JMEK 4189

A ROENTGENOLOGIC STUDY OF THE EFFECTS OF DUST INHALATION UPON THE LUNGS *

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THE possible pathologic features and the various causes of increased thickness of the prominent linear shadows, especially those extending from the hilus to the base of so many individuals examined for tuberculosis and other conditions, have been questions about which more or less doubt has existed. Furthermore, it is frequently difficult to assign to their exact diagnostic value, in the detection of early pulmonary tuberculosis, the more isolated thickened trunk shadows often found in the apical regions. In attempting to derive a better understanding of the causes of these changes from normal appearances it was decided to approach the subject by a study of the chests of a large number of individuals engaged in various dusty occupations. This work was instituted about a year ago on a small scale, but it soon proved to be of so much clinical and roentgenologic interest that it has been continued throughout the past year as time could be spared.

As a rule, we have found firms and corporations quite willing to have the investigations carried out upon their employees, and it has frequently been to their advantage so to do, either by being assured that the dust inhaled by their men was not so harmful as was claimed, or by having ways and means suggested whereby the dangers from dust inhalations could be lessened. The Trenton Potteries Company and the Whitehall Cement Works have been most generous in supplying material and otherwise aiding us. A number of carpet, plush and silk workers were furnished through the kindness of Dr. J. W. Schereschewsky, Surgeon U. S. Public Health Service, and the remainder has been supplied through the Occupational Clinic of the University Hospital. Up to the present time one hundred and thirty seven individuals have been examined, distributed through the following occupations:

Organic dust	
Carpet and plush workers	18
Tobacco workers	13
Silk workers	1
Inorganic dust	
Potters	39
Metal grinders	20
Cement workers	20
Asbestos workers	15
Coal miners and marine firemen	10
Not classified	1
Total	137

Each case has had a thorough clinical examination, followed by a roentgenoscopic study and a roentgenographic examination by stereoscopic plates. The clinical and roentgenologic studies have

* Read at the Eighteenth Annual Meeting of the American Roentgen Ray Society, New York City, September, 1917.

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been made independently, and as this is in the nature of a preliminary report during the progress of our investigations, there has as yet been no comparison of the details brought out by the two methods of examination, except in a general way. It is obvious, therefore, that all minor details should be omitted from this report, and the results of our investigations at this time be limited to a statement of certain well-established general facts.

The entire subject is naturally to be regarded as a study of pneumoconiosis, a general term employed in referring to the effects induced in lung structure by the prolonged inhalation of abnormal quantities of dust. In a general study of the subject we have preferred to omit all reference to such terms as anthracosis, siderosis and chalicosis for the reason that they are indicative of the results of inhalation of certain kinds of dust, whereas many occupations imply the breathing of various forms, and the effects are the same in general but may vary in degree.

This report deals entirely with the roentgenologic aspect of the subject and is made at this time in an endeavor to aid in the more accurate roentgen diagnosis of pulmonary disease. The clinical and pathologic aspects of pneumoconiosis are by no means new, but thorough roentgenologic studies have been very few. Perhaps the most valuable contribution is to be found in United States Health Bulletin No. 85, issued January, 1917, comprising a clinical and roentgenologic study of 433 cases of "miners' consumption" among the zinc miners in Missouri, by Dr. A. J. Lanza, Surgeon of the U. S. Public Health Service and Dr. Samuel B. Childs of Denver. Another important contribution was made

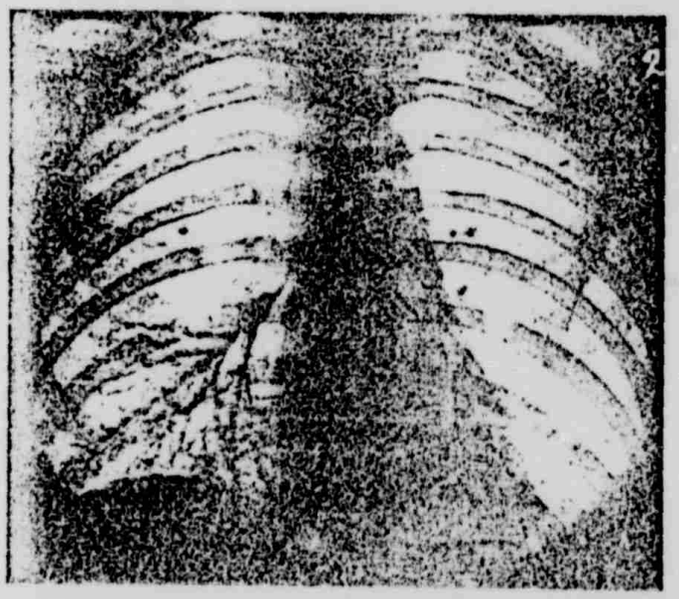


FIG. 1. OUTLINE OF THE LOWER PORTION OF THE BRONCHIAL TREE BY BISMUTH.

Chest of a young girl with supposed esophageal stricture, but in whom the supposed obstruction was merely neurotic in origin. The bismuth meal passed directly into the trachea and most of it descended into the right bronchus. Note the distribution of the lower branches. Dust inhalation does not seem to affect the outermost ones.

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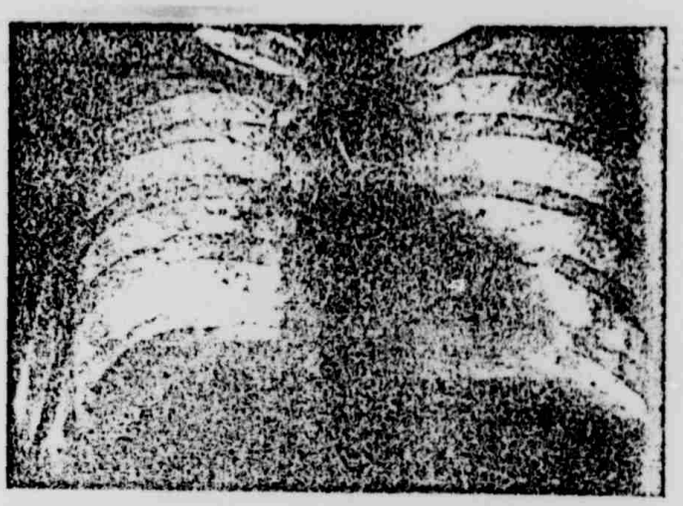


FIG. 2. PNEUMOCONIOSIS IN METAL BALL GRINDER (DRY), SEVENTEEN YEARS' OCCUPATION.

The hilus shadows are greatly enlarged and linear markings are thickened, especially to the right base. There is intense mottling with small dense discrete spots on both sides, but more on the right.

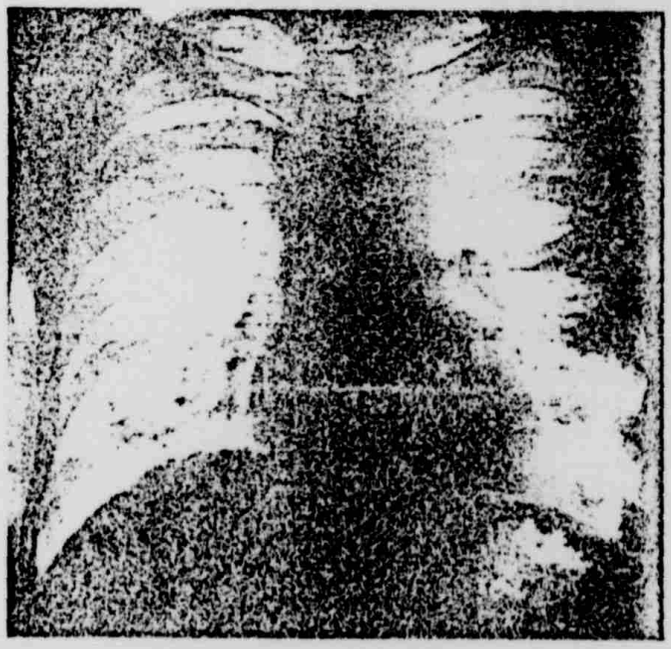


FIG. 3. PNEUMOCONIOSIS IN POTTER, FORTY YEARS' OCCUPATION, SHOWING COMPARATIVELY LITTLE EVIDENCE OF DUST EFFECTS FOR THIS TIME.

The hilus shadows are slightly increased, linear markings thickened, and there is a moderate amount of discrete mottling most marked around the middle of each lung.

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by Dr. W. W. Boardman in the June, 1917, issue of the AMERICAN JOURNAL OF ROENTGENOLOGY, dealing with cases of coal dust inhalation and reviewing the roentgenologic literature on the subject. Both of these were published while we were in the midst of our investigations, and it is interesting to note that the conclusions drawn by all of us, working independently, from the roentgenologic standpoint, have in the main been very much the same, differing only in minor details. Each of the above contributions has dealt with pneumoconiosis of a single origin, whereas we are endeavoring to study the condition as it arises from as many occupations as possible, and we have not, therefore, felt that our work conflicts with that of the other investigators. It has been proven by all that the roentgenogram, supplemented by a careful roentgenoscopic study, is by far the most accurate means of studying the effects of dust upon the lungs. The pathology of the disease has been well established by autopsy, and roentgen observations serve to accurately portray the exact conditions *in vivo*.

Practically all roentgenologists have had more or less opportunity to examine cases of pneumoconiosis, but most of these have been isolated examples of an advanced stage of the condition. In order to comprehend the various phases and to suspect and recognize them whenever seen and, most important, to differentiate the appearances of pneumoconiosis from those of other conditions, particularly tuberculosis, one must make a systematic study of the roentgen pathology through all the stages and from the standpoint of every source of

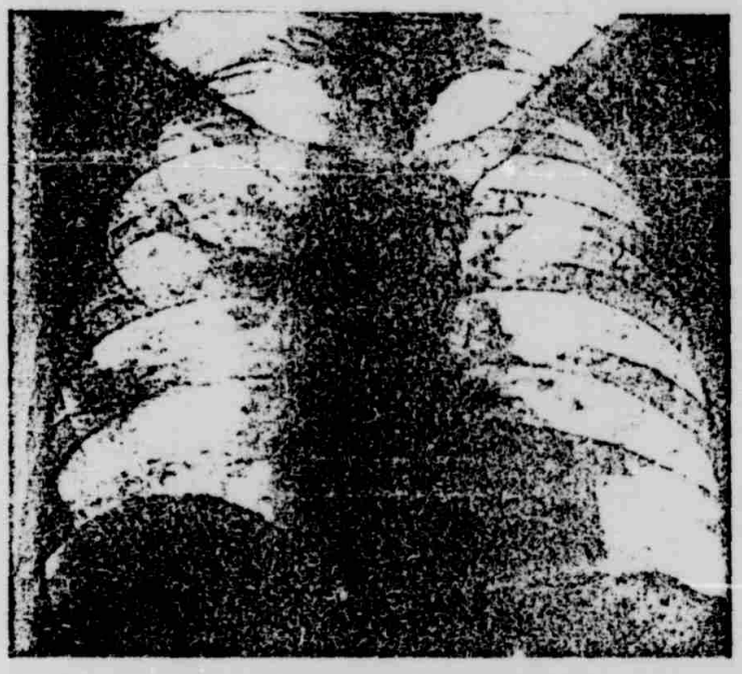


FIG. 4. PNEUMOCONIOSIS IN COAL MINER WHO WORKED THIRTY-EIGHT YEARS OUTSIDE THE MINES.

Roentgenoscopic examination: No interference with diaphragm excursion. Stereoroentgenograms: Increased hilus shadows, linear markings obscured, diffuse *pneumoconiosis*, with discrete spots, distributed from bases to apices, somewhat more marked on the right side where fibrosis is beginning. Note also the fibrosis in the subapical region. There were no unusual chest symptoms. This is a transitional case between the second and third stages.

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invasion. When one realizes the very numerous occupations that provide sufficient dust to induce changes in the lungs, and the fact that dwellers in some large cities are subjected to sufficient dust to produce perceptible shadows in the lung structure, it seems quite probable that errors in diagnosis must be frequent unless the possibility of pneumoconiosis be constantly borne in mind.

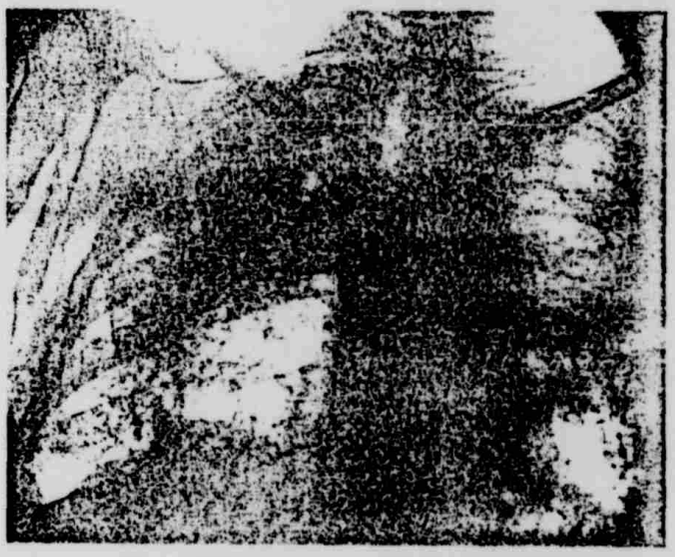


FIG. 5. PNEUMOCONIOSIS IN COAL MINER WHO WORKED THIRTY YEARS INSIDE THE MINES.

Roentgenoscopic examination: Diaphragm almost fixed. Stereoroentgenograms: Extreme fibrosis of the third stage, with greatest density in subapical regions, where the density simulates consolidation. Emphysema at bases. Bronchiectasis left side. Intense dyspnœa. Repeated sputum examinations negative.

Three stages are to be recognized in the progress of the condition. In order to explain the condition itself and the changes which take place brief reference must be made to the pathology, which is very simple. The first marked effect of excessive dust inhalation is irritation of the air passages which amounts to a chronic bronchitis. This in itself is responsible for more or less fibrous change which becomes legible in the roentgenogram as a thickening of the trunk shadows. This is no doubt also due to a certain amount of dust deposition in the cells and neighboring lymph structures. The thickened trunks and the lymphatic structures with increased density tend to increase the size and density of the hilus shadows. Added pigmentation of cells and increased depositions of dust particles in lymphatic structures further out along the branching systems of the air passages gradually produce small areas of such density as to be visible and give to the lungs the characteristic mottled appearance so common in advanced cases of pneumoconiosis. Our experience has shown that this density is more or less closely related to that of the dust inhaled, being least in organic dust and greatest among metal grinders. Naturally the fibrous change that starts early from irritation increases, and there is later a decided fibrosis following up the deposition of dust. This seems finally to involve a large part of the lung

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structure and is no doubt responsible for the dyspnœa by rendering the lung inelastic, which is readily determined by the lack of expansion noted by the fluoroscope, and particularly in the diaphragm. Bronchiectatic cavities are quite common in the late stages, and a similar process is manifest in the ultimate divisions of the passages as usually prominent trunk shadows, and an undue prominence of the finer linear markings. This is due to the causes just mentioned. It is the rule that the increase in thickness of bronchial trunk shadows is fairly uniform, which is the main dependence in distinguishing the case from one of peribronchial tuberculosis, but there are

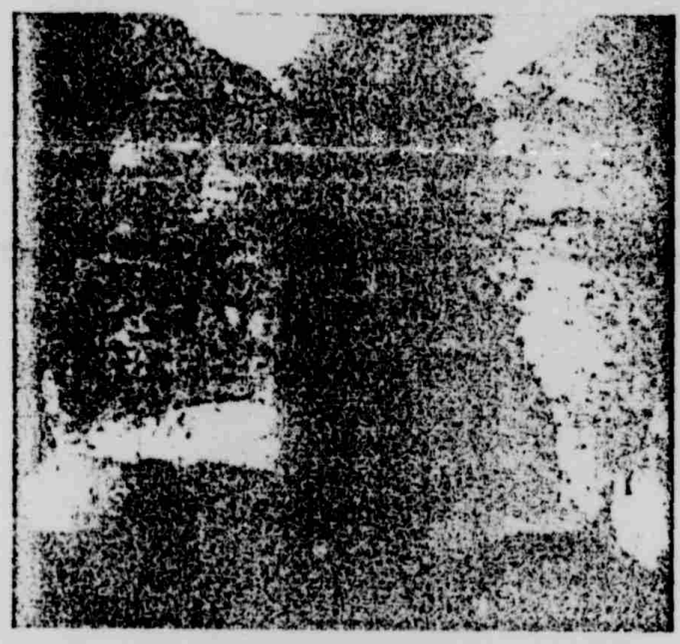


FIG. 6. PNEUMOCONIOSIS IN POTTER, FORTY-FIVE YEARS' OCCUPATION.

Roentgenoscopic examination: Almost complete fixation of diaphragm (intense dyspnœa). Stereoroentgenograms: Hilus shadows increased; linear markings obscured; emphysema bases; dense mottling becoming conglomerate, especially toward apices; extreme diffuse fibrosis, with bands to diaphragm, and heart and vessels drawn to the left; bronchiectatic cavities both subapical regions. Repeated sputum examinations negative.

emphysema. The division of the process into three stages seems to be a foregone conclusion among those who have made a study of the subject. Before any access to literature could possibly modify our views, we had made practically the same classification which has been presented by the authors already referred to.

The first stage, roentgenologically speaking, is characterized by an increase in the hilus shadows and a thickening of the exceptions, and it is these which makes the roentgenologic diagnosis difficult or uncertain. Boardman aptly calls attention to the fact that roentgenologists have no doubt been mistaking early evidences of pneumoconiosis for tuberculosis. If the distribution of the thickening is irregular, as it frequently is, and the trunks to one apical region only are involved, the two conditions are quite difficult to distinguish by the inexperienced observer, and often

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almost impossible to differentiate by even the most experienced. A still more difficult problem is the detection of a peribronchial tuberculosis in the presence of evidences of the first stage of pneumoconiosis. In several instances we have recorded our plate readings as suspicious but we have not yet checked these up with the clinical findings. Abnormalities in the diaphragm

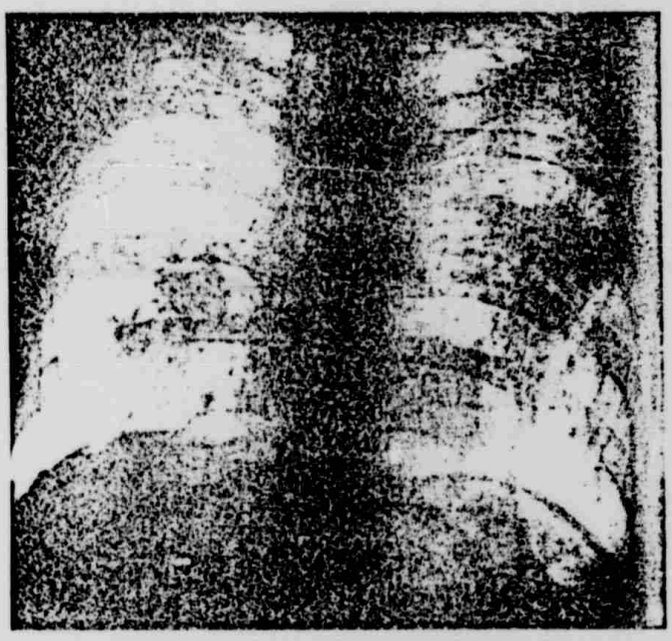


FIG. 7. PNEUMOCONIOSIS IN POTTER, FORTY-TWO YEARS' OCCUPATION.

Roentgenoscopic examination: Right diaphragm fixed at mid-point. Heart and vessels pulled to right. Emphysema at bases. Stereoroentgenograms: Hilus shadows and linear markings uncertain; dense mottling still visible but becoming conglomerate; extreme fibrosis in both apical and subapical regions. Repeated sputum examinations negative.

excursion are to be included in all the stages of the condition. We have certainly noted them in many instances in the first stage, contrary to the experience of Lanza and Childs. There is no general rule about them, however, in the first or even the second stages. When the excursion has been equally shallow on both sides in the first stage, we have frequently been unable to decide that this was not due to habit or to inability of many individuals of the labouring class to "show off" their diaphragms to best advantage. The position of the excursion during ordinary respiration between the limits of extreme inspiration and expiration is very variable. The most common finding was a restriction at the inner portion of the right diaphragm during full inspiration and either a decided flattening or a concavity of the outer aspect. It seemed as though the inner portion were halted in its descent by the process responsible for the thickened trunk shadows. It was our impression that the descending trunk shadows were usually more thickened on the right side than the left, but the interference offered by the cardiac shadow prevented a satisfactory proof of this supposition.

The second stage is characterized by a more or less uniformly arranged mottling

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throughout the lung structure due to depositions of dust in the lymph structures, cells, and fibrous tissue interspaces, with the addition of a certain amount of localized fibrosis. This stage comprises what has usually been regarded as the typical case of pneumoconiosis. Its onset seems to depend largely upon the quality of the dust inhaled. It occurs comparatively early in coal miners, cement workers and certain metal grinders, somewhat later in potters and asbestos workers, and quite late in those inhaling organic dusts. The volume of dust will, of course, enter into the statistics of this aspect of our work, and while this has been measured by Dr. Miller, comparisons have not yet been made. In metal grinders it was quite noticeable that mottling was observed before the usual first stage appearances were well advanced. Cement, asbestos and carpet mills were the dustiest buildings examined by Dr. Miller, but no computations were made in coal miners. On the whole, it has been our experience that certainly quality and probably weight or density are more important factors in pneumoconiosis than quantity, contrary to the statement of Boardman. The distribution of the mottling is interesting. Invariably we have found it first appearing in the right lung, on a level with the hilus shadow, which is quite contrary to the statements of Lanza and Childs. It certainly becomes quite perceptible on the right side before it appears on the left, and for some time after it does begin on the left side, it is noticeably more marked on the right. Later on it is impossible to demonstrate any difference on the two sides. The distribution is more or less symmetrical, but naturally not uniform, throughout the lung. From the starting point it gradually spreads to the bases and apices, but is never so marked at the extreme apices or bases as around the mid portion of the lung. The appearance of the

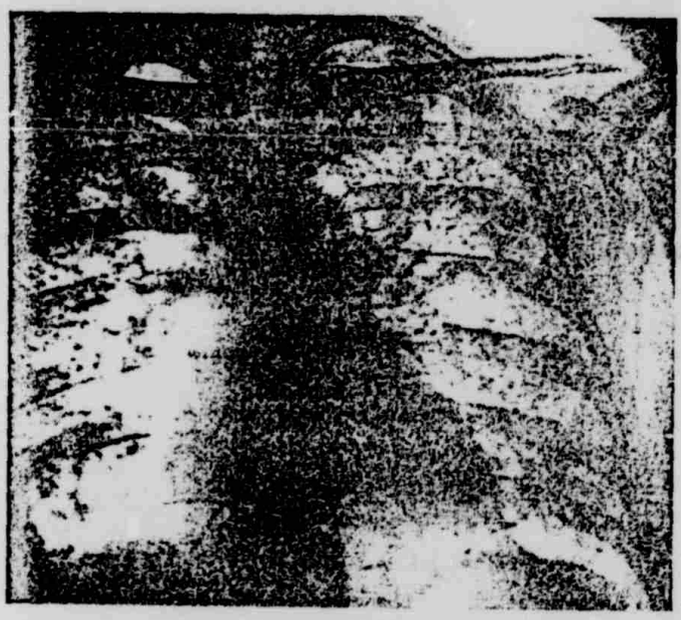


FIG. 8. PNEUMOCONIOSIS IN POTTER, TWENTY-NINE YEARS' OCCUPATION.
Dense mottling throughout both lungs. The appearance at the left apex suggests an associated tuberculous process.

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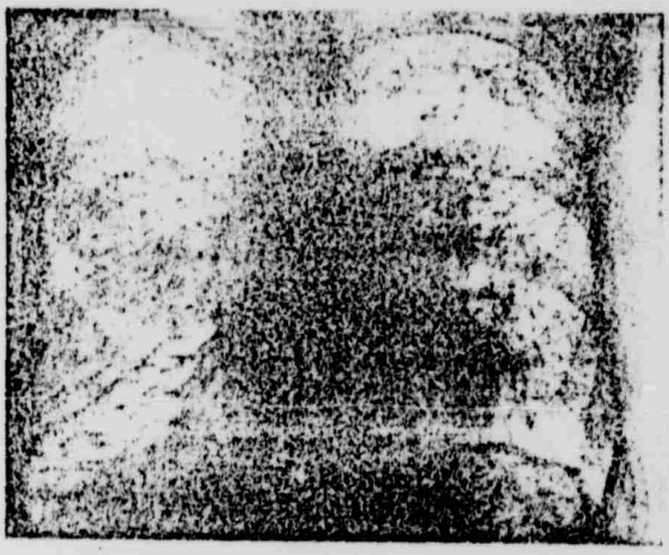


FIG. 9. CHEST OF A MALE AGED TWENTY-NINE, WHO, WHEN A CHILD, INHALED A VEGETABLE BURR: RESULTING FIBROSIS.

The appearance is that of an extreme fibrosis which prolonged clinical study has proved not to be tubercular in origin. In the right base are numerous bronchiectatic cavities which, under the fluoroscope, could be seen opening on inspiration and collapsing on expiration. Compare this with fibrosis due to pneumoconiosis.



FIG. 10. OLD HEALED PULMONARY TUBERCULOSIS INVOLVING RIGHT LUNG, WITH RESULTING FIBROSIS.

Large bronchiectatic cavities previously found are now irregular in shape. The left lung is the seat of a more recent process now healed clinically. Compare with fibrosis due to pneumoconiosis.

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mottling depends more or less upon the quality of the dust. In certain metal grinders the spots are very dense and sharply circumscribed and can be seen when very small. This is so to perhaps a less extent in coal miners, potters, and probably many other occupations. In cement and asbestos workers, among the inorganic dust occupations, the spots are noticeably softer and less sharply defined and the appearance is more like the early individual or conglomerate tubercle. In the organic dusts there is still further difference. Toward the end of the second stage the spots tend to enlarge and become conglomerate.

Errors in diagnosis are not so apt to occur in this stage. The appearance is so typical that no one is likely to mistake it for tuberculosis except possibly the miliary or bronchopneumonic types, and the history of the case is all that is necessary to correct any tendency to error. In a case examined without history, the distribution of the spots in the early stage and the comparatively slight amount of mottling in the apical regions later should put one on guard to ask questions. Here again, however, it may be exceedingly difficult to detect an early tuberculosis engrafted upon a well advanced case of pneumoconiosis in the second stage.

The third stage is the most interesting period in this condition from the roentgenologic standpoint. It is characterized by the appearance of diffuse fibrosis and all that the term implies. As an end result it does not differ greatly from the fibrosis that represents the terminal stage of chronic tuberculosis or some other less common causes. It is sometimes difficult to draw the line between the end of the second and the beginning of the third stage, and we are as yet uncertain as to the appearance at the period of transition. In some instances it would seem that the mottled appearance becomes increasingly conglomerate and passes over into the appearance of dense fibrosis, sometimes closely resembling consolidation. In other instances a general haze seems to spread over a certain portion of lung, resembling a thickened pleura in a flat plate but resolving itself into lung structure in stereoscopic plates. The greatest density is in the subapical regions, although this is not the region of most intense mottling in the second stage. We have imagined that the marked emphysema usually present at the bases must have some bearing upon this distribution. Dense fibrous bands can be seen extending in various directions, and frequently to the diaphragms, causing marked retractions. The heart and vessels are frequently dragged out of place. Bronchiectatic cavities are quite common. There is a very noticeable effect of inelastic lung structure upon respiration as studied by the fluoroscope. The ribs move little enough, and the diaphragms sometimes not at all. Is it in the least surprising that these unfortunate individuals suffer intensely from dyspnœa? In this stage the mottling has become extremely coarse and sometimes is to be no longer recognized as such.

The differential diagnosis between the fibrosis resulting from tuberculosis and pneumoconiosis is frequently a most difficult problem, and, we have had to acknowledge, sometimes well-nigh impossible. It has been hard to believe that some individuals have not had tuberculosis; but repeated sputum examinations, sometimes over a number of years, have been negative. Still more difficult frequently is the detection of a tuberculosis engrafted upon this stage of pneumoconiosis. Suffice it to say that our studies have convinced us that errors in diagnosis have been made with considerable frequency.

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