Comparison of Roentgenological Findings and Pathological Changes in Silicosis

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I INTRODUCTION

The treatment of silicosis, a recently recognized occupational disease, has been unsatisfactory. Therefore, prevention is the only measure to be taken. Unfortunately, however, anti-dust equipments in factories and protection of workmen from dust are far from being ideal. It is best to discover the patient as early as possible and shift his working post. In this respect, roentgenological examination plays a most important part.

Comparison of roentgenological findings and the pathological changes provides a ground for roentgenological diagnosis, and such studies were carried out by EVENSEN, SOMMER, DI BIASI, GARDNER, KIRCH, WORTH, NERRETER, GRAVENKAMP, GOUGH, AKAZAKI, NOZAKI, SANO, YAMAMOTO, KAGAMI, TAKANASHI, KAIDA, ABE, SATO and others. Nonetheless, there are many points which remain as yet to be elucidated.

We carried out a study to compare roentgenological and pathological canges in dissected lungs of patients with silicosis and silicotuberculosis, as well as in resected lungs of early silicosis with tuberculosis and of tuberculosis patients who had worked in a coal mine for some time.

II MATERIAL AND METHOD

1. Lungs dissected at autopsy

The material consisted of dissected lungs from 8 coal mine workers in Kyushu area who died of silicosis or silicotuberculosis (one was a resected lung, but included in this study because of the same purpose). As these lungs were needed in other studies also, the entire or an upper part of a unilateral lung was used.

2. Lungs resected by operation

We obtained from sanatoria in the Kyushu and Chugoku areas 61 resected lungs including those from individuals who were diagnosed as silicosis preoperatively, the lungs with silicotic changes at operation and those of the coal mine worker with

more than three years of employment and suffering from tuberculosis. About 43 lungs which had portions free of tuberculosis were examined. Not all parts of resected lungs could be examined since they were used for other studies also. Accordingly, a part of a lung which was free of tuberculous foci was subjected to examination.

3. Roentgenogram

The roentgenological changes were traced as far back as possible before operation or death. Only the well visualized roentgenograms taken antemortem or shortly before operation were used for comparison of pathological and radiological findings.

They were studied in detail as to the extent of the shadows, state of the edges, maculous opacities, area of dissemination, size and density, round translucency, changes of the vascular shadows and intensity of fine shadows.

4. Roentgenological classification

The roentgenological findings were classified as follows: those which showed no abnolmality were termed "0", and the so-called "PR_X" or "PR_{0-1}" in which silicosis was suspected were classified into S_0 and S_{0-1}, depending on the degree. S_1 and S_2 corresponded to PR_1 and PR_2 of the Japan Antipneumoconiosis Act, respectively.

5. Gross pathological examination

Dissected lungs were cut into thin slices of about 5 mm in thickness, and a celluloid plate was placed on each cut surface. Blood vessels, bronchi, lymph glands, silicotic foci, tuberculous foci, cavities and emphysematous changes were sketched to be reconstructed later for three dimensional observations.

6. Histological examination

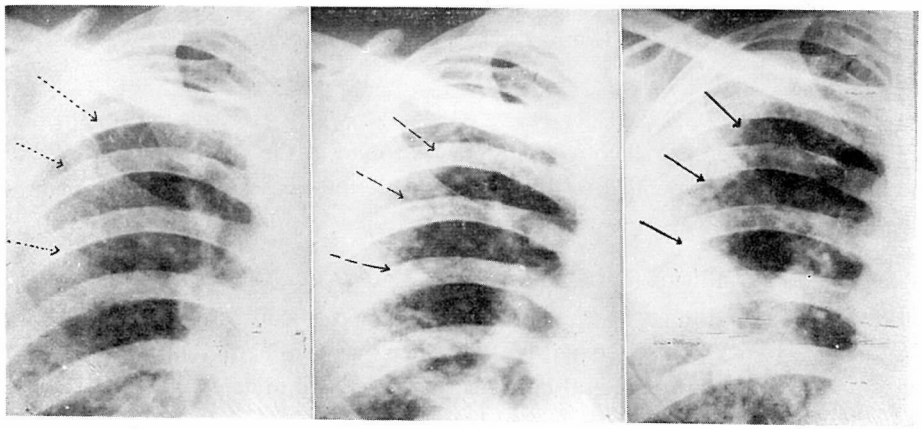
Histological specimens were made from each segment of the lung and subjected to H.E. stain, Van Gieson stain and stain of tuberculous bacilli. In addition, serial sections were made from a piece of specimen as big as the tip of an index finger and graphical reconstruction was carried out aiming at delineating silicotic nodules, blood vessels and bronchi in the main. Thus, by the graphical reconstruction, the relationship among the size, form and density of the nodules, bronchi and blood vessels was examined, and these findings were compared with maculous opacities on roentgenograms. A count of nodules was made from the volume of a specimen by measuring the area and thickness of each section, and by calculating the number of nodules per 1 cm^3.

III RESULTS

A Dissected lungs

1. Pleural thickness in silicosis and silicotic callosity

On the roentgenogram of silicosis, a light, homogeneous and indiscrete shadow was seen covering the lateral part of the upper and middle lung. In the advanced stage of silicosis, there was a more clearly delineated, dense shadow of a bandform. Macroscopic findings of a cut surface of the lung and a schematic tracing of a case



March 24, 1949 July 3, 1953 January 22, 1955

Fig. 1. Case 2. H. O. The figure shows that a shadow in the lateral aspect in the upper and middle lung fields has become gradually dense and sharp.

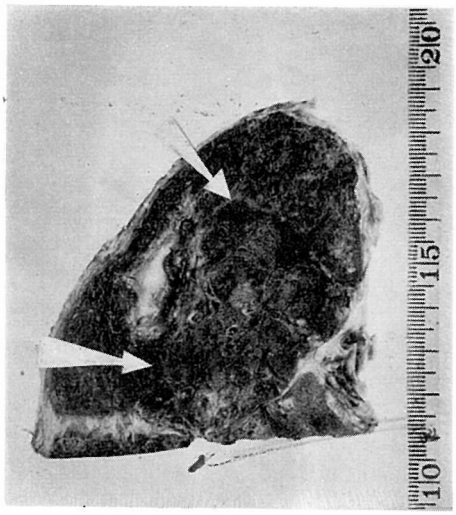
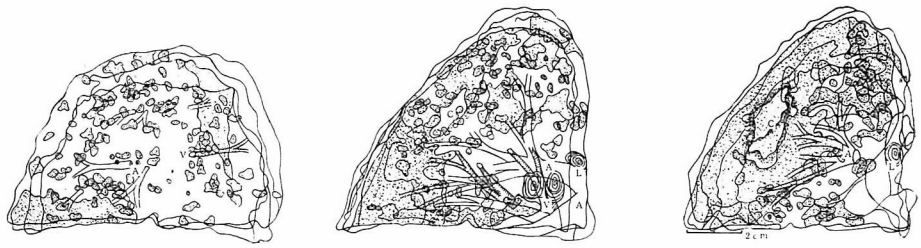


Fig. 2. Cut surface of the part corresponding to the roentgenogram of fig. 1. Lateral parts (arrows) show silicotic callosity, and the interior is emphysematous.



Anterior part Middle part Posterior part

Fig. 3. Reconstructive Schema of case 2 shows macroscopic changes; silicotic callosity is formed mainly in the lateral, dorsal and upper parts of lung.
A: Artery, V: Vein, L: Lymph gland, C: Cavity (As bronchi paralleled arteries they were omitted.)

are shown in Figs. 1, 2 and 3.

In autopsy materials, silicotic callosity was found in the upper, lateral aspect of the lung which corresponded to this part shown. In 4 cases out 8 the thickness of the largest cicatrix was over 3 cm, and in the other 4 approximately 1 cm.

2. Massive confluent foci

Because dissected lungs had advanced silicosis and silicotuberculosis, roentgenological changes were similarly extensive with massive confluent shadows. But, they were mainly found in the lateral parts of the upper and middle fields of both lungs, including the shadows in upper lateral lung fields described above.

Macroscopically, massive confluent foci were found mainly in segments S_1, S_2, S_{1+2}, S_6, S_9 and S_{10}, in the vicinity of the pleura. In histological examination, most of these foci which were bigger than the tip of the small finger were accompanied by tuberculous changes. Representive cases are shown in Fig. 4.

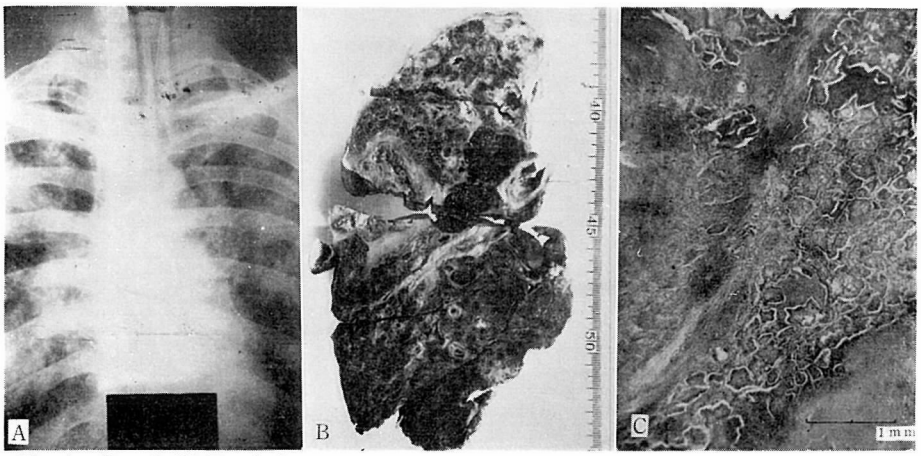


Fig. 4. Case 5. H. T. A. Roentgenogram. B. Macroscopic findings. C. A part of massive confluent foci (H. E. stain).

Table I Cavity and Roentgenograms

No. of case	Name	Age	M or N and years	Cavity			Round-translucency
				Localization (Segment)	Size	Nature	
1	E. T.	46. 00	M 6. 00	S_2	Tip of little finger	S	—
2	H. O.	54. 03	M 6. 00 N 2. 00	S_1 S_2 S_3	Soybean Hen's egg Red bean	S ST S	—
3	T. F.	45. 04	M 10. 00	S_1 S_2	Pigeon's egg Swallow's egg	ST ST	+
4	K. K.	49. 00	M 14. 03	S_2	Tip of thumb	ST	—
5	H. T.	37. 03	M 12. 05	S_1 S_2 S_3	Pigeon's egg Hen's egg Red bean	T T S	—
6	T. M.	45. 10	M 14. 11 N 3. 00	S_1 S_2	Red bean Red bean	S T	—
7	S. H.	53. 08	M 26. 04	S_1 S_2 S_6	Red bean Tip of little finger Red bean Swallow's egg	S T S T	—
8	Y. T.	45. 00	M 8. 10	S_{1+2}	Hen's egg	T	+

Remarks Age in years: Integral numbers show years and decimals months
M: Manual workers
N: Non-manual workers
S: Silicotic
T: Tuberculous
ST: Silico-tuberculous

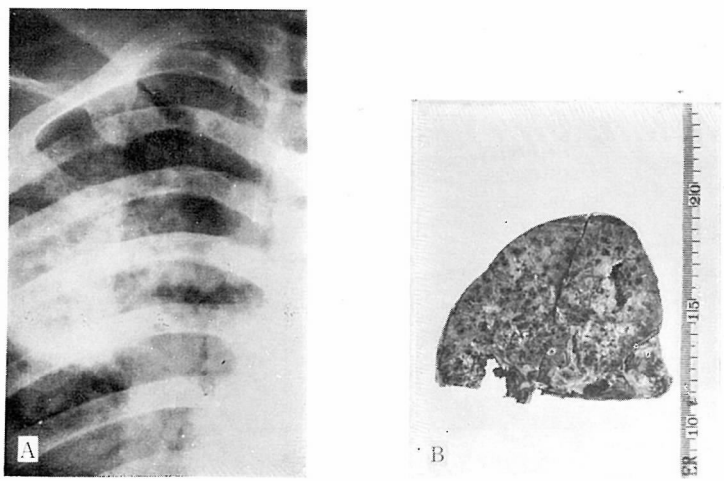


Fig. 5. Case 3. T. F. A. Roentgenogram. B. Macroscopic findings.

3. Formation of cavity

Round translucenscies with a cavity on roentgenograms were observed in 2 cases out of 8.

Pathological examination revealed cavities in 7 out of 8. The localization of the cavity, its size and nature are showed in Tab. I. One representative case is shown in Fig. 5.

4. Emphysematous changes

On the roentgenograms very light shadows were observed in the upper lung fields medially and in the lower lung fields laterally. It was therefore presumed that such shadows were emphysematous changes. This finding was seen in 6 out of 8.

Pathological examination demonstrated marked emphysematous changes in 3 out of 8 cases, moderate to slight changes in other 3, and no change in the remaining 2.

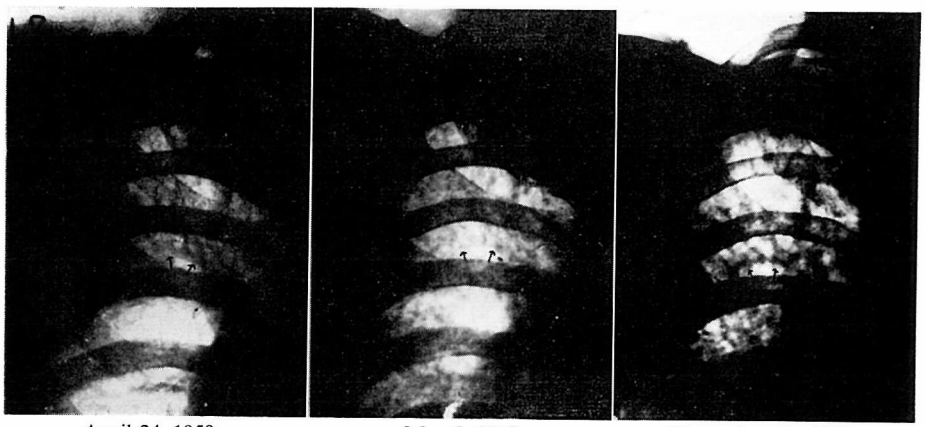
5. Lymph glands

Silicotic changes were observed in the lymph glands in 7 cases. One case could not be examined. In 6 out of 7, almost the entire lymph gland was fibrotic, and remarkably hyalinized. In another case, the above changes were noted in a greater portion of the gland. In all cases the size of the lymph gland was as big as the tip of the small finger to that of the index finger.

Roentgenologically the lymph glands which were swollen with silicotic changes were recognized not as individual shadows, but rather as irregular and massive hilar shadows. An illustrative case will be shown in Fig. 4.

6. Changes in vascular shadows

Changes of finer vascular shadows will be discussed later. Vascular shadows larg-



April 24, 1950 May 2, 1953 November 17, 1953

Fig. 6. Case 6. T. M. Changes of the shadow of the pulmonary vessels, as shown with arrows, are clear.

er than approximately 2 mm in diameter occasionally showed remarkable beading with the progress of silicosis. One case is shown in Fig. 6. Graphical reconstruction of all cases was carried out by a serial section on a part of the lung in order to investigate if the change of vascular shadows was due to actual lesions in vascular walls themselves. Such reconstructions are shown in Figs. 6, 7 and 8.

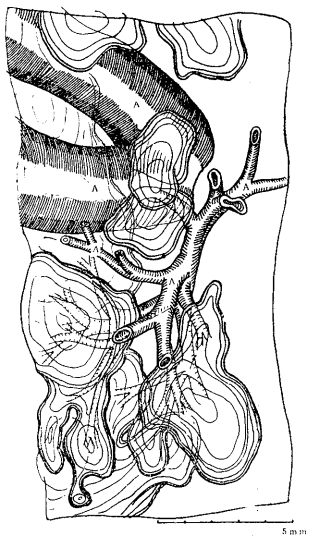


Fig. 7. Case 7. S. H. (Bronchi are not shown)

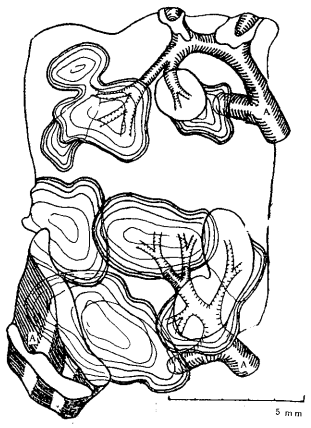


Fig. 8. Case 6. T. M.

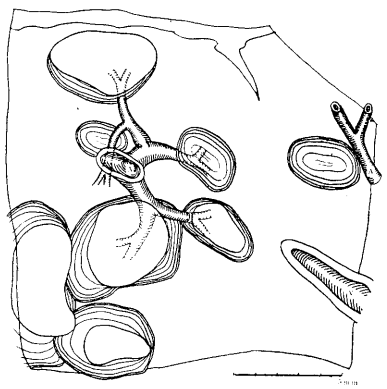


Fig. 9. Case 1. Z. T.

Analysis of the results shows that the diameters of the bronchi that were directly related to silicotic nodules were from 0.2 to 1.0 mm. The vessels with diameters larger than 2 mm which formed the vascular shadow on the roentgenogram were not directly associated with these bronchi or blood vessels. The size of completely developed silicotic nodules varied, but the diameters were from 1 to 7 mm, mostly

Table II Relationship between Histological and Roentgenological

No. of case	Name	Age	M or N and year	Roentg. class	Histological findings					
					Nodule				Hs	Hw
					Fine	Small	Middle	Large		
9	H. H.	33. 10	N 8. 06						0	0
10	K. W.	27. 01	N 4. 05						0	0
11	S. H.	27. 03	N 10. 11	0					0	0
12	K. O.	30. 01	N 6. 00						1	1
13	K. Y.	32. 08	N 16. 02						1	1
14	M. S.	32. 11	M 10. 03						0	0
15	K. H.	25. 02	N 7. 08						1	1
16	G. T.	42. 08	N 6. 04						1	1
17	K. H.	31. 06	M 3. 11						1	1
18	K. O.	46. 11	N 11. 04	S_0					1	1
19	H. A.	28. 11	M 3. 11						1	2
			N 5. 09							
20	T. H.	31. 04	N 9. 10						1	1
21	K. T.	30. 09	N 9. 11						1	1
22	K. N.	40. 10	M 8. 03						1	1
23	T. O.	30. 02	M 7. 04						1	2
			N 2. 06							
24	J. N.	27. 05	M 3. 01						1	1
25	K. S.	34. 05	M 9. 09		+				2	2
26	K. M.	33. 04	M 6. 04			+			2	2
27	K. U.	39. 07	M 8. 11		+				2	3
28	K. N.	37. 07	M 13. 10			+			2	2
29	K. O.	57. 03	M 10. 01	S_{0-1}			+		2	2
30	I. T.	42. 10	N 8. 09			+			2	2
31	T. K.	31. 08	N 10. 09			+			2	1
32	H. K.	31. 10	M 5. 02				+		2	1
33	Y. M.	34. 08	M 8. 08			+	+		2	2
			N 8. 04							
34	H. H.	46. 09	N 7. 03			+	++		3	3
35	T. I.	26. 00	N 5. 05			+++	+		3	2
36	M. Y.	28. 04	M 5. 01			++	++		3	3
			N 1. 11							
37	M. M.	31. 09	M 6. 02			+	+	+	4	3
			N 12. 03							
38	K. T.	33. 11	M 6. 04			+++			3	2
			N 1. 09							
39	T. K.	32. 08	M 4. 04				+++	+	4	2
			N 4. 07	S_1						
40	T. T.	32. 03	M 8. 02					+	4	2
			N 0. 06							
41	M. I.	51. 00	M 22. 07			+++	++		3	3
42	K. K.	41. 04	M 1. 09			+++	+		3	2
			N 15. 02							
43	K. S.	32. 05	M 2. 09				+++		4	1
44	M. S.	33. 00	M 8. 00			++	+++		4	2
45	M. N.	33. 07	M 1. 00			++		+	4	1
			N 3. 00							
46	T. I.	45. 02	N 20. 06			++	+++		4	4
47	T. K.	49. 01	M 9. 05				+++	++	4	3
48	M. N.	30. 03	N 9. 00					+++	4	4
49	H. N.	41. 06	M 8. 00	S_2		++	++	+	4	3
			N 5. 00							
50	Y. H.	38. 05	M 8. 00			++	++		3	3
			N 12. 11							
51	T. I.	53. 05	N 37. 08			+++	+++		4	4

Remarks: As fine nodules and fine maculous opacities were observed in all cases

Findings (43 Resected Lungs)

Roentgenological findings										
Maculous opacities				Fine opacities		Vascular shadows				
Fine	Small	Middle	Large	Rw	Fine linear	Obscureness	Fragmentation	Bending	Beading	Spicular formation
				0	−	±	−	−	−	−
				0	−	±	−	−	−	−
				0	−	±	−	−	−	−
				0	+	−	−	−	−	±
				0	−	−	−	±	−	±
				0	−	+	+	−	−	±
	⊕			1	+	+	±	−	−	+
⊕				1	+	+	±	−	−	+
⊕				1	+	+	+	−	−	+
				2	±	+	−	−	−	+
⊕				1	+	+	+	−	+	++
	⊕			1	+	−	−	−	−	±
				2	±	±	+	−	+	+
				1	±	−	−	+	−	+
				2	++	+	+	+	++	++
⊕				2	++	+	+	+	+	+
⊕				1	++	±	±	−	−	+
⊕	⊕			2	++	+	+	+	+	+
⊕				2	++	+	+	+	−	+
	⊕			2	++	+	+	+	++	++
	⊕			3	++	+	+	−	−	++
	⊕			3	+	±	±	−	±	+
	⊕			2	++	+	++	+	+	++
⊕				1	++	−	±	±	−	+
⊕				2	++	+	++	+	+	++
⊕	⊕			2	++	±	+	−	−	+
	⊕			1	+	±	±	±	−	+
	+++	+	±	3	++	+	±	+	+	++
	++	++	+	3	+	++	++	+	++	++
	+	+		2	++	++	++	++	++	++
	+++	+++	±	3	+++	++	+++	++	+++	+++
	+	++	+++	3	++	++	++	++	++	+++
	+++	+		3	++	++	+	+	+	+++
	+++	++		2	+++	+++	+++	++	+++	+++
	+++	+++	±	1	+	++	++	+	++	+++
	+++	+++		1	+	+	++	+	++	+++
	+++	+++	+	2	++	++	++	+	++	+++
	+++	+++		4	+++	+++	+++	++	+++	+++
	+++	+++	++	3	+++	+++	+++	++	+++	+++
	+	++	++	4	+++	++	++	+	++	+++
	+++	+++	±	4	+++	+++	+++	++	+++	+++
	+++	+		4	++	+	++	+	++	+++
	++	++	±	4	+	++	++	++	+++	+++

above S_1, they were not shown in the table.

from 2 to 5 mm.

B Resected lungs

1. Roentgenological classification

The age, occupational history and other data on 43 cases examined are summarized in Tab. II. Occupational history was classified into manual workers (driving man, digger, packer and repairing man) and non-manual workers (transport man, mechanic, miscellaneous worker and underground overman).

2. Relationship between silicotic changes and roentgenological classification

The size and density of nodules were examined by graphical reconstruction. The density of nodules was roughly represented by the number of nodules par 1 cm^3. These descriptive methods are shown in Tab. III and the results, in Tab. II. The classification of silicotic changes was as follows; Hs0—no silicotic changes, Hs1—no clear and typical nodule, but silicotic granuloma around peripheral vessels, Hs2—small nodules are less than ++, or medium size nodules +, Hs3—there are as many small nodules as +++, or medium nodule as ++, Hs4—there are more medium nodules than ++ or more large nodules than +.

Table III Descriptive Method for Relationship between Size and Density of Nodules

Density / Size of nodules	Division of size	+	++	+++
Smaller than 1 mm and nodular	Fine	Narrowly perceived		
1–2 mm	Small	1–4 pieces/cm^3	5–8 pieces/cm^3	More than 9 pieces/cm^3
2–3 mm	Middle	〃	5–7 pieces/cm^3	More than 8 pieces/cm^3
Larger than 3 mm	Large	1–2 pieces/cm^3	3–4 pieces/cm^3	More than 5 pieces/cm^3

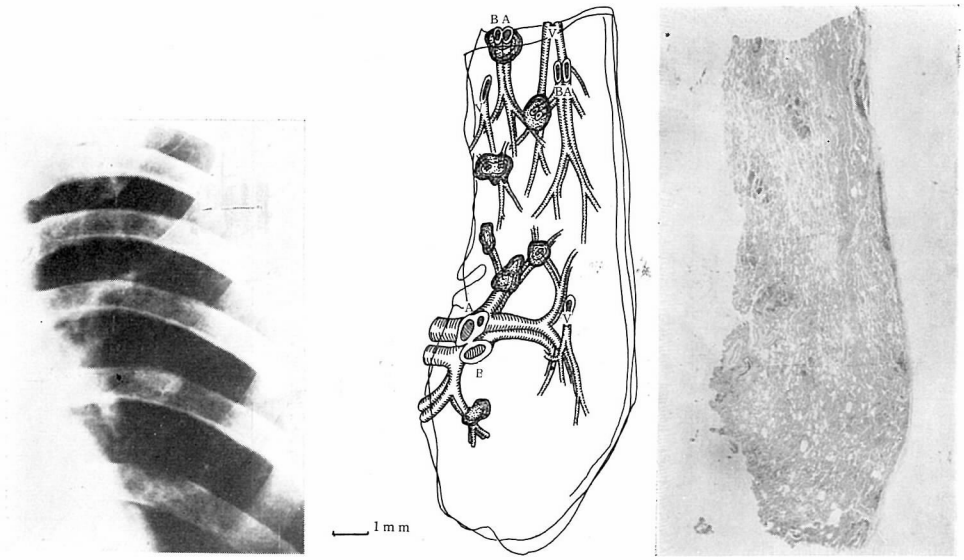
3. Relationship between nodules and maculous opacities

Although it was more difficult to measure the size and density of maculous opacities than measure those of nodules, rough measurement of the former was made.

To express the density of maculous opacities the number of maculous opacities were counted per 1 cm^2 in the middle of the upper, middle and lower fields of both lungs where there were no ribs or large blood vessels, and were averaged. In changes of S_{0-1} or less extensive, it was marked ⊕ when there were maculous opacities in an area smaller than two intercostal spaces anteriorly in both lung fields, and ⊕ when maculous opacities were only barely recognizable. In changes more advanced than S_1, fine maculous opacities were not considered. The descriptive method of the size and density of maculous opacities is shown in Tab. IV. One example of large and small maculous opacities is shown in Figs. 14 and 15.

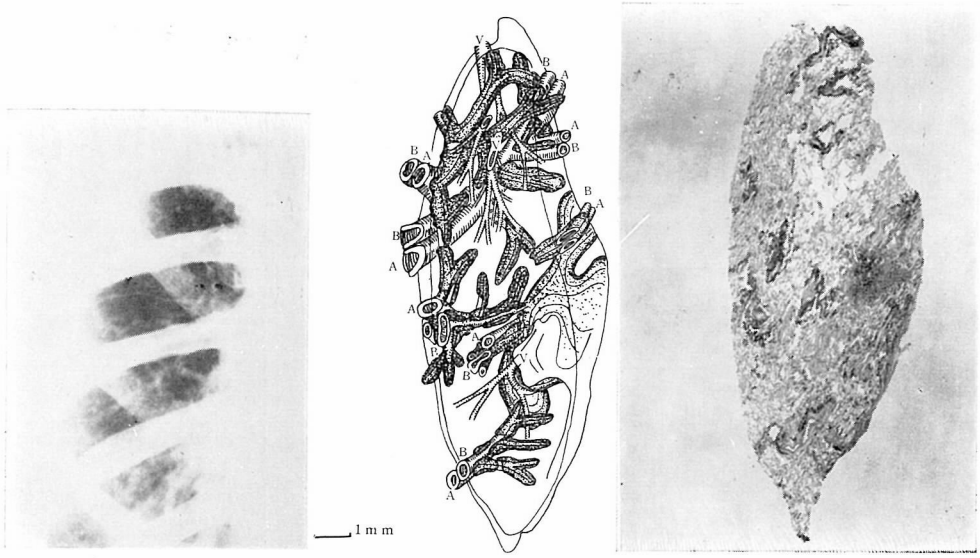
Table IV Descriptive Method for Relationship between Size and Density of Maculous Opacities

Density / Size of maculous opacities	Division of size	⊕	⊕	⊕	±	+	++	+++
Smaller than 1 mm	Fine	Obscure, but seems to be disseminated	Within 2 intercostal breadths			Disseminated more than 2 intercostal breadths		
1–2 mm	Small	〃	Within 2 intercostal breadths 1–3 pieces/cm²	Within 2 intercostal breadths more than 3 pieces/cm²	Less than 1 piece/cm²	1–2 pieces/cm²	2–3 pieces/cm²	3 pieces/cm²
2–3 mm	Middle				Less than 1 piece/cm²	1–1. 5 pieces/cm²	1. 5–2 pieces/cm²	More than 2 pieces/cm²
Lager than 3 mm	Large				Less than 0.5 piece/cm²	0. 5–1 piece/cm²	1–1. 5 pieces/cm²	More than 1. 5 pieces/cm²



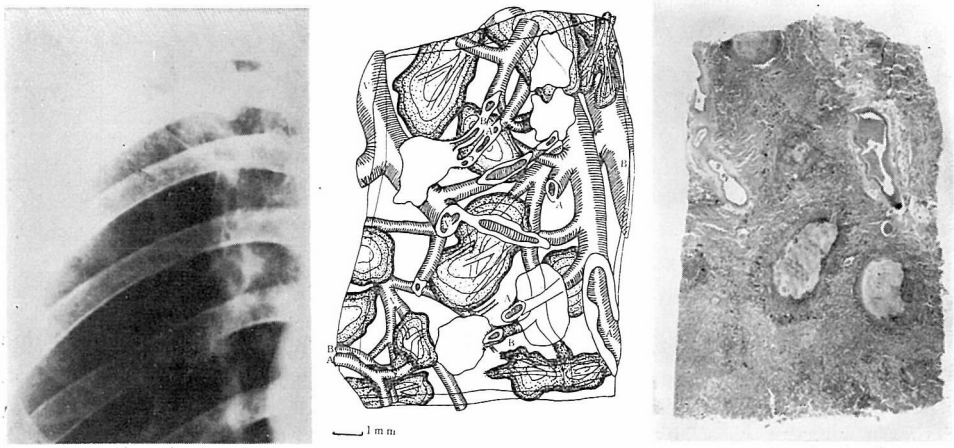
Roentgenogram Reconstructive schema Photograph of a section
Developed at the same time as schematic tracing (same magnification)

Fig. 10. Case 20. T. H. S_0, Hs 1, Hw 1. The volume of specimen is 342 mm³.
A: Artery V: Vein, B: Bronchi, L: Lymph gland, C: Cavity.



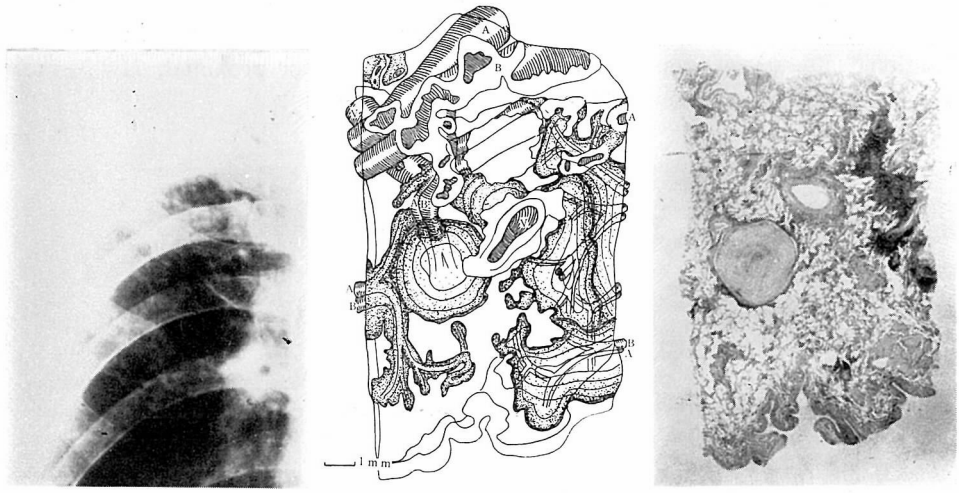
Roentgenogram Reconstructive schema Photograph of a section

Fig. 11. Case 30. I. T. S_{0-1}, Hs 2, Hw 2, Rw 3, 323 mm³.



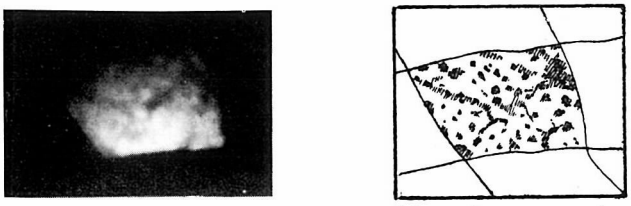
Roentgenogram Reconstructive schema Photograph of a section

Fig. 12. Case 42. K. K. S_2, Hs 3, Hw 2, Rw 2, 420 mm³.



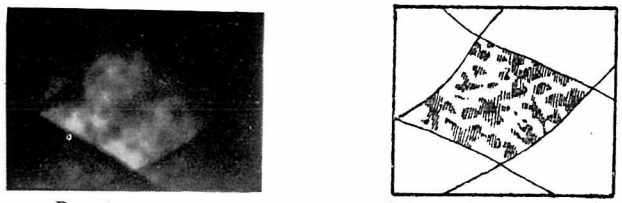
Roentgenogram Reconstructive schema Photograph of a section

Fig. 13. Case 51. T. I. S_2, Hs 4, Hw 4, Rw 4, 323 mm³.



Roentgenogram Schematic representation

Fig. 14. Case 38. K. T. Right upper lung field. This case had many small maculous opacities.



Roentgenogram Schematic representation

Fig 15. Case 45. M. N. Left upper lung field. This case showed many large maculous opacities.

4. Silicotic changes around arteries and bronchi

Silicotic granuloma involving many dust cells, and vaginal silicotic changes due mainly to fibrous proliferation around the peripheral bronchi and arteries were often observed besides full grown silicotic nodules. These changes were seldom seen around veins. This state is shown in Fig. 16. In order to facilitate their study, a further classification of the degree of the vaginal and silicotic changes was made as follows; Hw0—normal, Hw1—slight silicotic changes in some or whole area around the terminal bronchi distally, and along the arterioles, Hw2—silicotic changes as in Hw1 seen in the entire perivascular space, Hw3—silicitic changes as in Hw2 and additional alterations around the terminal bronchi further proximal, Hw4—more advanced and extensive than Hw3.

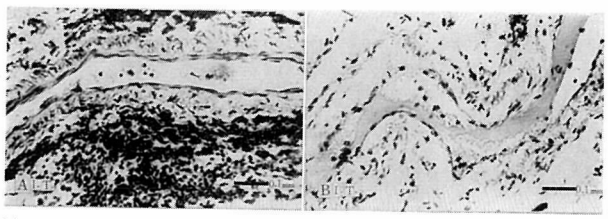


Fig. 16. Case 30. I. T. A. Pulmonary artery. There are carbonic pigmentation and fibrous proliferation around the pulmonary artery. B. Pulmonary vein. No similar changes are seen along the vein of the same diameter as the artery.

Silicotic changes around the peripheral bronchi and arteries by a serial section are shown in Figs. 17 and 18.

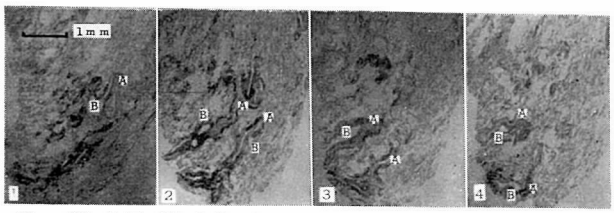


Fig. 17. Case 30. I. T. Hw2, Rw3. Sections of 20μ thickness; each section was cut at distances of 200μ.

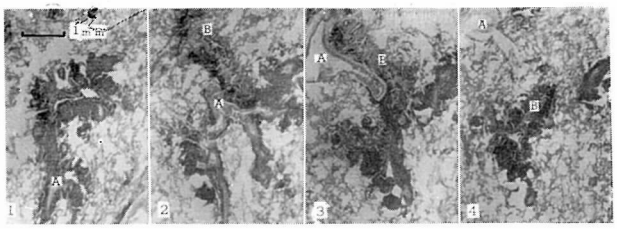


Fig. 18. Case 46. T. I. Hw4, Rw4. (Conditions same as above)

5. Fine shadows

By fine shadows are meant densities other than the vascular shadows. They are densities resembling spread rice-bran and of fine linear and funicular configurations. The grade of densities of fine shadows are described here as follows; (−)—nearly normal, (±)—the grade of densities not quite normal, (+)—hardly recognizable, (++)—clearly recognizable, (+++)—very clear shadows.

Cellular shadows have been described as Rw in the table in order to compare them with Hw. The roentgenograms and schematic tracings of normal and individual fine shadows are shown in Figs. 19, 20 and 21.

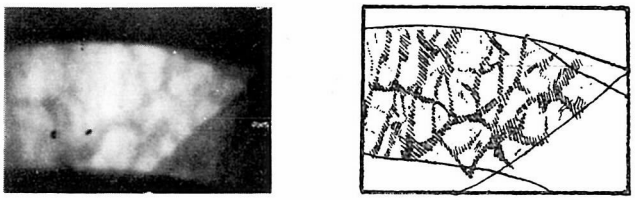


Fig. 19. Case 11. S. H. Normal (−).

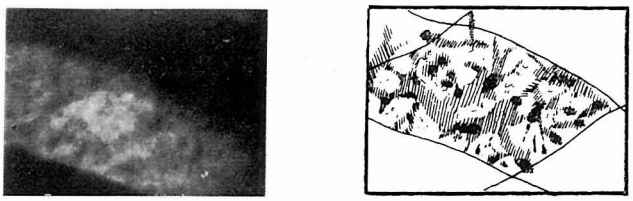


Fig. 20. Case 27. K. U. Rice bran (++).

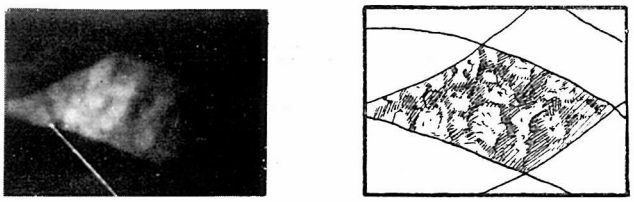


Fig. 21. Case 26. K. M. Funicular shadow (++).

6. Changes of vascular densities

That silicotic roentgenograms show various vascular changes is described in literature. They have been expressed as spicular formation of the edges of vascular shadows, partial fragmentation, beading and obscureness of vascular shadows of the lung. Each category of these changes was further graded from normal (−) to most advanced (+++). Individual roentgenograms and their schematic tracings are shown in Fgs. 22, 23, 24 and 25.

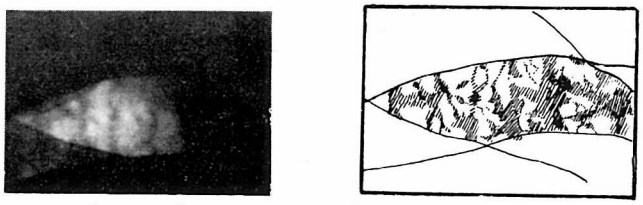


Fig. 22. Case 29. K. O. Spicular formation (++).

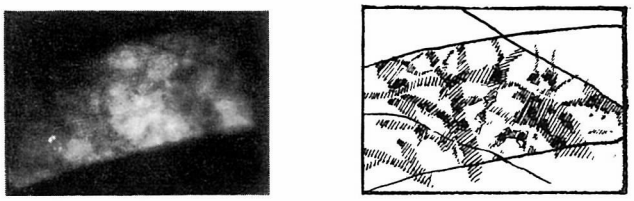


Fig. 23. Case 17. K. H. Partial fragmentation (+).

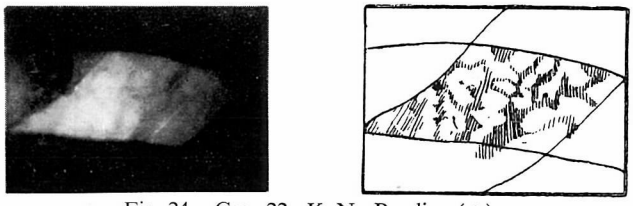


Fig. 24. Case 22. K. N. Bending (+).

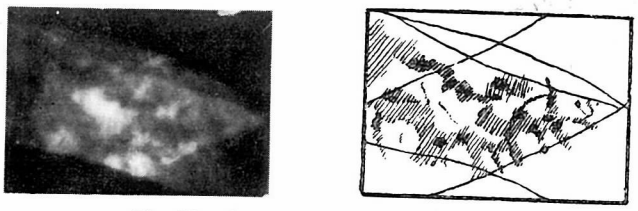


Fig. 25. Case 19. H. A. Beading (+)

IV DISCUSSION

1. Cause of a uniform shadow observed in the upper lung fields lateraly

We have studied the roentgenological changes in 7 cases from the stage as early

as possible, and found in 6 cases a uniform shadow in the upper field bilaterally which became more dense and definite with the development of silicosis. They were the shadows of silicotic callosity formed in the apical and upper parts of lungs laterally and dorsally, and found in all cases. Moreover, emphysematous changes of various extensions and degrees were seen surrounding this silicotic callosity.

We think that the shadows due to silicotic callosity were exaggerated by the light emphysematous densities. The projectional relation will be seen in Fig. 26.

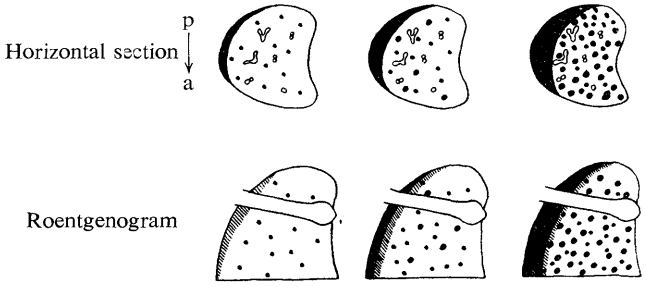


Fig. 26. Development of uniform shadows in the lateral aspect of apical and upper lung field.

2. The site of formation of silicotic nodules and massive confluent foci

AKAZAKI stated that in relatively slight cases without pleural adhesion, nodules were seen disseminated like miliary tuberculosis. In advanced cases, they somewhat tended to be localized in the dorsolateral parts of the upper and lower lobes. DI BIASI, TANAKA and others mentioned that massive confluent foci were mainly formed in the lower parts of the upper lobes and in the upper parts of the lower lobes.

Similarly, in our roentgenograms, confluent and massive shadows were mainly observed in the lateral aspect of the upper and middle lung fields bilaterally.

3. Cavities and roentgenograms

Many authors reported that most of cavities larger than the tip of a thumb observed in the silicotic lung were tuberculous. AKAZAKI also noted that in their autopsy materials the size of silicotic cavities was that of a thumb tip at the largest. In 4 of our autopsied cases, silicotic cavities were observed, the sizes being from a pin head to soybean.

In 2 of our cases who had large tuberculous cavities, apparent round translucencies were observed, but no such translucencies were seen in silicotic cavities. This was due to the fact that cavities were small and buried in massive confluent foci and silicotic callosity, making it difficult to detect them because of the covering shadows.

Generally speaking, it was our experience that silicotic cavities were hard to discover owing to their size and the surrounding tissue changes.

4. Emphysematous changes in silicosis and roentgenograms

It is already known that emphysematous changes are added as silicosis advances. In our autopsy materials emphysematous changes were seen everywhere, but roentgenological alterations were not always demonstrated.

The emphysematous changes were abnormally light shadows in the upper and lower parts of lung fields, and those which gave increased density contrasts for various shadows. Some did not show changes coresponding to histology, however.

5. Hilar markings

Normal hilar markings are complex densities consisting of large blood vessels, bronchi and lymph glands. In silicosis, swelling of lymph glands is superimposed to render hilar markings further complicated. Hilar markings were often enlarged, or formed massive irregular shadows, and no individual shadows were discerned. Therefore, it seems that silicotic shadows in the vicinity of the hilus and mediastinum also added to these shadows.

6. Relationship between the state of nodules and the roentgnological classification

It is important in roentgenological diagnosis to know what degrees of pathological changes would correspond to disseminated, maculous opacities on roentgenograms.

Volume of the lung in a living body is different from that of a collapsed lung after operation or of a lung preserved for histological studies. Roentgenological interpretation will depend on many other factors.

Silicotic nodules as above were not always disseminated equally in the whole lung, but we used resected lungs for the study. In spite of these drawbacks, we believed that our studies would serve as a reference for roentgenological diagnosis of silicosis, if interpretation of the results be made with reservation.

Silicotic nodules of each roentgenological type will be as Tab. V.

7. Relationship between silicotic nodules and maculous opacities

In general, size and density of silicotic nodules would show corresponding maculous opacities.

When there were nodules larger than 3 mm in diameter maculous opacities larger than 3 mm were seen. As nodules increased in number maculous opacities increased in proportion. Our separate experiment using a model of the lung suggested that when nodules become larger than 3 mm in diameter, individual nodules could form individual maculous opacities in lung fields with changes less than S_2. When all nodules were smaller than 1 mm in diameter maculous opacities were proportionally smaller.

8. Site of early appearance of silicotic changes

Table V Relationship between Classification of Roentgenological Findings and Disseminated State of Silicotic Nodules

0	No silicotic nodules are perceived but in some cases silight fibrous proliferation and carbonic pigmentation of a high degree.
S_0	No clear and silicotic nodules larger than 1 mm in diameter are perceived, but in some cases slight, vaginal fibrous proliferations are seen involving carbonic pigmentation around peripheral vessels in some or in the entire areas.
S_{0-1}	Nodules of 1–2 mm in diameter are present less frequently than 8/cm³, occasionally those of 2–3 mm less frequently than 4/cm³, and rarely those of 2–3 mm 5–7/cm³ or less.
S_1 and S_2	Nodules of 1–2 mm in diameter are present as frequently as more than 9/cm³, or those of 2–3 mm, 5/cm³ or more. Occasionally, nodules larger than 3 mm in diameter are present as frequently as 1/cm³ or more. The number of nodules does not differ from S_1 and S_2, but nodules larger than 3 mm in diameter are many, and their size is larger.

SIMSON stated on the basis of graphical reconstruction studies that the initial locale of silicotic changes was around the bronchi peripheral to end bronchi and along the parallel arteries. TAKIZAWA had a similar opinion. We, too, have seen similar findings. GEEVER stated that the venous system had more marked changes, but our study showed otherwise.

Early silicotic changes around peripheral vessels should show corresponding shadows.

9. Cause of cellular opacities

The investigators who studied early silicosis roentgenologically have pointed out that in an early stage cellular opacities appear prior to the appearance of maculous opacities.

ZORN recognized apparent cellular opacities by magnification radiography. One of the authors (ONO) carried out magnification radiography in 28 cases with silicosis and observed in 6 cases cellular opacities which were not recognized on regular posteroanterior films. DI BIASI also recognized reticulation prior to the appearance of roentgenological alterations characteristic of silicosis and mentioned that in this stage silicotic nodules and band-like structure were formed around small vessels. NOZAKI reported that early silicotic and granular tissues around lung vessels could cause increased lung markings.

We compared the degree of cellular opacities on the roentgenograms and the de-

gree of silicotic and fibrous proliferation around peripheral arteries and bronchi and found a somewhat parallel relationship with individual variations.

It seems that narrow vessels which do not by themslves from roentgenological densities, may give shadows of a band shape when superimposed by silicotic changes, and cause cellular opacities.

10. Appearance of fine shadows

Fine shadows are not simple, but are the result of summation of shadows of complicate and delicate histological lesions. By fine shadows we refer to irregular and linear shadows, disseminated shadows like spread rice bran, cellular shadows and vascular shadows which make up the background of maculous opacities. They provided the basis for roentgenological diagnosis of S_0 and S_{0-1}.

These roentgenological changes have the same cause as cellular opacities and will show various, delicate patterns depending upon the size and density of fine nodules, build of patient, state of nutrition and conditions of radiography. They are very fine and sometimes hard to differentiate from normal. Accordingly, the diagnosis of silicotic changes is not always possible from these findings.

11. Changes of vascular shadows

Since PENDERGRASS's first report that in the initial stage of silicosis changes of lung markings were observed, many investigators have recognized the appearance of changes of vascular shadows prior to maculous opacities. Recently, NOZAKI and others compared the pathological changes and the roentgenological findings, and stated that slight silicotic changes were difficult to ascertain on the roentgenograms and, more often than not, unrecognizable. Rather, in the initial stage of silicosis, the changes of hilar markings and abnormal lung markings (rigidness and spicular formation) and other althations provide a clue to diagnosis. Some stated that the changes of vascular shadows were due to actual lesions of the vascular wall. Recently, however, more investigators think that they are caused by the superimposition of shadows of nodules and other silicotic changes on the vascular shadows.

In our study, obscureness of vascular shadows was occasionally observed, irrespective of pulmonary silicotic changes, such as in obesity. However, most individuals who had slight silicotic changes showed spicular formation on the edges of vascular shadows. As the lesions in the lungs became larger, more remarkable would spicular formation become and so they were thought to indicate the existence of silicotic changes prior to the appearance of maculous opacities. They progressed further to partial fragmentation and beading.

Bending of vascular shadows was occasionally caused by traction and pressing, but in the early stage they often seemed only to be bending.

In spite of the fact that changes in early silicosis are restricted around fine vessels which do not contribute to vascular shadows, there occur some alterations of vascu-

lar shadows, and superimposition of the shadows is the only plausible explanation. These changes of vascular shadows are important in the diagnosis of early silicosis.

V CONCLUSION

1. Silicotic callosity was formed under the pleura covering the apex and the latero-dorsal parts of the upper, middle and lower lobes. On the early roentgenograms a uniform, indiscrete shadow appeared in the lateral parts of the upper and middle lung fields. In the advanced stage, the shadow became more discrete. Such development was thought to be due to the growth of the callosity and the advancement of emphysematous changes.

2. Many silicotic nodules and massive, confluent foci were formed mainly in segments S_1, S_2, S_{1+2}, S_6, S_9 and S_{10} in the vicinity of the pleural cicatrix.

3. Silicotic cavities were smaller than tuberculous cavities, and were observed in the center as well as in the surrounding part of the silicotic callosity. Cavities smaller than the tip of the thumb were not discernable on the posteroanterior film.

4. Autoposied cases revealed emphysematous changes of about the same degree in the dorsal aspect of the upper lobe and the caudal aspect of the lower lobe; the roentgenograms showed a light shadow covering a fairly wide area of the lateral lower lung fields, nothing more than increasingly defined maculous opacities and uniform shadows in the lateral upper lung fields.

5. The hilar lymph glands were swollen to the size of the thumb tip to the tip of the little finger, and on the roentgenograms they were seen as an irregular, massive shadow at the hilum, and no individual shadows were discerned.

6. Most of the isolated densities that were larger than the tip of the little finger in the lung field were the shadows of caseous pneumonic foci or silicotic lesions superimposed upon them.

7. The diameters of the bronchi which were related to completed nodules were smaller than 0.5 mm and were near the end bronchi or even further distal.

8. When nodules larger than 1 mm were absent, no maculous opacities were seen. Changes of vascular shadow, disseminated rice bran type densities and fine, linear shadows would be observed, depending on silicotic changes around peripheral blood vessels and bronchi.

9. When nodules of 1–2 mm in diameter were present at in numbers less than $8/cm^3$, or when those of 2–3 mm were less than $4/cm^3$, or rarely when they were $5–7/cm^3$, spicular formation of the edge of vascular shadows and cellular opacities became marked, and maculous opacities were occasionally seen.

10. When nodules of 1–2 mm in diameter were present in densities of more than $9/cm^3$, or when those of 2–3 mm more than $5/cm^3$, maculous opacities were seen localized or disseminated.

11. When nodules with diameters of more than 3 mm were present, they were

always noticed as maculous opacities.

12. Cellular opacities resulted from vaginal, silicotic and fibrous proliferation formed around the arteries and bronchi.

13. When maculous opacities were disseminated in bilateral lung fields, the number of nodules did not differ, but nodules larger than 3 mm were more numerous in S_2 than S_1. Namely, as roentgenological findings became more advanced, the size of nodules became larger.

14. Spicular formation, beading, partial fragmentation and obscureness of the vascular shadows were observed on the roentgenograms, but no acutual resions larger than 2 mm in diameter which are generally considered to be related to the formation of the vascular shadow were found on the vascular walls themselves. They were caused by the superimposition of the maculous opacities upon the peripheral vascular densities.

15. The number of maculous opacities on the roentgenograms was much less than the actual number of nodules, and the shadows were smaller than the latter. They were caused by the summation of the maculous opacities in the peripheral regions.

16. A silicotic change started as a fibrous proliferation containing numerous dust cells, around the bronchi and arteries which are more peripheral than the end bronchi. Around the veins, these changes were qulte slight.

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