X-RAY STUDY OF ADVANCED TUBERCULOSIS OF THE LUNGS WITH AUTOPSIES

THE DEGREES OF DENSITY OF GENERAL HOSPITAL No. 17*

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FROM our teachings we had the following general ideas in regard to the significance of different degrees of density on x-ray plates of tuberculosis of the lungs: first, that the greater the density the greater the amount of fibrous tissue in the lesion; second, that a thickened pleura is capable of showing very marked density; third, that massive caseation shows less density than fibrous tissue and even less than many thickened pleurae, in fact often shows only mild semi-translucent snowstorm effects; fourth, that scattered tubercles are visible practically only in the greater evidence of the normal lung detail; fifth, that normal lung detail is produced by bronchial tubes and blood vessels; sixth, that annular figures signify cavities and their absence the absence of cavities.

Confidently we read our plates with those ideas in mind. Six autopsies occurred and we compared the carefully sectioned lung with our reading. It failed to correspond in so many particulars that we set about a special study and proceeded to read our x-ray plates not from previous instruction but from the comparison of the autopsies.

We sectioned the lungs most carefully, compared the plate with every part and tried to determine what each shadow meant. In addition, in order to discover how much of a shadow different normal and pathological tissues produced, we x-rayed a number of tissues separately and created a number of conditions in the way of cavities containing both air and fluid, localized caseous consolidations transferred from other lungs, watery, serous, blood and purulent effusions covering the lungs, and conditions representing thickened pleura over both human and pigs' lungs. We studied the lungs both within and without their thoracic cage, with and apart from the heart, in cut sections and under every circumstance which our imaginations could devise. Our plates were all stereoscopic.

We found the study of pigs' lungs particularly instructive from the fact that the bronchial tubes are larger and extend nearer to the periphery, thus making them easier of recognition by the x-ray.

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We made a number of x-ray pictures of the following structures:

1. Normal pericardium
2. Two thicknesses of pericardium
3. Small piece of collapsed lung with tubercles
4. Small piece of collapsed emphysematous lung with tubercles
5. Small piece of collapsed lung with tubercles, the whole covered with pericardium
6. A piece of lung with ordinary visceral pleura on side so that the pleura would be seen in optical section
7. Piece of lung with small cavity; cavity was cut in half, cut side uppermost and penetrating about one-half the lung tissue
8. Piece of blood vessel about the size of the adult carotid and one-tenth of an inch deep in optical section
9. Piece of blood vessel empty and another filled with blood in longitudinal section
10. Piece of adult trachea about one-eighth of an inch deep in optical section
11. Piece of bronchus in longitudinal section
12. Longitudinal section of dividing bronchus at hilum filled with blood.

We learned that:

First. Even a dense thick fibrous membrane, like pericardium, interferes very little with the ray and casts almost no shadow. This is true even when it is doubled. We were not surprised to find, therefore, that thickened pleura evidently apparent at autopsy could not be detected on the plate. Pathological conditions in the lungs are visible by their shadows only when the air content in this area is much less or much greater than that neighboring. We can imagine a pleura sufficiently thickened over one lobe to so compress it as to diminish the general air content and thus produce a shadow, but this would require the pleura to be probably a quarter of an inch or more in thickness which never occurs except over a massive lesion when the thickened pleura would be lost in the lesion itself.

Second. Tubercles to the size of a pea in collapsed lung tissue are not differentiated, the whole mass appearing of equal density. Therefore, it is not the caseous debris *per se* which makes the shadow, but simply the comparison of the air content.

Third. An artery the size and thickness of the carotid casts so little shadow even when filled with blood that it is likely the blood vessels *per se* have little or nothing to do with the hilum shadow or normal lung detail. The hilum shows up not on account of specific structures, but merely on account of the lack of air content.

Fourth. The trachea and bronchial tubes cast a slightly more dense shadow than blood vessels, and from the study of bronchial tubes standing alone and in the pigs' lungs, we believe that they are entirely responsible for normal lung detail.

Fifth. A cavity in the lung becomes evident not on account of the density or thickness of its wall, but on account of the air in it, and the

air usually so rarefies the tissue before and behind as almost to obliterate it. The cavity of the trachea, for instance, so modifies the dense tissue of the sternum and spinal column between which it lies that it is seen through them. As a consequence, it is usually impossible to diagnose whether the condition before or behind a cavity in the lung is normal or pathological. On account of this very rarefaction, however, a cavity sometimes intensifies special things, which are smaller in extent than the cavity itself, so that we feel confident, though we never had the opportunity to try the experiment, if a bladder filled with air were placed on the outside of the body in front of an imbedded metallic substance, or possibly a kidney or bladder stone, it would rarefy the tissue about the stone so as to make it more apparent. Since we wrote this sentence, we have learned that others have done this with success. In addition, no matter how thick the wall, a cavity never shows contour and always appears as a ring.

To learn whether or not the inflammatory elements in the wall of a cavity are of importance in the production of the wall seen on the x-ray plate, an x-ray was taken of intestinal ulcers:

1. An unopened piece of intestine with ulcer. The plate showed only the outline of the intestine with practically no indication of the ulcer.

2. Piece of intestine opened with ulcer uppermost. This showed the ulcer in ill defined outline.

3. Piece of intestine opened with ulcer covered with barium. This showed the barium covering the ulcer as well as the barium accidentally dropped over other places but did not outline the ulcer.

The same three pieces of intestine were also covered by one-quarter inch of rectus muscle. All showed the intestine in faint outline and the last the barium in the intestine. In other words, the inflammatory elements *per se* are not the cause of the cavity wall shadow.

Artificial conditions were also produced in the following ways:

1. A pig's bladder was blown up, one inch and a half in diameter with air and introduced into the center of a pig's lung. In spite of the thick walls of the bladder and the fact that it was not blown up to a great degree allowing the walls to fall in folds, the plate showed simply the typical appearance of cavity with ordinary walls. In other words, in spite of the muscular and connective tissue in the bladder walls, it was the air content which was particularly visible, rather than the wall itself. Immediately below where the bladder was introduced there was a triangular space made in the lung tissue. In spite of the fact that this had no definite wall except above, where the bladder crossed it, this cavity showed up quite as well as the bladder cavity.

2. A small three-quarter inch square of collapsed human lung containing scattered tubercles was introduced into the middle of a pig's lung. This showed up as a single mass, the tubercles not being differentiated. The density was homogeneous and faint, comparing about with single rib or fibrosis density. It was sharply defined and showed the exact shape of the piece inserted.

3. A mass of caseation one inch in diameter was introduced into the

center of a pig's lung and showed slightly greater density than the preceding. It was about as dense as heart density, though slightly less homogeneous. The edges were not so well defined and shaded off into normal lung. In other words, though caseation is more dense than collapsed lung and showed it on the plate, the margin of the caseated mass, due probably to slight differences in the pictures, was less clear cut.

4. Pigs' lungs were infiltrated with barium sulphate both by insufflation after death and by attaching a bag filled with barium over the snout shortly before death, with the idea that it would be easier to trace the bronchial tubes. Subsequent studies proved these experiments unnecessary since the bronchial tube in the pig is so evident throughout its course. Its shadow is manifested on the plate as a line of lessened density varying in size with the calibre of the tube, bounded by two white lines. We do not agree with the description that a bronchus is indicated by two flat bands of great density separated by an area of slight density, since slight density would convey the idea of greater density than normal when in reality it is less. On account of the air in the bronchial tube, it is often noticeable that when a bronchial tube passes in front of or behind an object the density of which corresponds with or is greater than the boundary line of the bronchus, the bronchus is still traceable as an area of lessened density, but the boundary lines are effaced. It is interesting to note that the barium in both cases confined itself almost entirely to the upper portions of the lungs, confirming the fact described by others that inhaled particles are carried naturally to the apices.

5. The bladders of three pigs were filled, one with water, one with blood, and one with air, and x-rayed. The density of the water and blood was exactly the same. The bladder filled with air showed as a clear space bounded by a narrow white line.

6. The bladder filled with water was flattened out to one inch in thickness, placed before a lung, and x-rayed. It showed the density of heart with lung detail visible behind it. Ordinarily a pleural effusion fails to show lung detail behind it, because, in addition to casting its own shadow, it compresses the lung, thus obliterating lung detail and increasing the shadow. The faint shadow immediately above a pleural effusion, commonly stated to be due to thickened pleura, we believe due to upward compression of the lung.

7. A bladder filled with pus was placed in front of the left lung, and a bladder filled with serum behind the right lung, and the whole was surrounded by a layer of skin and fat three-fourths of an inch thick and x-rayed. The pus showed slightly denser than the serum, and not quite so dense as the heart.

From these studies, we thought we determined first that lung detail so called is due practically entirely to bronchial tubes, for if due to blood vessels it would be obliterated by the bladder filled with fluid. Moreover, their definition is due less to their walls than to the rarefaction of the tissue above and below by the air content, in as much as a sinus without walls through normal lung tissue shows up practically as well. We do not dispute the anatomical fact that the blood vessels accompany the

bronchial tubes, but only that they do not participate in the production of normal lung detail shadow.

In general it is evident that the hilum shadow is made up of bronchial tubes, bronchial glands, arteries, veins and the massive connective tissue at the root of the lung, but it is impossible to decide how much is due to each structure, since the shadow is the result of the absence of air in comparison with the lung rather than the presence of individual structures. The hilum shadow more than anything else demonstrates the necessity of having the plates absolutely uniform as to time exposure, distance, milliamperage, etc., for on some plates which appear practically perfect the bronchial tubes passing through the hilum are evidently shown, while on others apparently equally perfect they are not shown at all, and from this we judge that correspondingly large features might be missed in the lung due to similar unconscious differences in penetration.

It appears that when the lesion extends from the anterior to the posterior aspect of the lung, the plate will show it, but if the lesion is reasonably localized with considerable normal tissue before or behind it, or both, it may be entirely lost.

The x-ray shadow is produced neither by caseation, nor fibrosis *per se*, but is merely a matter of more or less air than normal. Any sort of a consolidation of the lung tissue produces shadow, but the shadow is invisible if the consolidation is less than a certain size, probably 1 cm. in diameter, though multiple masses of even less size may produce shadow if these masses overlap, thus producing an optical mass of greater size. Cohn[1] and Sewall and Childs[2] assert that new tubercles cast no shadow, and whatever shadow is visible is due to the vascular engorgement about them. Our experiments prove that anything lessening the amount of air casts a shadow, but the shadow of new tubercles may be, and almost always is, too small to be seen. The vascular engorgement may be sufficient to make the shadow visible. From the numerous plates of lobar and broncho-pneumonias recently made, we know that congestion of the lung does produce a shadow, though the amount of congestion necessary has not been determined. From our studies we believe that a few widely scattered small tubercles are invisible, but that a large number become visible on account of their overlapping in optical section. The assertion of Sewall and Childs that lung detail is entirely and of Baetjer[3] that it is mostly due to blood vessels does not seem justified.

All of our autopsied cases showed both lungs so infiltrated that we had no opportunity for the study of the early typical apical lesions on which so much of Dunham's excellent work has been done; in the study of our advanced lesions, however, we were forced to disagree with some of the prevailing ideas relative to the significance of various densities, and on this account have formulated our findings into the following series. On account of the unavoidable differences in technique of different plates, we thought it worth while comparing these densities when possible with something on the plate, so that in case the plate were over or under exposed a comparison would still be at hand.

The following is the working scale we formulated:

0° Pneumothorax. Perfect clearness.

1° Compensatory emphysema or cavity, the latter being usually more homogeneous.

2° Normal lung.

3° Scattered tubercles. Slight mottling, usually seen neighboring an extensive lesion.

4° Fibrosis. Density of moderate degree, simulating the density of a single rib near the base of the lung.

5° Numerous scattered tubercles or caseous broncho-pneumonia. Density of greater degree than fibrosis in flaky or cottony areas resembling a thick snowstorm. About the density of crossing ribs near the base, but not so homogeneous.

6° Massive caseation. Homogeneous density like frosted glass. Simulates heart density. Fluid cannot be distinguished from caseation except by location and demarkation.

7° Calcification. Bright speck, greater than the density representing sternum, heart and spine over one another.

In spite of all this study and differentiation, however, our most recent reading of the x-ray plates of which we have autopsy protocols, after sufficient time had elapsed for us to forget the autopsy findings, was only 50 per cent. perfect, 25 per cent. fair and 25 per cent. wrong. These failures were not, of course, failures in the diagnosis of massive lesions, but in the differentiation of fibrous tissue from caseation, the diagnosis of occasional cavities and the presence or absence of a few tubercles. The majority of cavities show annular figures and the majority of annular figures signify cavities, but the autopsy sometimes showed no cavity where there was a figure, and sometimes a cavity where there was none, and the number of them was sufficiently great to make the diagnosis very uncertain. In other words, we are still far from perfection; in fact, our x-ray readings are yet not as satisfactory as the original diagnosis from physical signs.

We regret that we did not see the article by Sampson, Heise and Brown[4] before our autopsies, since their explanation of the annular shadows as localized interlobar pneumothoraces seems as if it might cover a certain number of cases. As far as we know such localized pneumothoraces have never been found at autopsy, and their presence or absence will require special sectioning of the lung with these in mind.

It has been commonly stated (Barjon[5], Honeii, Brown and others) that though the x-ray usually fails to show a small lesion at the apex as definitely as physical signs, any lesion which it is capable of showing it usually demonstrates as larger than the physical signs outline it, and the larger the lesion the more true this is. This statement has been repeated such a number of times that most clinicians believe it, yet we have never seen it based on the scientific grounds of comparison. If only the superficial examination of haste and inexperience is taken into consideration the statement is undoubtedly true; that it is far from true in comparison with the specialist's examination is evidenced by our autopsy findings compared with the physical diagnosis and x-ray findings.

The following table shows this comparison:

	Perfect	*Fair*	*Wrong*
Physical Diagnosis	62 per cent.	28 per cent.	10 per cent.
X-ray Diagnosis	43 per cent.	19 per cent.	38 per cent.

We wish to reiterate that those wrong diagnoses were wrong only in details not in general involvement.

The following is the comparison of the autopsy, physical diagnosis and x-ray findings on which the previous table is based. All of the physical examinations were made by one of us, and the plates were read by all three, both individually and in concert, as well as by three x-ray experts visiting the hospital as inspectors, and we have taken the best x-ray readings not the worst.

COMPARISON OF AUTOPSY, PHYSICAL DIAGNOSIS AND X-RAY FINDINGS

CASE NO. 197

AUTOPSY	PHYSICAL DIAGNOSIS	X-RAY DIAGNOSIS
Right Lung *Upper lobe.* One inch fibrous tissue then two large cavities and the rest of the upper lobe caseo-fibrosis. Pleura thickened.	Large cavity surrounded by fibrosis.	*Plate taken after death.* Large cavity surrounded by caseo-fibrosis.
Middle lobe. Compensatory emphysema. Pleura thickened.	Compensatory emphysema.	Caseo-fibrosis.
Lower lobe. Large cavity at apex surrounded by caseo-fibrosis. Two cavities just below. Rest compensatory emphysema. About 50 per cent. air bearing. Pleura thickened.	Fibrosis at apex to fifth rib. Few scattered tubercles immediately below. From angle of scapula down compensatory emphysema.	Upper part caseo-fibrosis; rest normal. No ring.
Left Lung *Upper lobe.* Entirely hollowed out by cavity. Pleura thickened.	Entire lobe large cavity.	Entire lobe large cavity.
Lower lobe. Cavity one inch in diameter at apex. Caseation for an inch below. Rest of lobe numerous scattered tubercles of pea size. Pleura thickened.	Cavity at apex with caseation to fifth rib with numerous scattered tubercles below.	Dense shadow over entire lower half of lung diagnosed massive caseation, though the autopsy showed numerous scattered tubercles. The cavity was not indicated.

CASE NO. 395

Right Chest Pneumothorax.	Pneumothorax.	Pneumothorax.
Left Lung *Upper lobe.* Normal to third rib. Few scattered tubercles to fifth rib. Mass of coalesced tubercles to base. Pleura normal.	Caseo-fibrosis to third rib. Scattered tubercles to fifth rib, massive caseation between fifth and seventh ribs.	Normal to fourth rib, caseous broncho-pneumonia to base.
Lower lobe. Marked emphysema. Pleura normal.	Emphysema.	Large cavity in center of lobe. Fibrosis at apex. Another reading: Two cavities in center of lobe. Fibrosis at apex.

CASE NO. 296

AUTOPSY	PHYSICAL DIAGNOSIS	X-RAY DIAGNOSIS
Right Lung *Upper lobe.* Three large cavities one outside midclavicular line with caseation. No fibrosis. No air bearing tissue. Pleura slightly thickened.	Two large cavities surrounded by fibrosis.	Caseation outside midclavicular line, fibrosis inside surrounding cavities. Another reading: Completely fibrous.
Middle lobe. Number of large scattered tubercles. Pleura normal. Slight emphysema. About 70 per cent. air bearing.	Compensatory emphysema.	More recent and not so dense infiltration. Another reading: Fibrosis and caseation. Another reading: Slight fibrosis.
Lower lobe. Apex two large coalesced tubercles each one-half inch in diameter. A few scattered tubercles with emphysema below. About 85 per cent. air bearing. Pleura normal.	Cavity at apex. Compensatory emphysema below.	Cavity between fifth and seventh rib, also at apex surrounded by fibrosis. Another reading: Normal.
Left Lung *Upper lobe.* Four large cavities surrounded by caseation. No air bearing tissue. No fibrosis. Pleura slightly thickened.	Four large cavities surrounded by caseation.	Four cavities surrounded by fibrosis. The fibrosis was diagnosed by several experts.
Lower lobe. Upper half large and small cavities. Rest of lobe closely approximated tubercles; 15 per cent. air bearing. Pleura normal.	Compensatory emphysema with scattered tubercles.	Massive fibrosis with cavity towards apex. Another reading: Normal.

CASE NO. 439

Right Lung *Upper lobe.* Large cavity at apex extending to second interspace; three smaller cavities 1.5 to 2 cm. in diameter immediately below; rest of lobe caseo-fibrosis (fibrosis predominating). No air bearing tissue. Pleura thickened.	Cavity at apex and between third and fourth rib; rest of lobe caseous.	Cavity at apex; five small cavities immediately below, only three of which could be found at autopsy, and these three were smaller than the x-ray appeared to show them; rest of lobe fibro-caseous, though on different plates the shadow varied, so that it was impossible to be sure whether fibrosis or caseation predominated, yet the shadow was always less than the heart shadow. The density varied from a snow-storm effect to a homogeneous density. A rather dense line at the base of the lobe, thought by some to be thickened interlobar pleura, proved to be dense fibro-caseation within the lobe. There was no special thickening of the pleura between the upper and middle lobes, though it was obliterated.

Autopsy	Physical Diagnosis	X-ray Diagnosis
Middle lobe. Few scattered tubercles; 97 per cent. air bearing. Pleura normal.	Normal.	Normal.
Lower lobe. Several masses of caseation at apex, 1 to 3 cm. in size. At base posteriorly near spinal column recent half gangrenous pneumonic process; rest of lobe contains a very few scattered tubercles; 85 per cent. air bearing. Pleura normal.	Massive caseation at apex with scattered tubercles below.	Normal.
Left Lung *Upper lobe.* Practically entirely hollowed out by two large cavities; the upper extends from the apex to the base posteriorly and to the second interspace anteriorly outside midclavicular line; the second begins about the clavicle inside the midclavicular line and extends almost to base anteriorly. Pleura thickened.	Large cavity at apex with small cavities below.	Cavities with fibro-caseation below.
Lower lobe. Cavity at apex 2 cm. in diameter filled with grumous-sanguinolent fluid. Another cavity 3 cm. in diameter toward middle of lobe, filled with similar fluid. These cavities are surrounded by fibro-caseation. The lower half of the lobe shows numerous scattered tubercles. The hilum shows eight hard anthracotic glands. On the bronchial trunk extending from the hilum to the base are numerous nodules of apparently anthracotic-lymphoid tissue varying in size from 2 to 8 mm. Pleura normal.	Massive caseation at apex, scattered large tubercles below.	Upper part fibro-caseous; lower part normal. The anthracotic glands were not visible.
Case No. 495		
Right Lung *Upper lobe.* Apex for three-quarters of an inch shows considerable air bearing tissue with few scattered tubercles, then a cavity 3 cm. in diameter extending from the clavicle to the second rib in the midclavicular line filled with thick yellowish, greenish, tenacious material. Small cavity at outer margin of lung under clavicle 1.5 cm. in diameter: rest of lobe shows numerous scattered tubercles, varying in size from 2 to 15 mm. About 40 per cent. is air bearing. Pleura normal.	Caseation to second rib, numerous scattered tubercles below.	Fibrosis upper half, caseation lower half. Cavity near junction of clavicle and sternum. (There was no cavity at this point. The cavity found in the middle of the lobe had probably never been evacuated). Another reading: Cavity at apex, fibrosis below, caseation at base. (As is evident this apparent cavity proved to be almost normal air bearing tissue in an unexpected situation.)

Autopsy	Physical Diagnosis	X-ray Diagnosis
Middle lobe. Scattered tubercles. Slight emphysema; 80 per cent. air bearing. Pleura normal.	Few scattered tubercles with emphysema.	Emphysema and scattered tubercles.
Lower lobe. Scattered tubercles. Slight emphysema; 70 per cent. air bearing. Pleura normal.	Not recorded.	Emphysema and scattered tubercles.
Left Lung *Upper lobe.* Outside midclavicular line fibro-caseation and many cavities from 1 to 2 cm. in diameter. Inside midclavicular line caseous-pneumonia anteriorly and air bearing tissue posteriorly. About 10 per cent. air bearing. Pleura obliterated.	Caseation with cavitation to fourth rib, pea to marble sized tubercles below.	Cavity inside midclavicular line between first and second rib; rest of lobe caseation. Another reading: Cavity at apex and at sterno-clavicular junction; rest of lobe caseation.
Lower lobe. Upper half (apex to angle of scapula) fibro-caseation with many cavities 1 to 3 cm. in diameter. Lower half caseous-broncho-pneumonic patches with small amount of air bearing tissue between them; 20 per cent. of lobe air bearing. Pleura obliterated.	Not recorded.	Upper half caseation, lower half scattered tubercles.
	In this case the autopsy showed a tuberculous abscess of the ninth to twelfth vertebrae without clinical symptoms or physical signs which the x-ray diagnosed.	

Our investigations like those of other writers[6] have taught us that conclusions should not be drawn from one plate, nor even from one autopsy comparison, because of the possibility of plate variation. Our current was not very uniform and hence we probably found more than the ordinary variation, but it has proven that the greatest care must be exercised before judgment is passed.

We had only four cases out of over 200 within the four months of the study in which the x-ray showed something undiscovered by physical diagnosis, the last two came to autopsy, the first two were determined clinically only. In the first two cases, Nos. 366 and 262, there is an area apparently of fibrosis under the right scapula in such a situation that it was easily passed over on physical examination unless particularly sought for.

In one it represented almost surely the healed remains of a long passed abscess; in the other it probably represented the same, but there was question whether or not it was entirely cured. These two conditions were by measurement one and one-half inches in diameter, were located between the fifth and eighth rib posteriorly, and centered about two inches from the spine. It is possible that they might have been interlobar instead

of intrapulmonary abscesses. After a study of the literature[7] and seeing some of Webb's, Bullock's, Marshak's and Dunham's plates we are inclined to wonder if a certain number of the abscesses diagnosed in the past as pulmonary may not have been interlobar. Yet in 500 autopsies at the Phipps Institute none was ever found.

The third case in which the x-ray showed something undiscovered by physical signs was one of advanced tuberculosis of both lungs and tuberculosis of the ninth to twelfth vertebrae. The latter gave neither symptoms nor signs, but was very evident on the x-ray.

The fourth case in which the x-ray showed something undiscovered by physical signs is rather important in that it gives us a possible explanation of cracked pot sound. All sorts of explanations have been offered to explain cracked pot over cavities. The x-ray finding in Case No. 296, subsequently proven by autopsy, showed a double cavity, one superimposed on the other in two situations where cracked pot sometimes occurred. The x-ray shows a similar condition in Case No. 17, below a cracked pot sound.

That the x-ray cannot always be relied on appeared in Case No. 17, in which the physical diagnosis shows a lesion from the fourth rib and sixth dorsal spine up with cavitation near apex, while the x-ray shows it to be only above a line extending from the junction of the third rib with the sternum to the outer junction of the clavicle with the first rib. In this case the physical findings are very much greater than the x-ray findings, and are explained by the fact that the x-ray has shown only the condition extending from front to back and not the superficial anterior lesion with normal or even emphysematous lung behind it.

Of the x-ray work so far done, Dunham's[8] is the most satisfactory and apparently the most accurate. It was a pleasure after making a number of comparisons to discover how many of our conclusions agreed. Whether or not his fan-shaped densities and prolonged or thickened linear markings are peculiar to tuberculosis, we are unable to state since all of our autopsies showed advanced lesions on both sides. In addition all of our lesions were active so that we could not follow him into inactivity.

In our readings we have followed the order and general method of Dunham as described in the AMERICAN REVIEW OF TUBERCULOSIS, and found it satisfactory: I plate (whether good, over or under exposed, etc.), II bones, III muscles, diaphragm, heart, IV trachea, V hilum, VI right lung, VII left lung.

CONCLUSIONS

1. Much of the teaching and speculation in regard to x-ray shadows in connection with tuberculosis of the lungs is far from correct as is proven by autopsy.

2. The principal inaccuracy is that fibrous tissue shows more dense than caseation when the opposite is true; in fact, we found not only massive caseation, but even scattered tubercles, when they were numerous, to be denser than fibrosis.

3. In the case of caseation or any other consolidation, like pneumonia,

it is not the caseation or pneumonia *per se* which interrupts the rays and produces the shadow, but the lack of air in comparison with the air-bearing lung.

4. Cavities in the lung are frequently indicated by annular figures, but cavities are also frequently found at autopsy with no rings on the plate; conversely, annular figures are frequently found on the plate with no corresponding cavities at autopsy.

5. The pleura at autopsy was sometimes normal, sometimes thickened, but we were unable to distinguish the difference on the plate.

6. In spite of careful study of six cases while comparing them with the sectioned lungs at autopsy, our subsequent readings of even these cases have never yet been accurate.

7. The failures on the part of the x-ray appear to be due principally to the fact that no two plates are ever taken under exactly similar conditions of milliamperage, time exposure, and distance, producing a difference between plates which may readily be attributed to the pathological. Again the pathological may be so over-exposed as to be lost. In other words each plate is a law unto itself.

8. Advanced tuberculosis with massive fibrosis or caseation, numerous tubercles, or large cavitation can usually be diagnosed by the x-ray, though still more accurately by physical signs. The best results are achieved by careful physical diagnosis compared with the x-ray plate and, if differences are found, submission of these to physical examination before conclusion is reached.

9. Physical signs have frequently brought out lesions and extensions invisible on the x-ray; while the latter have shown only rare ones not found by the former.

10. The x-ray showed a possible explanation for cracked pot sound over cavity, namely, two cavities, superimposed.

11. Though there have been a number of careful autopsy comparisons with plates of advanced tuberculous cases, there is room for more; and there has been entirely too little comparison with early cases. The principal study still remaining, therefore, is a number of carefully taken plates of patients dying of other than lung disease with the expectation of finding at autopsy the occasional occurring early tuberculosis, and the comparative study of these lungs and plates.*

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