification of hilar or mediastinal lymph nodes
tba—opacities suggestive of active clinically significant tuberculosis
od—other significant disease. This includes disease not related to dust exposure, e.g., surgical or traumatic damage to chest walls, bronchiectasis, etc.

Optional

ax—coalescence of small rounded pneumoconiotic opacities
bu—bullae
cn—calcification in small parenchymal opacities
cv—cavity
di—marked distortion of the intrathoracic organs
em—marked emphysema
hi—marked enlargement of hilar shadows
ho—honeycomb lung
k—Kerley (septal) lines
px—pneumothorax
rl—pneumoconiosis modified by rheumatoid process
tb—inactive tuberculosis

[a] U/C Classification of Radiographic Appearances of Pneumoconiosis was arranged into a table by the American College of Radiology for its teaching seminar in Washington, D. C., 13–14 June 1970.

*Type:* The nodules are classified according to the approximate diameter of the predominant opacities. Strict adherence to measurement is not intended.

$p$ = rounded opacities up to about 1.5 mm in diameter (Figs. 3 and 4)
$q$ = rounded opacities exceeding about 1.5 mm and up to about 3 mm in diameter (Fig. 5)
$r$ = rounded opacities exceeding about 3 mm in diameter up to about 10 mm in diameter (Fig. 6)

*Profusion:* The standard films define the midcategories.

Category 0—small rounded opacities absent or less profuse than in category 1
Category 1—small rounded opacities definitely present but relatively few in number. The normal lung markings (vascular pattern) are usually visible.

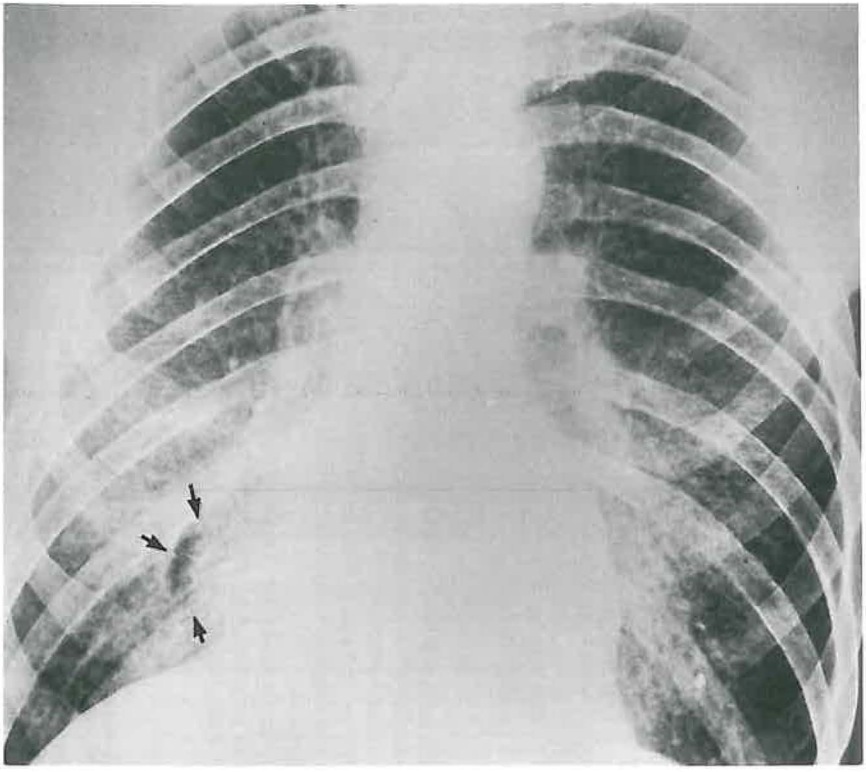

**FIG. 3.** Coal workers' pneumoconiosis, category 3 $p$ and $u$ in a West Virginia coal miner. The profusion of small opacities is 3/4, and it is difficult to identify the individual rounded and irregular small opacities. See Fig. 4. The cardiac outlines, right and left, are ill defined, probably grade 3. There is a medium sized bulla in right lower lobe indicated by arrows.

Category 2—small rounded opacities numerous. The normal lung markings are usually still visible.
Category 3—small rounded opacities very numerous. The normal lung markings are partly or totally obscured.

The category of profusion is based not on extent, but only on the concentration of opacities in the affected zones.

*Extent (10)*: The specific zones in which the opacities are seen are recorded. Each lung field is divided into thirds—upper, middle, and lower zones. Thus, there can be a maximum of six zones affected.

*Notes (10)*
(1) $q$ and $r$ are used in place of $m$ and $n$ of the ILO 1958 scheme because of

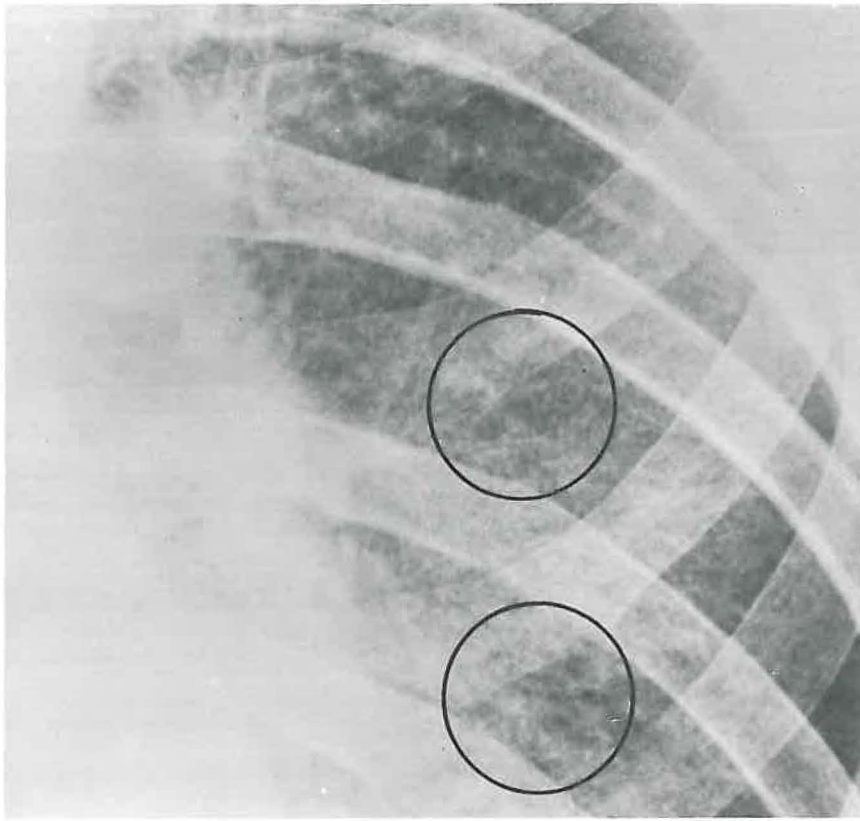

**FIG. 4.** Same case as Fig. 3. Close-up of the left middle lung. The $p$ opacities (upper circle) predominate, and it is difficult to identify the irregular opacities (lower circle) $u$ on the lower interspaces. The left cardiac border is ill defined.

phonetic and scriptory errors caused by using *m* and *n*. No change of definition is entailed.

(2) In category 1, small rounded opacities are commonly seen in the upper and middle zones but may occur in any zones or in one lung only. Rarely in categories 2 and 3 are they present in only one lung.

(3) There is evidence (11–14) that subdivision into finer grades than the four categories—0, 1, 2, 3—is possible without the use of extra standard films and that it conveys extra information for epidemiological purposes. The instructions are to

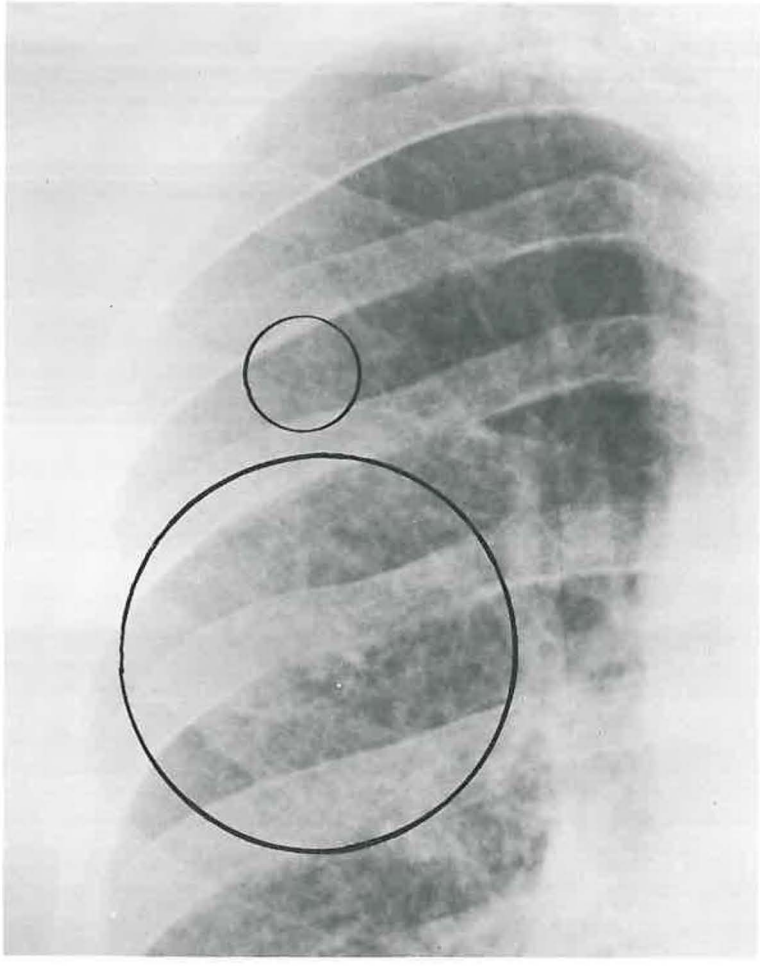

FIG. 5. Small rounded and irregular opacities in coal workers' pneumoconiosis. The rounded opacities in the fourth interspace posteriorly (small circle) are largely *p* and *q*. The irregular opacities in the fifth and sixth interspaces (large circle) are largely the *t* type ("circular," "network," "linear").

classify the film in the usual way into one of the four categories and, if during the process a neighboring category is considered as a serious alternative, to record this after the formal category. Thus category 2/1 is a film which is category 2 but category 1 was seriously considered as an alternative. The film which is without doubt a category 2, i.e., a midcategory closely similar in profusion to the standard film, would be classified as 2/2. In films within category 0 a subdivision is also possible. Thus, category 0/1 is a film which is category 0 but category 1 was seriously considered. Category 0/0 is a normal film without small opacities. Occasionally films look exceptionally "normal," i.e., exceptional clarity of the normal architecture. These "barn door" normal films are usually, though not exclusively, from young individuals. Provision for these is made by the category 0/—. Thus the formal four-point scale becomes a twelve-point scale: 0/—, 0/0, 0/1, 1/0, 1/1, 1/2, 2/1, 2/2, 2/3, 3/2, 3/3, 3/4. In practice this elaborated scale takes no longer than the four-point system, and it is easier for the reader, as his doubts about the borderline films are quickly recorded (Figs. 17 and 18).

### Small Irregular Opacities (10)

This category is the main new feature of the classification. The term is used to describe features which in other schemes have been called

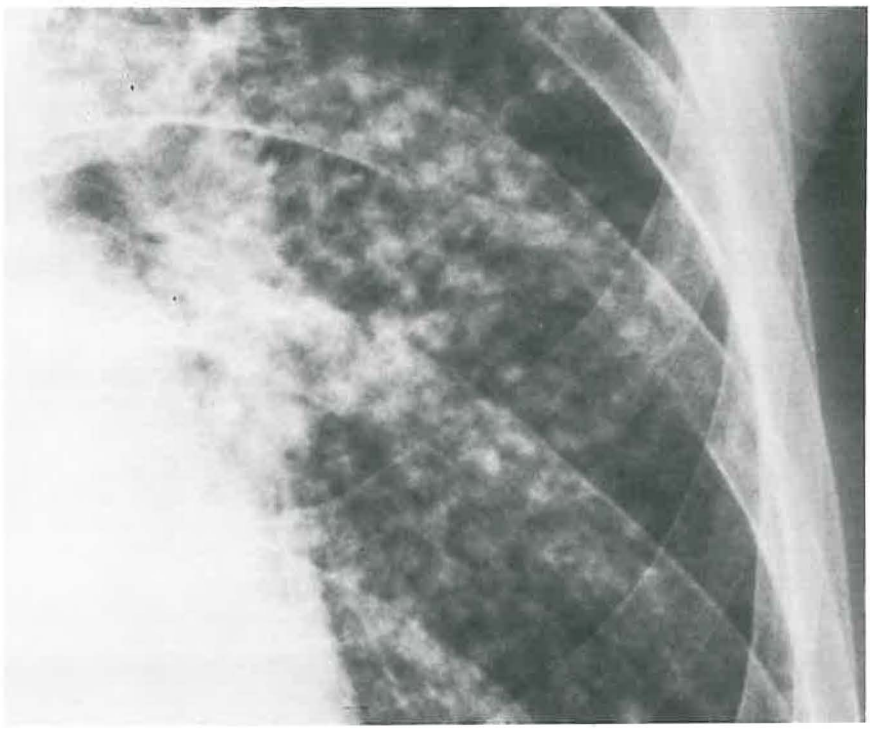

FIG. 6. Coal workers' pneumoconiosis with a pattern of small rounded opacities, *r*. As usual there are small irregular opacities in the same field; the *r* opacities are more dominant.

linear, reticular, fibrotic, network, and honeycomb (Fig. 7). It includes films which would be classified as L in the ILO 1958 scheme and also some, but not all, films formerly read as Z. Small irregular opacities are of varying thickness, shape, and density and often have a curved or linear appearance. They tend to obscure the normal lung architecture (vascular pattern), particularly when present in considerable profusion. Hence, obscuration of normal lung architecture is a feature of the higher categories of both small "rounded" and small "irregular" opacities.

*Type:* On account of the irregularity of the opacities, the dimensions used for the rounded opacities cannot be applied, but to conform to the general scheme, the types may be roughly divided into three:

$s$ = fine irregular or linear opacities
$t$ = medium thick irregular opacities (Fig. 8)
$u$ = coarse (blotchy) irregular opacities (Fig. 9)

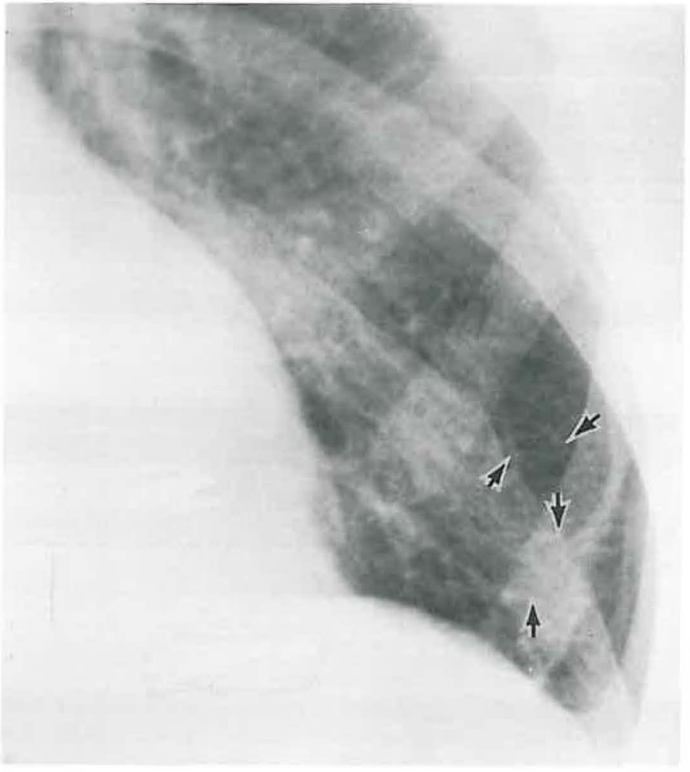

**FIG. 7.** Coal workers' pneumoconiosis in a Pennsylvania soft-coal miner with small rounded opacities, $p$; and straight B lines (Kerley) and curvilinear patterns, $u$. The rounded opacities $p$ (upper two arrows) are not well seen in the illustration. The lines and irregular opacities are well illustrated in the area of the lower arrows.

Assessment is made of the predominant type of small irregular opacity by comparison with the appropriate standard film.

*Profusion:* The standard films define the midcategories.

Category 0—small irregular opacities absent or less profuse than in category 1
Category 1—small irregular opacities definitely present but relatively sparse. The normal lung markings are usually visible.
Category 2—small irregular opacities numerous. The normal lung markings are usually partly obscured.
Category 3—small irregular opacities very numerous. The normal lung markings are usually totally obscured.

The category of profusion is based not on extent, but only on the concentration of opacities in the affected zones.

*Extent* (*10*): The specific zones in which the irregular opacities are seen are recorded. Each lung is divided into thirds—upper, middle, and lower zones, as for rounded opacities.

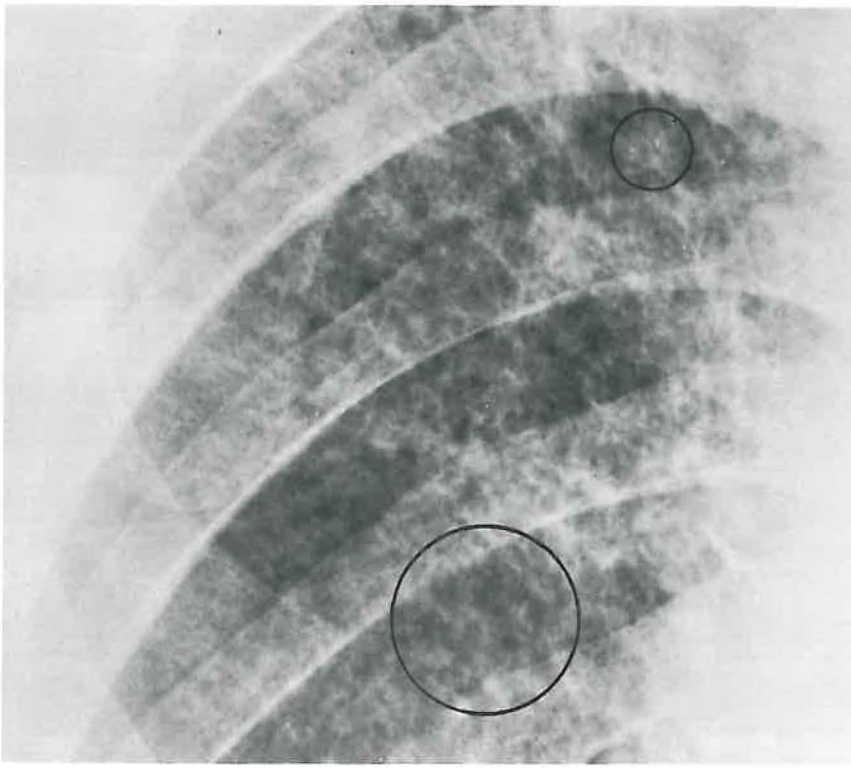

FIG. 8. Right upper lobe of a West Virginia miner with coal workers' pneumoconiosis to illustrate small irregular opacities *u* (lower circle) and ax (upper small circle).

Murphy, in a special study of asbestosis, used two zones, upper and lower, in each lung field (15).

*Notes (10)*

(1) The types *s*, *t*, and *u* are less well differentiated than the *p*, *q*, *r* sequence of small rounded opacities. It is not known whether the subdividing of irregular opacities in this way will be useful, nor was it known when *p*, *m*, and *n* were first suggested that pathological and functional differences existed between the different types. Subsequent research has shown they are meaningful.

(2) In category 1, small irregular opacities are commonly seen in the lower zones, but may occur in any zones or in one lung only.

(3) The differentiation between "rounded" and "irregular" opacities is readily seen by comparing the standard films of each type, but films occur in which both types are seen. It is recommended that both "rounded" and "irregular" should be recorded if both types are clearly seen in the same film. However, further research is needed to show how well they can be differentiated (Figs. 3–9).

(4) Experience in classifying films of mineral dust pneumoconiosis has revealed a

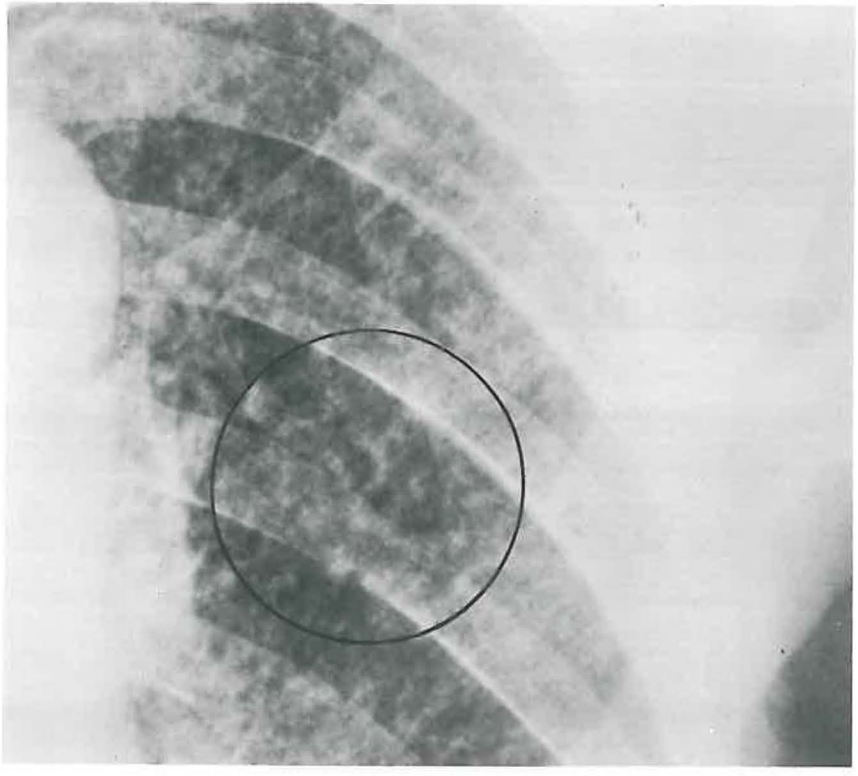

**FIG. 9.** Same case as Fig. 8. Left upper lobe. Note that *u* opacities (within circle) are more dominant on the left side and *t* opacities on the right. The *q* opacities are seen where the profusion of irregular opacities are less dominant.

small proportion which, though undoubtedly abnormal and probably the result of dust exposure, do not fit well into the ILO classification. The U/C classification provided a means of classifying these as they often fit well into the "small irregular opacities" group.

(5) Where there is a marked difference in profusion in different parts of the lungs, the zones predominantly affected are the ones over which averaging is made.

### Large Opacities

The scheme used is that in the ILO 1958 classification, with the additional qualification of "well defined" (wd) and "ill defined" (id). The well-defined large opacities are those covered by A, B, and C in the ILO 1958 system. The ill-defined are those opacities in which the edge is very poorly differentiated from the surrounding lung. Large opacities of that type sometimes occur in advanced asbestosis, but they are also seen in other types of pneumoconiosis. Thus U/C provides a more complete system of recording the features of large opacities.

Category A—an opacity having a diameter exceeding 1 cm and up to and including 5 cm, or several opacities each greater than 1 cm, the sum of whose greatest diameters does not exceed 5 cm (Figs. 10–12)

Category B—one or more opacities larger or more numerous than those in category A whose combined area does not exceed one-third of the right lung field (Fig. 22)

Category C—one or more opacities whose combined area exceed one-third of the right lung field (Fig. 13)

*Notes*

(1) The abbreviation wd or id should be used to indicate whether the shadows are well or ill defined (Figs. 10 and 13). Reference to the standard films will help to make the differentiation. Sometimes both types should be recorded.

(2) When recording large opacities the type and category of small opacities in the background should also be noted. If small opacities are not seen, a comment to this effect must be recorded (Figs. 17 and 18).

### Pleural Thickening (10)

Pleural thickening is classified according to type (diffuse or plaques), site, and extent, but changes which might represent pleural thickening over the diaphragm and cardiac outline are recorded separately, because there is insufficient evidence, especially in cases of asbestosis, to be certain whether the ill-defined outline of the cardiac border (shaggy heart) or diaphragm is the result of pleural thickening or alteration of adjacent lung parenchyma (Fig. 13).

*Costophrenic Angle:* Obliteration of the costophrenic angle is recorded separately from thickening over other areas because it is so commonly seen in individuals with no history of dust exposure (Fig. 13). A lower-limit standard film is provided. No upper-limit film is used. If the thickening extends further up the chest wall, then

the film should be classified as costophrenic angle obliteration *and* pleural thickening, if this is as up to grade 1 or more. Costophrenic angle obliteration is recorded as absent or present, right or left.

*Note:* Leafing (scalloping) of the diaphragm should not be recorded as costophrenic angle obliteration.

*Chest Wall:* Pleural thickening is recorded in four grades as follows:

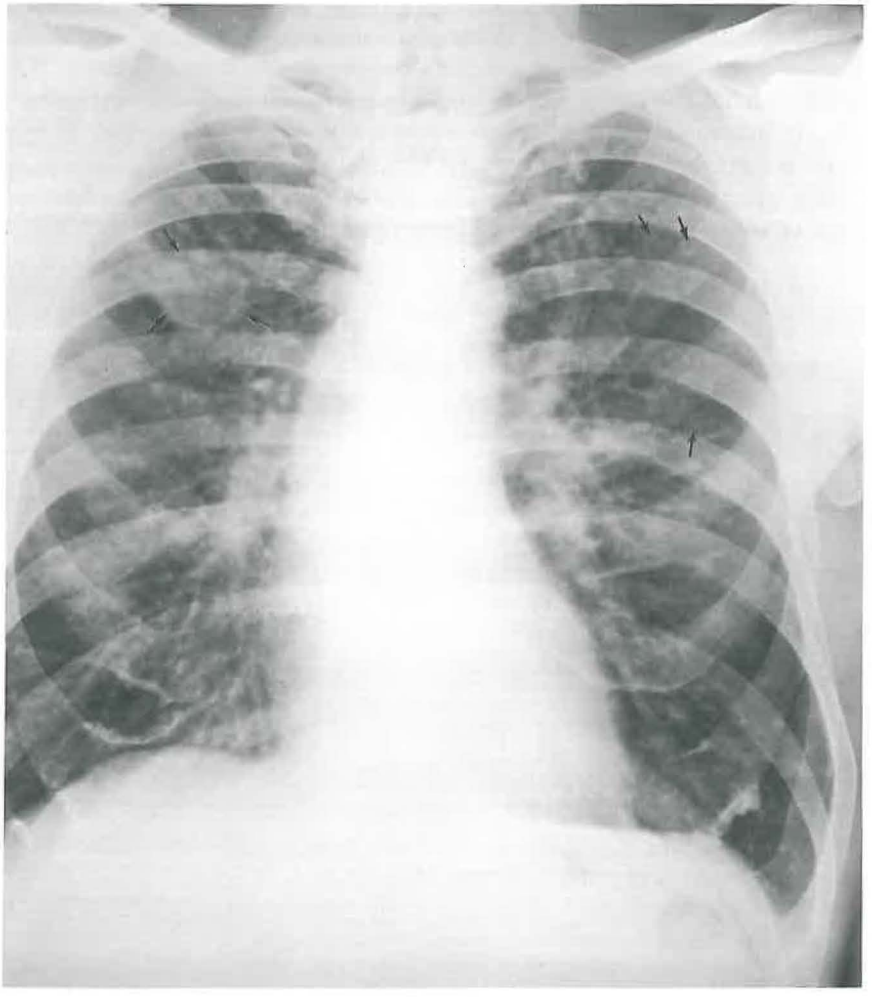

FIG. 10. Coal workers' pneumoconiosis in a Pennsylvania soft-coal miner; category 3 *r* A. The background of small opacities *r* extend throughout both lungs. The large opacity in the right upper lobe "A" is interpreted as evidence of a complicated pneumoconiosis. It is well defined.

Grade 0—not present or less than grade 1
Grade 1—definite pleural thickening up to 5 mm thick which alone or combined with similar shadows does not exceed half of one chest wall. The standard film is at the lower limit of grade 1.

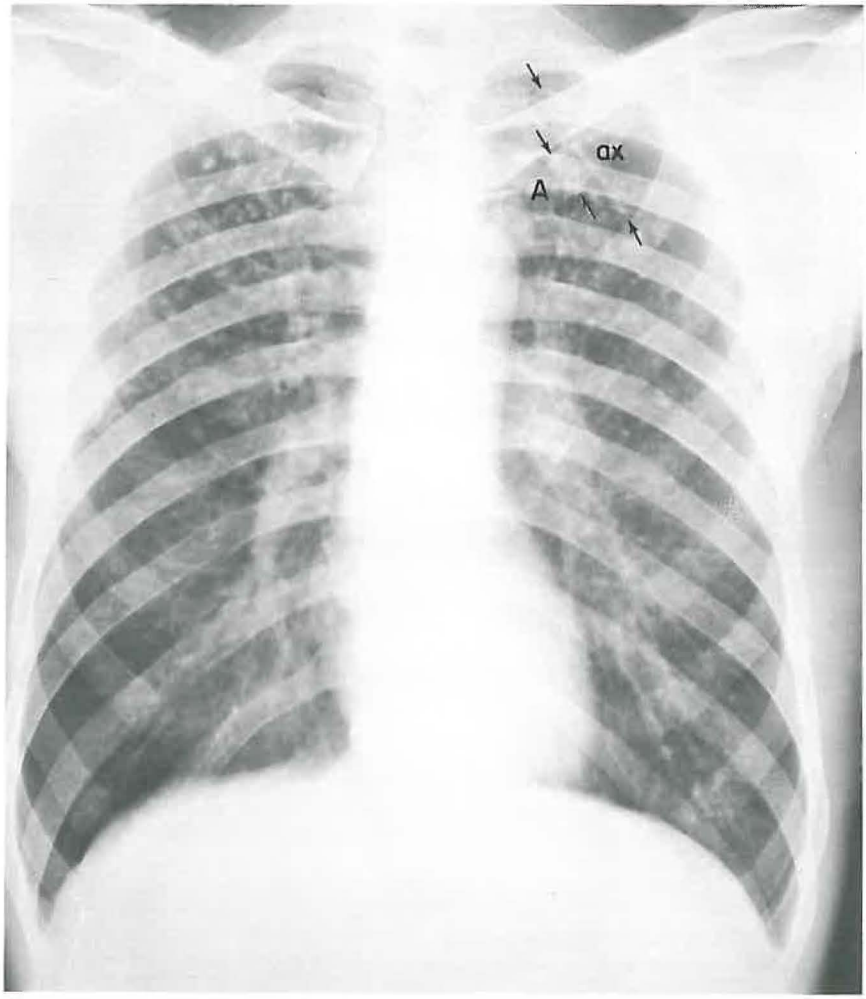


**FIG. 11.** Coal workers' pneumoconiosis in a Pennsylvania coal miner. Category 2 *q* A, ax, hi, cn. Many of the small rounded opacities are calcified "cn," but some are not. There are two conglomerate lesions in the left upper lobe. The oval lesion approaches the size of Category "A." It seems to be a well-defined large opacity. The long coalescent lesion is categorized as "ax." When a large opacity is present, it is not necessary to identify and record ax. It is not known whether the calcification is due to histoplasmosis or to some other process such as tuberculosis. The hila are prominent.

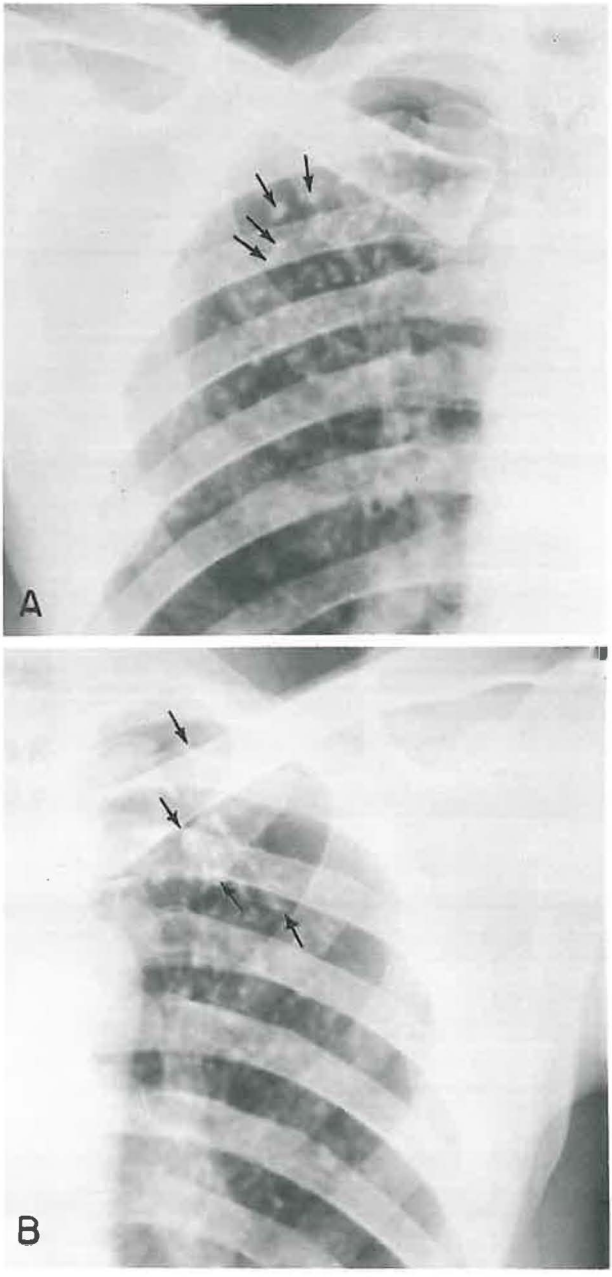


**FIG. 12.** Same case as Fig. 11. (A) Close-up of the right upper lobe to show the detail of the calcium deposits in the small opacities *q*. (B) Close-up of left upper lobe showing the details of the oval conglomerate opacity, "A" and the long shadow pattern, "ax."

Grade 2—pleural thickening more than 5 mm thick and up to half of one chest wall, *or* less than 5 mm thick if it extends more than the equivalent of one-half of one chest wall. The standard film is at the lower limit of grade 2.

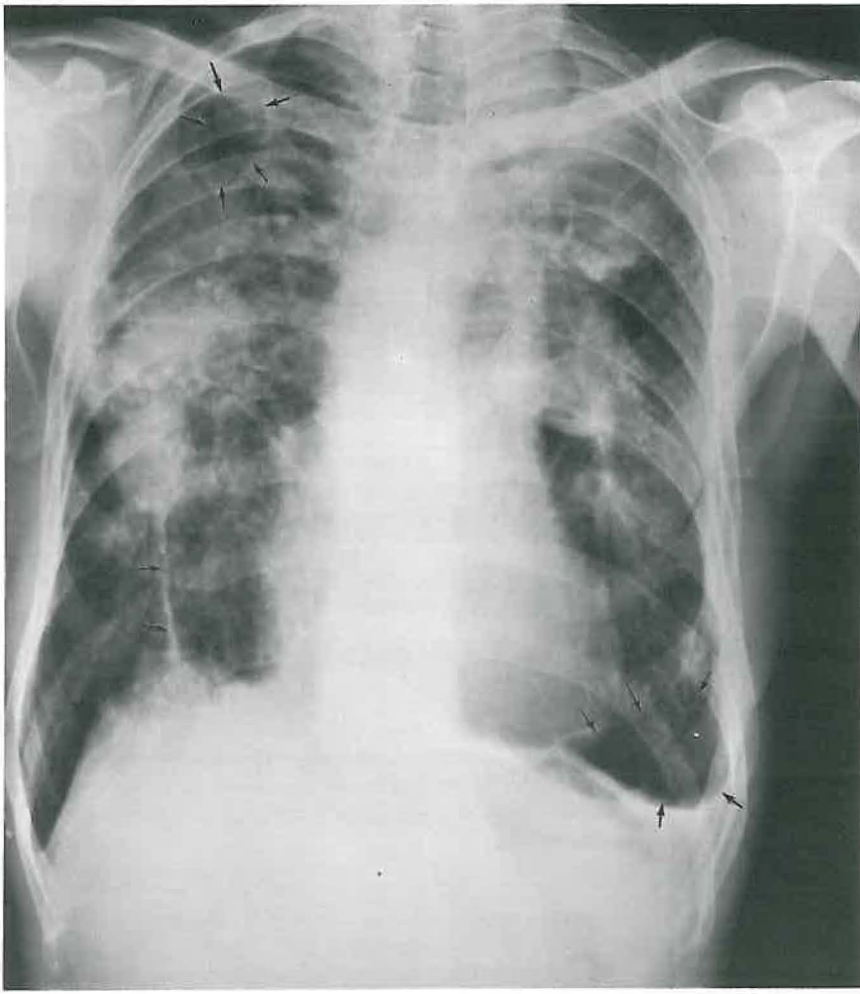

FIG. 13. Coal workers' pneumoconiosis in a Pennsylvania soft-coal miner, 3 *q* C, hi, di, em, pl, and bullae. The small opacities are obscured by the large ill-defined opacities and emphysema. The hila are displaced upward and the heart and aorta to the right. The domes of the diaphragm are distorted. There is a band-like shadow which extends from the large opacity in the right midlung to the dome of the diaphragm (arrows). There is a large bulla in the right apex and in the left costophrenic sulcus (arrows). The left costophrenic sulcus is obliterated, and there is a slight scoliosis. The right cardiac border is partially ill defined.

Grade 3—pleural thickening more than 5 mm thick and extending more than the equivalent of one-half of one chest wall

*Note*

(1) Do not record the "companion" rib shadows that simulate pleural thickening.

(2) The sharpness of the outline of the pleural thickening varies greatly. In asbestos-exposed workers it may appear as a well-defined band along the lateral chest wall (see Grade 1 standard film) or as a much more wide-spread shadow. The widespread and well-defined forms are recorded together as "diffuse." Occasionally, localized areas of uncalcified pleural thickening—pleural plaques—are seen on the diaphragm or chest wall, and should be recorded as such. The diffuse and localized forms should be considered together when grading pleural thickening.

(3) Pleural thickening on the ventral or posterior walls of the chest may lead to obscuration of the lung fields and may be recognizable on lateral views.

### Ill-Defined Diaphragm (10)

This is recorded as absent or present and right or left. The lower limit is one-third of the affected hemidiaphragm. A lower-limit standard film is provided.

*Note:* A single adhesion, scalloping, hernia, eventration, calcification, plaque, and tumor are not included within the term "ill-defined diaphragm."

### Ill-Defined Cardiac Outline (10)

Only the length of the cardiac border affected is used for grading. The degree of poorness of definition is not separately recorded. Four grades are used. Regardless of which side is affected, the grading is based on the length of the left heart border.

Grade 0—up to one-third of the left cardiac border or equivalent (Fig. 13)
Grade 1—between one-third and two-thirds of the left cardiac border or equivalent
Grade 2—between two-thirds and the entire left cardiac border or equivalent
Grade 3—more than the left cardiac border (Figs. 3 and 4)

*Note*

(1) The sharpness of the cardiac border is affected by heart movement and hence the exposure time of the radiograph. If this is the only cause for the irregular cardiac border, do not record it.

(2) Cardiac fat pads are not included in the grading. Grade 1 is set fairly high, so only the more definitely abnormal films will be graded 1 or above.

(3) In asbestos-exposed workers the earliest change in the radiograph may be an ill-defined cardiac outline.

### Pleural Calcification (10)

This feature is recorded separately from pleural thickening, the site noted, and whether the calcification is uni- or bilateral. It is also graded with the help of standard films.

Grade 0—no pleural calcification
Grade 1—an area of calcified pleura with greatest diameter not exceeding 2 cm, or a number of such areas, the sum of whose greatest diameters does not exceed 2 cm in length
Grade 2—an area of calcified pleura with greatest diameter exceeding 2 cm and not exceeding 10 cm, or a number of such areas, the sum of whose greatest diameters exceeds 2 cm but not more than 10 cm (Fig. 14)
Grade 3—an area of calcified pleura with greatest diameter exceeding 10 cm or a number of such areas whose sum of greatest diameters exceeds 10 cm [Figs. 15(A) and 15(B)].

*Note:* Uni- or bilaterality is recorded because calcification due to mineral dusts, including asbestos, is often bilateral, whereas that due to other causes, such as infection and trauma, is more usually unilateral.

### Additional Symbols (10)

Additional symbols are used as in the ILO 1958 scheme to record features which are not in the main classification. If all symbols are op-

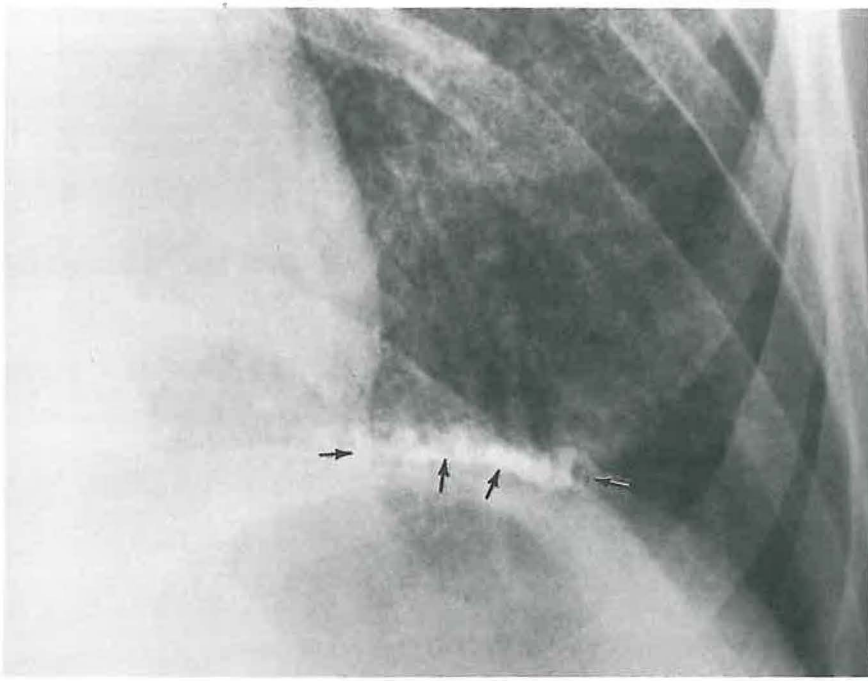

**FIG. 14.** Calcified pleural plaque, grade 2, on the left dome of the diaphragm in a West Virginia miner who has extensive complicated coal workers' pneumoconiosis. There are numerous small rounded and irregular opacities. The calcified pleural plaque is seen clearly, because the plaque is on the crest of the dome and is recorded in an axial view.

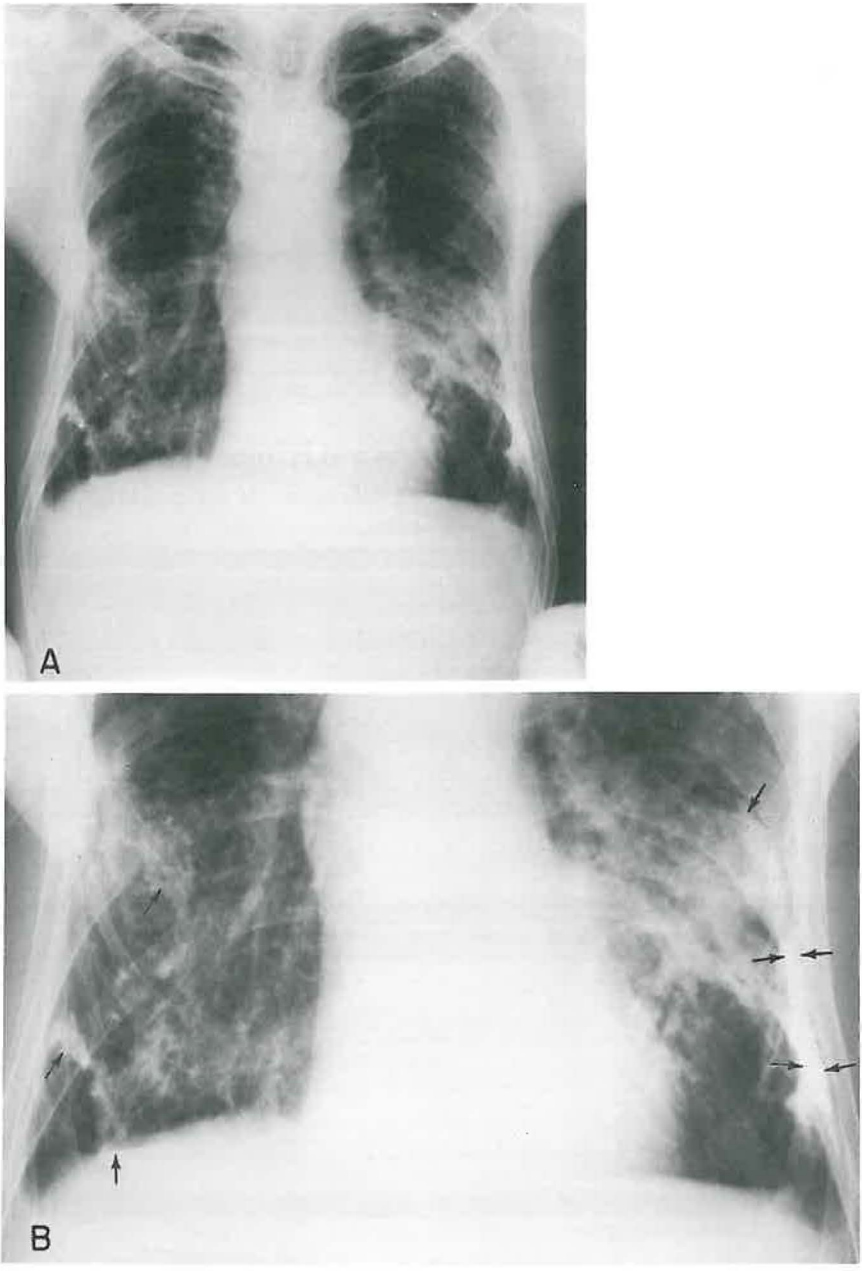


FIG. 15. (A) Extensive calcified pleura, grade 3, along thoracic walls and right dome of the diaphragm in a Pennsylvania soft-coal miner. The small opacities are largely obscured by the calcium deposits. Lateral views oftentimes provide informa-

tional, the recording is usually incomplete. Two groups—obligatory (Fig. 16) and optional—are therefore recommended. See Table I.

GENERAL INSTRUCTIONS (10)

When deciding whether a film is to be classified within the scheme, the following recommendations are made:

(1) Decide if *any* of the changes seen in the pleura or the parenchyma sufficiently resemble the pattern of any of the pneumoconioses to be recorded. If so, proceed with the classification.

(2) If it is probable that *all* the changes seen are the result of some

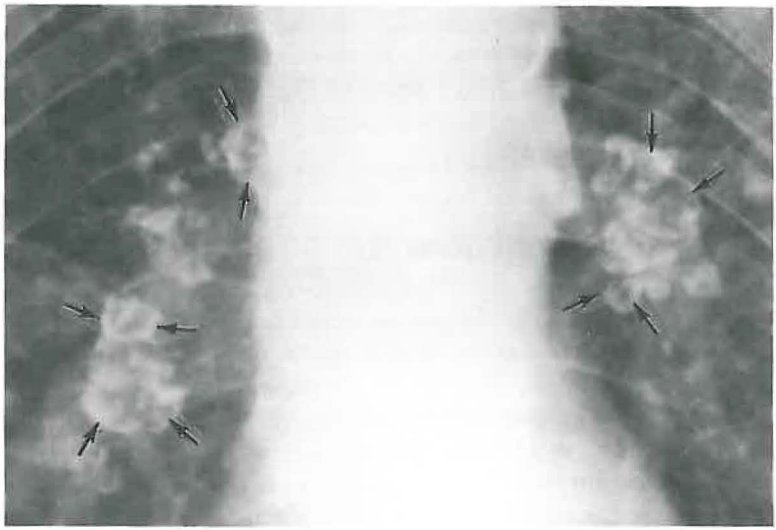

FIG. 16. Coal workers' pneumoconiosis in a Pennsylvania soft-coal miner. Category 3 *r*, hi, es. This illustration is a good example of eggshell calcification in the hila lymph nodes. Eggshell calcification is defined as shell-like calcifications measuring up to 2 mm in thickness present in the peripheral zone of at least two lymph nodes, which may be broken or unbroken, but the ring-like shadow must be complete in at least one node; there may be flecks of calcium in the central portions, and one of the nodes must be at least 1 cm in its greatest diameter.

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tion not seen in the axial view. This is true particularly where the calcium deposits are on the anterior or posterior chest wall or on the sloping portions of the domes of the diaphragm and are not in a position for axial projections of X-ray radiation in the usual P-A view. (B) Close-up view, which provides more detail. The arrows illustrate the thickness of the pleural calcification along the left lateral chest wall. The large shadows in the lower half of the left and right lung fields are due to calcified pleura on the anterior chest wall (arrows). There is a calcified pleural plaque on the right dome of the diaphragm (arrow).

etiology other than pneumoconiosis, do not classify but record opinion using appropriate symbols and comments.

(3) If changes might be due to pneumoconiosis, classify features, but make a note that other etiology is possible.

In the U/C scheme, unlike the ILO schemes, no provision is made for doubtful pneumoconiosis. This omission is intentional since the scheme is intended principally for epidemiological studies where a "suspect" group contributes little to the information. The provision of a twelve-point scale for both small rounded and small irregular opacities provides a method of classifying radiographs less than category 1.

In epidemiological studies failure to record all readings can be an important source of loss of information. To reduce this to a minimum the recording sheet (Fig. 17) is so designed that at least one entry must be made between each pair of heavy lines. In Fig. 18, ten sketches of the roentgen appearance of lesions in pneumoconiosis are given, together with their corresponding readings.

## RADIOLOGIC CONSIDERATIONS (2)

The radiologic problems in the pneumoconioses concerned with the interpretation and evaluation of the shadow patterns of intrathoracic structures must be considered in the light of a complete occupational history and the physical examination.

Physiologic changes in vascular patterns are due to several processes which influence the amount of blood present in arteries or veins or both at a given time. Some important influences are shunt effect, the phase of cardiac cycle, and the varying degrees of intrathoracic pressure present when the roentgenogram is recorded after the patient takes a deep breath and holds it.

When abnormal intrapulmonary changes develop, vessel shadows become less well defined. Increased prominence of vessel shadows under such circumstances occurs rarely, if at all.

Emphysema, as a rule, is not well portrayed in P-A roentgenograms of coal workers' pneumoconiosis. I have the impression that in the presence of well-established emphysema, the shadow pattern of preexisting small opacities may lose some or all of their identity (Fig. 22). By the same deduction, it is reasonable to anticipate that the shadow pattern of small opacities may not be seen in the presence of advanced generalized emphysema of a soft-coal worker who has a long history of dust exposure.

The patterns of small opacities found in the pneumoconiosis of soft-

| Survey | | ROUNDED SMALL OPACITIES | | | IRREGULAR SMALL OPACITIES | | | LARGE OPACITIES | | PLEURAL THICKENING | | | | | ILL-DEFINED DIAPHRAGM | ILL-DEFINED CARDIAC OUTLINE | PLEURAL CALCIFICATION | | | | | Reader _____ Date _____ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number | Quality | Type | Profusion | Zones R L | Type | Profusion | Zones R L | Type | Size | Costophrenic angle | Diffuse | Plaques | Grade | None | | | Diaphragm | Wall | Others | Grade | None | Symbols | Comment |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) | (18) | (19) | (20) | (21) | (22) | (23) | (24) |
| | | | / | | | / | | | | | | | | | | | | | | | | | |
| | | | / | | | / | | | | | | | | | | | | | | | | | |
| | | | / | | | / | | | | | | | | | | | | | | | | | |
| | + | p | 0/- 0/0 0/1 | | s | 0/- 0/0 0/1 | | | 0 | 0 | | | 0 | | 0 | 0 | | | | 0 | | 0 | |
| | ± | q | 1/0 1/1 1/2 | | t | 1/0 1/1 1/2 | | wd | A | R | | R | 1 | 0 if none | R | 1 | | R | | 1 | | ca es | |
| | ± | r | 2/1 2/2 2/3 | | u | 2/1 2/2 2/3 | | id | B | L | | L | 2 | | L | 2 | | L | | 2 | | co od | |
| | U/R | | 3/2 3/3 3/4 | | | 3/2 3/3 3/4 | | | C | | | | 3 | | | | | | | 3 | 0 if none | cp tba | |

**FIG. 17.** Recording sheet for classification of radiographic appearances of pneumoconiosis, without notations. In epidemiologic studies, it is extremely important that at least one entry must be made between each pair of heavy lines. When one is recording a single study, some modification is necessary if the large form seems inappropriate.

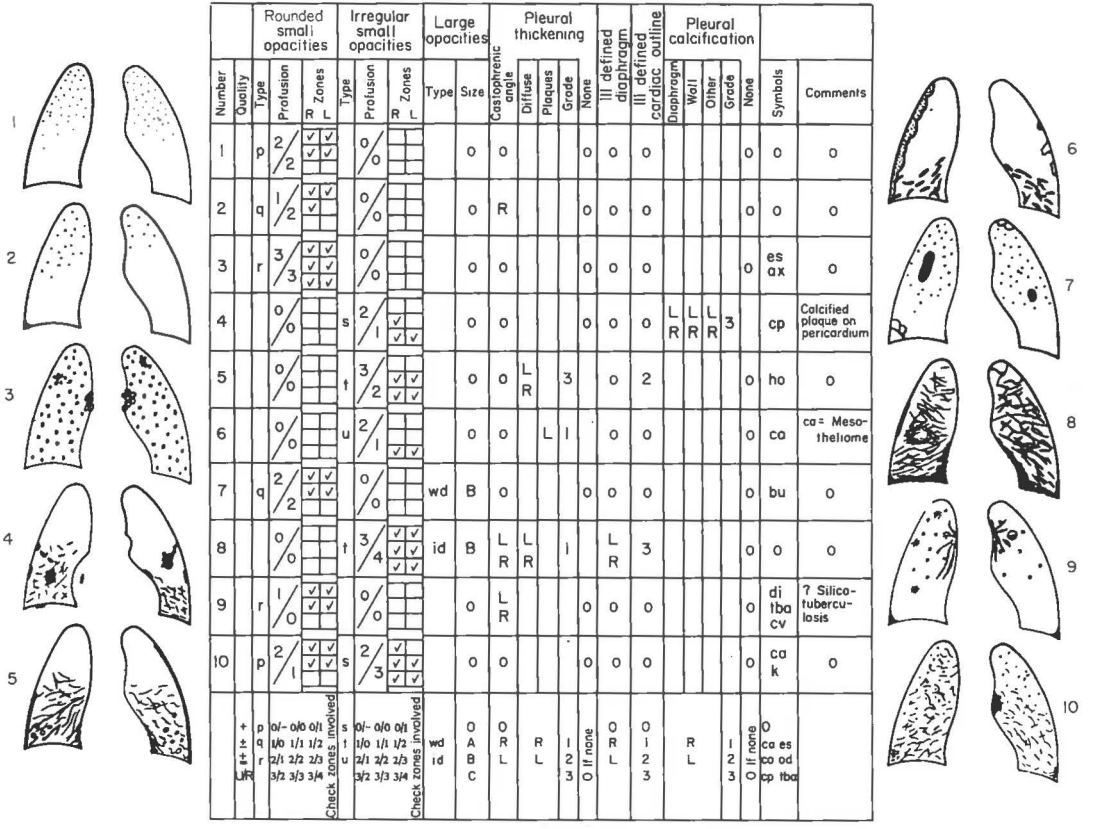



**FIG. 18.** Schematic representation of some radiographic features. Compare the pattern illustrated in the chest diagrams with the numbers and symbols recorded on the report form.

coal miners of Pennsylvania are similar to those which occur in anthracosilicosis and graphite workers' pneumoconiosis (16, 17). However, in many instances the opacities are largely in the lower half of the lung field, whereas in anthracite miners of Pennsylvania, they more often are seen in the upper two-thirds of the lung fields. The abnormal changes include micronodular densities, lace-like and sponge-like shadows, Kerley lines, and pleural thickening and calcification [Figs. 3, 15(A), and 15(B)]. The pattern of changes not infrequently simulates the appearance of a moderately advanced asbestosis (18).

Large opacities vary in size from 3–15 cm or more. They may be single or multiple, round, elongated, triangular, or oval in shape. They occur in the upper, middle, or lower lung fields on one or both sides. A single massive lesion may extend to the interlobar fissure, or if two are present, one on either side of the fissure, they may grow toward each other and obliterate the fissure. On the roentgenogram the lesions ultimately appear as a single mass.

Large opacities may be located anteriorly or posteriorly and may occur in the mid or peripheral, or both, portions of the lobe. It is necessary to make P-A, lateral, and oblique views to determine their exact position (Figs. 20 and 21).

Massive lesions, when present, sometimes are caused by undrained cavities or cysts filled with black fluid (Fig. 19). The cavities and cysts may appear on the roentgenograms as either massive lesions or cavities with or without fluid levels, depending on whether or not there is communication with a bronchus. If cysts and cavities contain air, they may be thick- or thin-walled, regular or irregular.

Cavities and cysts are thought to be due to liquefaction necrosis from infection (19), carcinoma of the lung with central necrosis, or ischemic necrosis (20). In necrosis due to carcinoma, the walls are usually thick and irregular.

Theodos *et al.* (21), in a study of 1980 anthracite-coal miners during a 13-year period, made the following interesting observations on large opacities: When conglomerate masses were asymmetrical, generally, an associated infection was found; definite cavities were seen in the roentgenogram of 206 or 10.4% of the 1980 coal miners.

If a positive sputum could not be obtained in the presence of cavitation, then neoplasm, lung abscess, and fungus disease had to be excluded. If none of them were found, cavitation was attributed to ischemic necrosis.

In 206 cases with cavitation, acid-fast bacilli were found by smear or culture in 141, or 68.4%. Carcinoma of the lung accounted for two cases of cavitation; cystic bronchiectasis for two; and no adequate cause of cavitation could be ascertained in four cases.

The remaining 57 cases, or 27% with cavitation, were attributed to ischemic necrosis. Cavitation appeared as a unilateral process in 37; it was bilateral in 19 instances. In 20 cases, the cavitation appeared initially as a large opacity; in 6 of the 20, the cavities were filled with secretions

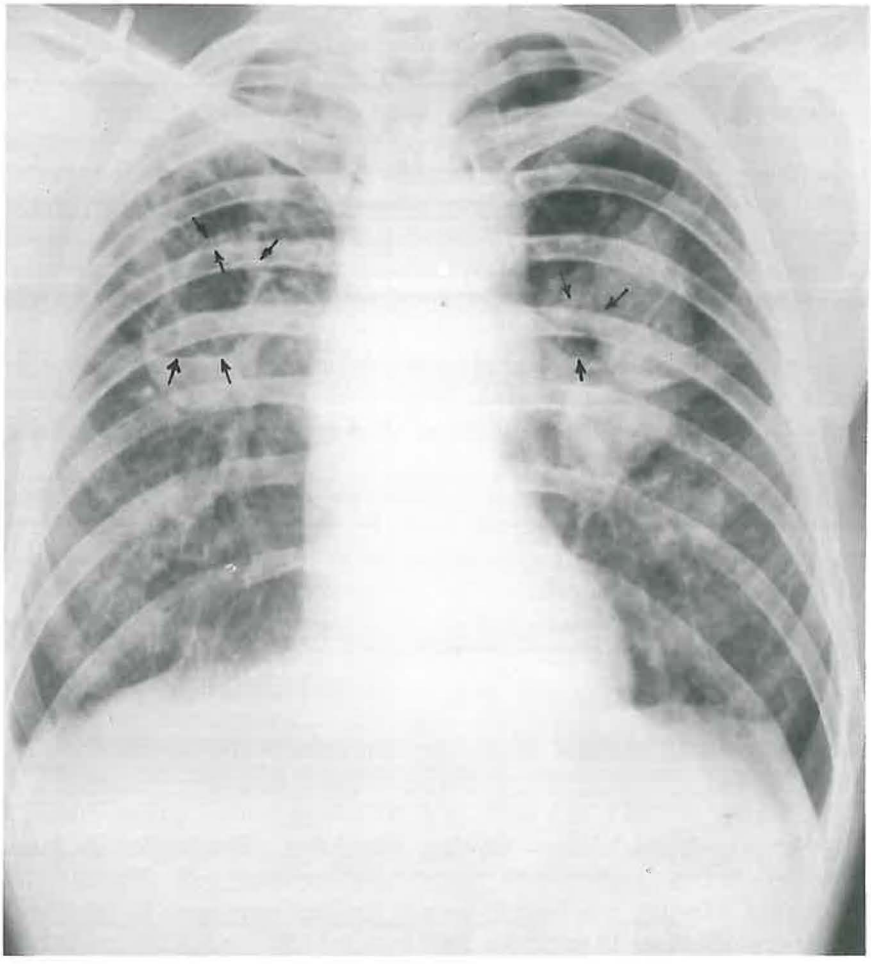


FIG. 19. Coal workers' pneumoconiosis with cysts in the right and left lungs. Note the thickness of the cavity walls and the air and fluid levels (arrows). These cysts are not thought to be due to an infection such as tubercle, staphylococcus, or Friedlanders bacillus. They are thought to be due to necrosis resulting from anemia infarcts. The cysts may fill and the evidence of the cavity then will disappear. They do not have the symptoms and signs of an active infection. These cysts may be small or large. In addition to the large opacities which may represent infarcts that do not communicate with a bronchus, there are many small irregular opacities *u*. There is some peaking of the domes of the diaphragm due to inelasticity of the lungs.

and were invisible. The cavities were small, slit-like, or large. Their contents were ink-like, nonpurulent, and of a maple-syrup-like consistency.

The clinical picture of ischemic necrosis rarely included fever, toxicity, or generalized debility. A benign course of cavitation due to ischemia was readily distinguished from that due to tuberculosis. The ischemic process was followed as long as 11 years.

The authors emphasized the importance of recognizing the nontuberculous nature of the cavitation to avoid hospitalization in a tuberculous facility and permit the miner to live in normal relationship to his family and the community, as well as to be gainfully employed if pulmonary function permits.

When massive lesions and emphysema develop, the background pattern of small opacities may largely disappear (Fig. 22). It also seems important to be aware that the pattern of abnormal changes in coal workers' pneumoconiosis may vary from mine to mine in central and western Pennsylvania (4–8) and from state to state in the United States.

### Massive Fibrosis and Carcinoma

Unilateral well-defined large opacities in coal miners may represent carcinoma, cyst, or massive fibrosis. There may or may not be a background of small opacities. The lesion may remain unchanged for 1–5 years. There may be a history of hemoptysis and a suspicious looking cytological smear.

Another type of massive lesion simulates a pattern of encroachment, fixation, and constriction of a large main bronchus. Such an appearance may occur in primary massive fibrosis or carcinoma. Operative removal may be the only way by which the lesion can be identified.

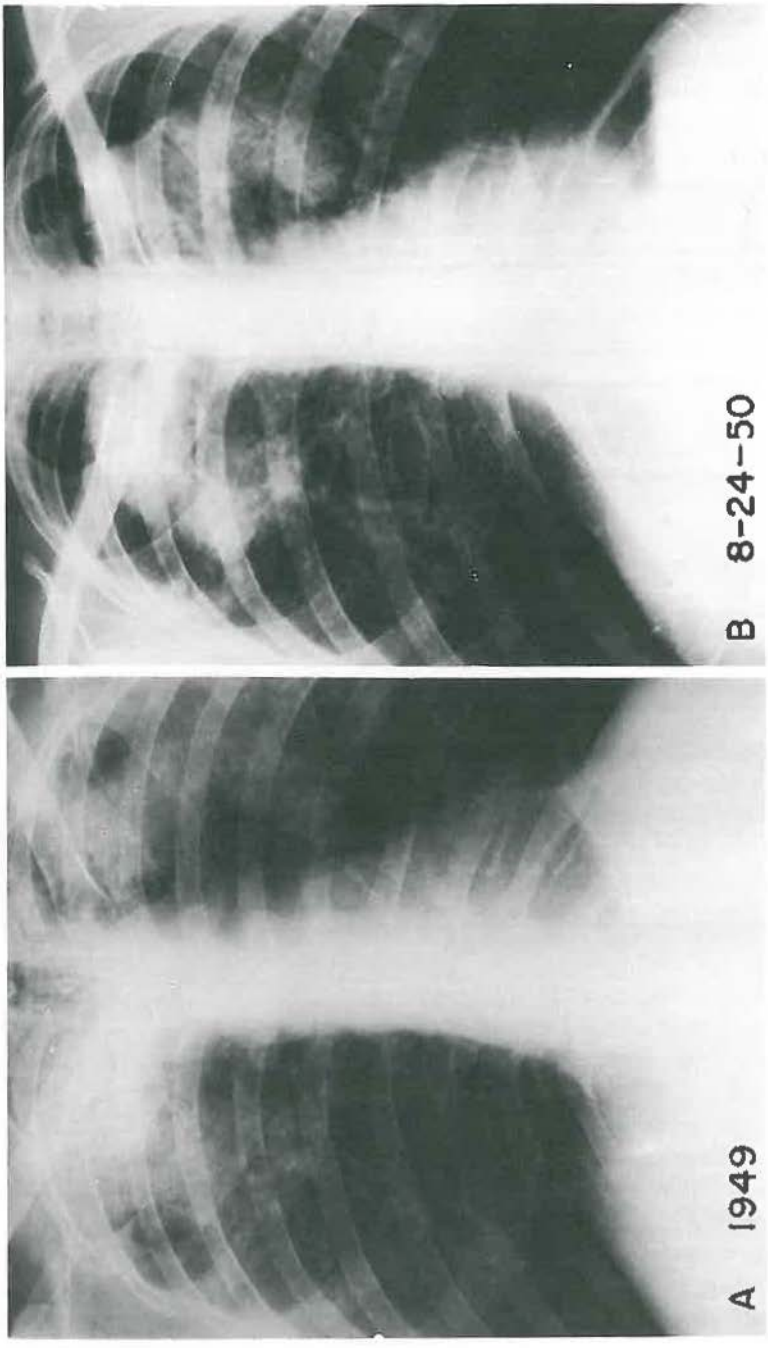
### Migration of Massive Lesions

Massive lesions may migrate centrally. When such a massive lesion becomes part of the shadow complex of the mediastinum, the roentgenographic appearance simulates a tumor and has been so diagnosed and treated [Figs. 20(A)–20(D)].

Large opacities, seen in lateral views, may be anterior or posterior to the midline of the thorax. Major migration of large masses is a slow process. Such migration may require 5–25 years (Figs. 20 and 21).

Gough (22) noted that when massive fibrosis causes shrinkage of the upper portions of the lung, severe bullous emphysema may develop. On occasions, in bullous emphysema the shadow pattern simulates a large opacity due to the crowding and distortion effect of the adjacent lung parenchyma.

When tuberculosis without cavitation is present in massive lesions,


A 1949
B 8-24-50

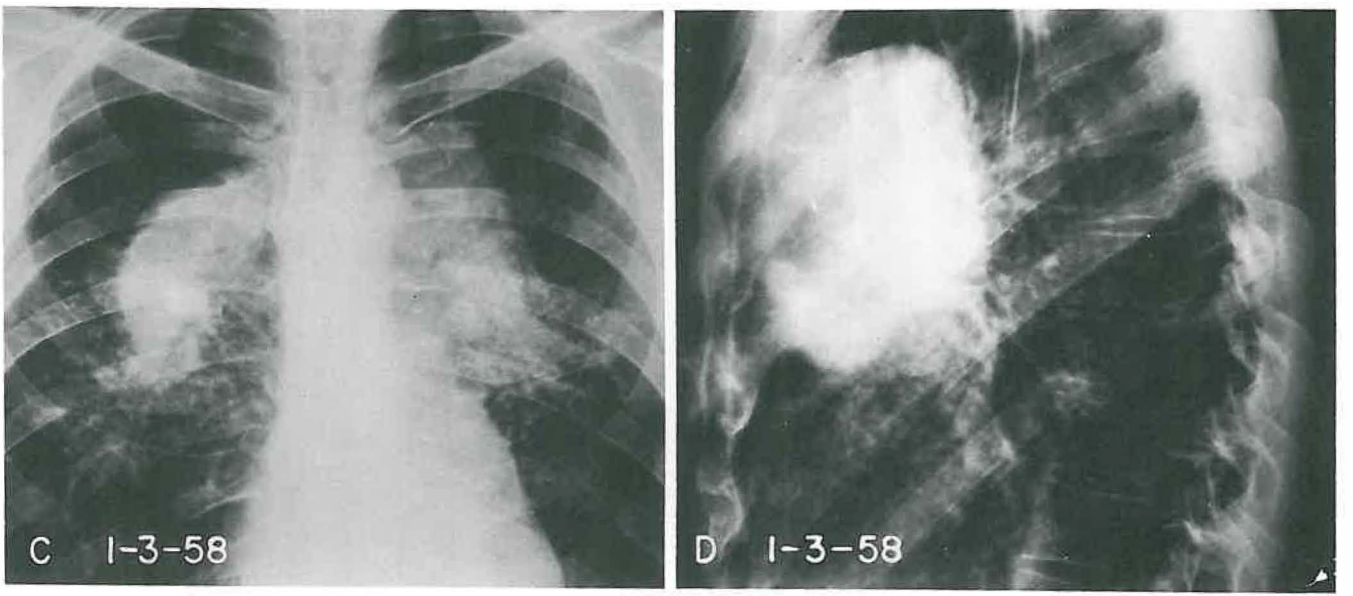



**FIG. 20.** Complicated coal workers' pneumoconiosis, category 2 *r*, C, em, hi, di, in which there is evidence of migration of large opacities. (A) 1949; (B) 1950, slight evidence of migration toward the midline; (C) 1958, further evidence of migration; (D) 1958, the two opacities have migrated anteriorly and appear as a single opacity in the lateral view.

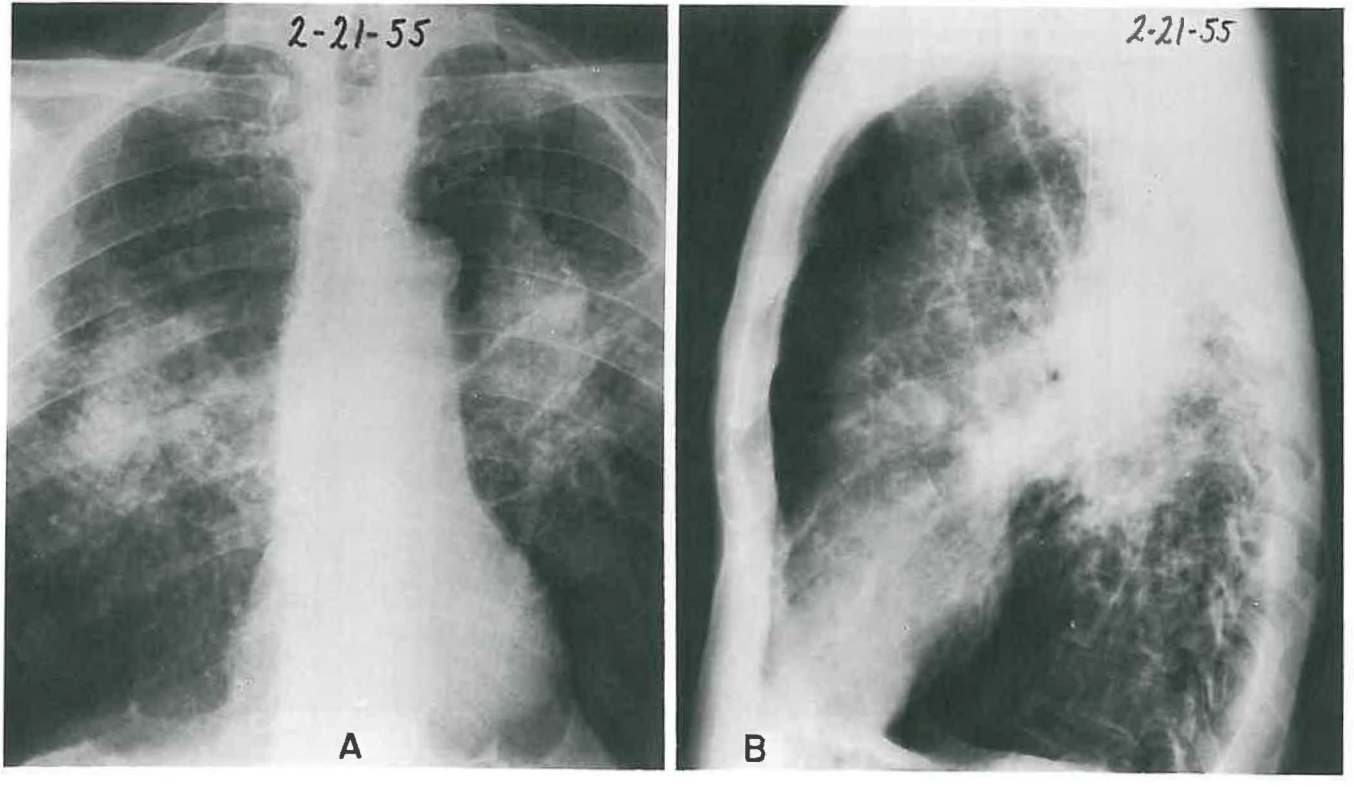



**FIG. 21.** (A) Complicated coal workers' pneumoconiosis, category 2 *r*, B, em, hi, di. (B) Lateral view of the same case. Compare with Fig. 20(D). In this instance the lesions have migrated posteriorly. In workers who have large opacities, lateral views sometimes provide important information.

multiple areas of calcification may be noted throughout the large opacity. At first, calcification within the large opacity is scarcely visible, but over the years the deposition of calcium becomes more prominent. It may also appear within lymph nodes. One cannot differentiate between the calcification of histoplasmosis and that of tuberculosis from the roentgenographic appearance. Tubercle bacilli are found in less than 50% of massive lesions (22). However, tuberculosis is so serious a complication that, from the radiologic standpoint, one should report massive lesions with or without cavity as suspicious of tuberculosis so that appropriate clinical and bacteriological studies can be carried out to diagnose or exclude a tuberculous process.

### Rheumatoid Changes

These changes were described by Caplan (23) in 1952. The roentgenographic lesions are round or irregularly round, well defined, 1–5 cm or larger in size, bilateral, often peripheral, and usually rapid in development (but once developed, they remain unchanged for years). There is usually a background of micronodulation of pneumoconiosis. Rheumatoid nodules may undergo liquefaction. Some show small areas of dense calcification (24).

Miall (25) described a similar pattern of lesions in the lung in patients with rheumatoid arthritis uncomplicated by coal workers' pneumoconiosis. He and others confirmed that inheritance is important in the etiology of the disease. Some rheumatoid changes simulate silicosis, sarcoidosis, and other conditions with patterns of widespread nodulation (26).

In one patient in which there was no history of harmful dust exposure, a single large opacity due to a rheumatoid granuloma was removed because of a presumptive diagnosis of carcinoma of the lung (27).

### Heart Disease

It has long been known clinically that cor pulmonale was often the mode of death in the pneumoconiosis of coal miners: "Cor pulmonale is common in progressive massive fibrosis, but rare with simple pneumoconiosis. Severe vascular lesions are associated with the former but rarely with simple pneumoconiosis (1 [p. 16])."

Wells, in Gough's department and mentioned by Gough (22), studied the arterial tree at postmortem examination after injecting opaque material. The roentgen examination of the specimen shows considerable reduction in the pulmonary tree, due to the various forms of arterial obstruction such as endarteritis, thrombosis, massive fibrosis, and emphysema. Cor

pulmonale was present often. "The presence of such vascular changes is not necessarily the major cause of cor pulmonale (1 [p. 16])."

From a group of 375 hard-coal miners with various categories of anthracosilicosis, electrocardiograms were done on 148 patients. The reasons for the choice of those 148 patients were not given. Of those, 24 or 16.2% showed evidence of strain of the right side of the heart (28). There appeared to be no correlation between stage of anthracosilicosis as determined by the roentgenogram and incidence of strain of the right side of the heart.

Cor pulmonale with increased preponderance in the size of the right side of the heart is difficult to evaluate on a single chest roentgenogram. If serial roentgenograms with P-A, oblique, and lateral views are available, one may observe an increased preponderance in the size of the right heart.

The conventional roentgenogram of the chest for cardiac disease is not very revealing in the presence of large and small opacities and emphysema. The vascular pattern of pulmonary vessels cannot be evaluated, because it may be obscured by the small opacities. The size and shape of the heart may not be informative because of distortion due to the lung lesions.

### Pleural Abnormalities

Involvement of the pleura in coal workers' pneumoconiosis is not as dominant as in asbestosis, but it does occur, and it is important that the abnormalities be recorded.

Pleural thickening may manifest itself as pleural plaques, generalized thickening, and obliteration of the costophrenic sulci (Fig. 13). Such changes may involve the domes of the diaphragm, the interlobar pleura, the walls of the thorax, and the cardiac pleura. Slight pleural thickening on the anterior and posterior walls and in interlobar fissures are seen in oblique and lateral projections, but may not be in P-A and A-P projections. We do not attempt to record pleural "caps." Slight and even definite costophrenic obliteration and interlobar thickening may result from preexisting inflammatory processes. This is always considered in our evaluation.

The pleural thickening may be generalized or occur as plaques. So-called "peaking" of the domes of the diaphragm is a form of pleural thickening especially at the sites of the interlobar fissures, but one should be mindful that a similar pattern may be produced in inspiration by an "inelasticity" of the adjacent intralobar bronchial and vascular structures and other tissues (Fig. 22).

Pleural calcification occurs either as plaques or in generalized forms

in coal workers who do not have a positive history of exposure to asbestos dust (7, 8). Plaques are easily overlooked when they occur on areas of the domes of the diaphragm or chest walls that are not recorded in an axial view.

Pneumothorax is seen occasionally in coal workers' pneumoconiosis and is easily recognized (Fig. 23).

Pleural collections oftentimes are observed in cardiac decompensation or as a complication to some pulmonary infection or malignancy.

## CONCLUSION AND SUMMARY

In conclusion, it seems important and appropriate to again emphasize a few observations that have been recorded elsewhere. They are:

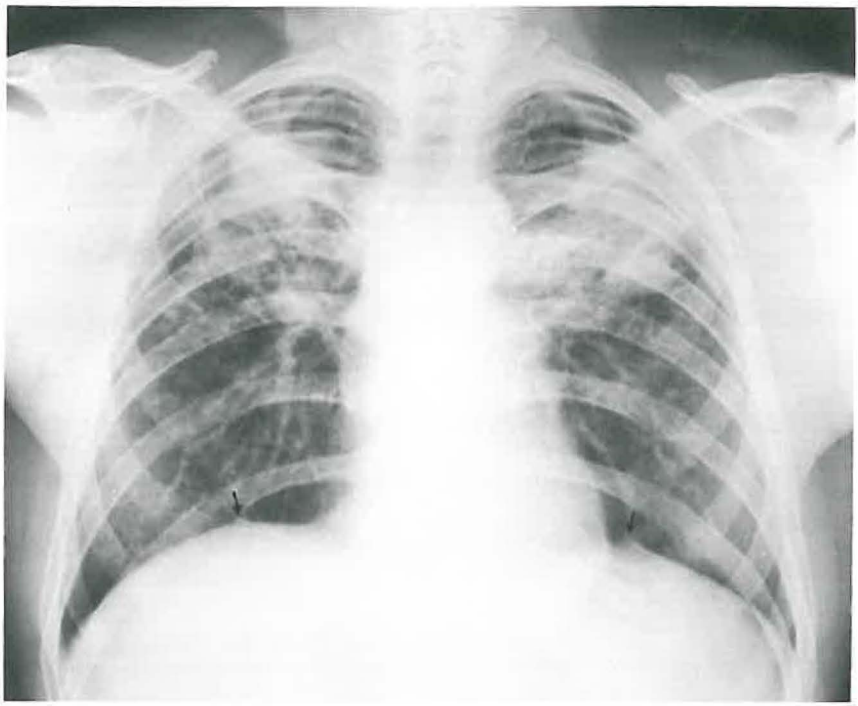


**FIG. 22.** Coal workers' pneumoconiosis in a Pennsylvania miner, Category 2 *q*, B, em, hi, di. The small opacities are largely obscured by the large opacities and the emphysema. The hila are displaced upward, and one can see the stretch effect due to distortion and the upward pull on the hila and the pulmonary vessels. Note the peaking of the domes of the diaphragm (arrows).

Coal workers' pneumoconiosis cannot be diagnosed in the living in the absence of radiographic changes. There is no characteristic physiological derangement which is indicative of dust in the lungs (1 [p. 25]).

The most desirable chest radiograph for the study of pneumoconiosis or other pulmonary disease is one in which the lung is shown in greatest detail (1 [p. 27]).

The conventional chest roentgenogram has no value in establishing the presence or severity of chronic bronchitis (1 [pp. 31–33]).

A mechanism should be developed for distribution in the United States of standard ILO films to any interested physician, radiology department, or investigator in pneumoconiosis (1 [p. 32]), and all men in the coal

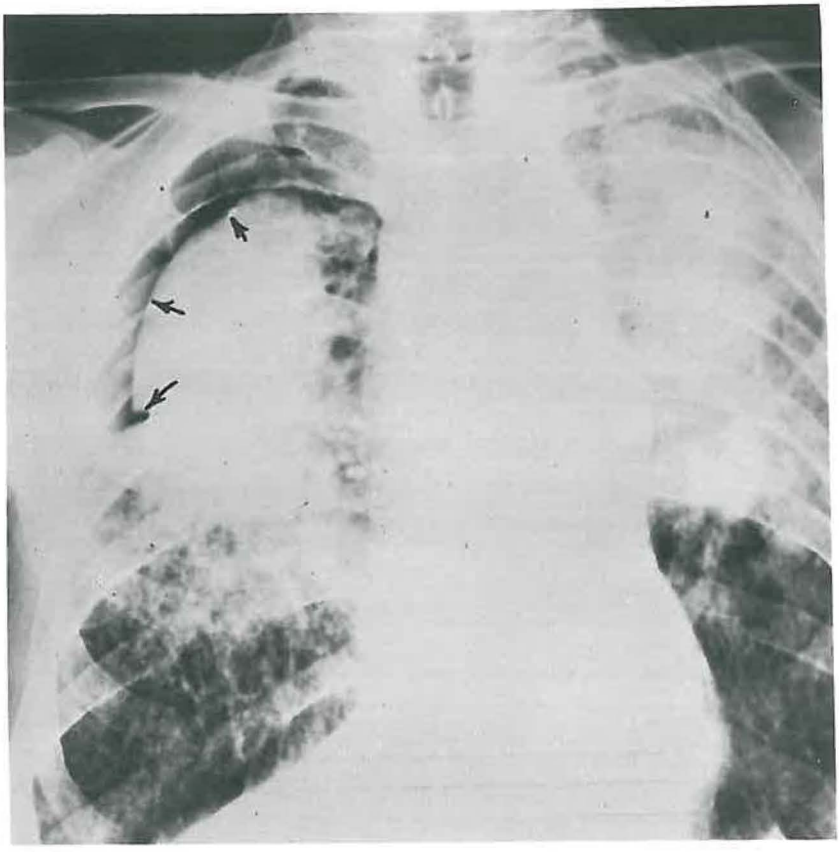


FIG. 23. Complicated coal workers' pneumoconiosis, category 2 *r*, *u*, C pn, hi, di, with a pneumothorax on the right. Note that there is no visible pattern of adhesions modifying a partial collapse of the right upper lobe.

industry should have a preemployment medical examination including chest radiographs and pulmonary function studies. These examinations should be repeated at least at 5-year intervals.* This material should be collected in a manner suitable for scientific examination as well as clinical use (1 [p. 32]).

Prospective studies of the natural history of coal workers' pneumoconiosis are needed, and they should be correlated with all environmental factors. One goal of these studies should be to determine the relationship between the exposure and the risk of disease, resulting in a determination of guidelines for permissible safe exposure for the miners' working lifetime (1 [pp. 32–33]).

Proper correlation of pathological findings with clinical, X-ray, and physiological studies have been seriously impaired by the lack of autopsy material. Effective mechanisms must be developed which will provide access to autopsy material in conjunction with other studies. An adequate central facility should be available for the study of that material (1 [p. 33]).

This chapter includes critical comments on the essentials of chest radiography as it concerns equipment and technique; roentgenographic patterns of coal workers' pneumoconiosis in the United States; the aims, principles, and details of the U/C Classification of the radiographic appearances of pneumoconioses; and the radiologic considerations of the interpretation and evaluation of the shadow patterns as they obtain to the occupational history and the physical examination.

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* The Federal Coal Mine Health and Safety Act of 1969 substantially makes these requirements.

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