DISEASE OF LUNGS IN BOILER SCALERS

WITH A CASE REPORT AND REVIEW OF THE LITERATURE

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The tubes, flues and fireboxes of all steam boilers have to be cleaned periodically and during the cleaning process a good deal of dust is evolved. Ships' boilers are of two types, each of which consists of an arrangement of tubes in an enclosed space: (i) the original Scotch marine boiler in which the heat generated by the fuel passes through fire tubes surrounded by water which is converted into steam; and (ii) the water tube boiler in which, as its name implies, the water circulates in tubes surrounded by hot gases generated by the fuel. In the first type flue dust is found inside the fire tubes, and scale consisting of mineral salts deposited from the water is outside the tubes. In the second type the scale is inside and the flue dust outside the water tubes. In many modern boilers distilled and de-aerated water is used and therefore no scale is deposited in the water tubes. The tubes of water-tube boilers are usually scaled with an instrument fitted with rotating serrated or knurled rollers driven by air pressure and passed through the tubes. Scale is removed from the exterior surfaces of the fire tubes by means of a long pointed rod, called a slicing tool, and also by wire brushes. The flue dust in the fire tubes and fireboxes is removed by brushing.

The boiler scalers who in many cases work in confined spaces are liable to inhale two types of dust, (i) the scale deposited from the water circulating in or outside the tubes, and (ii) the dust in the fire tubes, flues or fireboxes. The distinction is of some importance because W. E. Cooke (1930) in his original paper entitled 'Pneumokoniosis due to flue dust,' showed that his sample of boiler scale contained much less silica than did the flue dust. In the samples analysed 6.4 per cent. of insoluble siliceous matter was found in the boiler scale, but in the flue dust there was 26.4 per cent. Cooke described the clinical and pathological features of a man of 35 years who had worked for 9½ years as a boiler cleaner and who developed chest symptoms with x-ray appearances suggestive of advanced silicosis. Autopsy revealed generalized patchy fibrosis in both lungs with tuberculous lesions in the right upper lobe. Chemical analysis of dried lung tissue showed a greater percentage than normal of insoluble and total silica. He was of the opinion that the fibrosis of the lung preceded the tuberculous infection by many years.

Williams (1931) described the clinical and x-ray findings in six boiler scalers, one of whom came to autopsy. In this case there was a diffuse 'anthracosis' with relatively slight formation of fibrous tissue. Tubercle bacilli were found only on guinea-pig inoculation. Williams concluded that while the

number of men examined was too small to make general inferences, the dust inhaled during boiler cleaning tended to encourage the development of pulmonary fibrosis. Dunner (1943) published a description of the clinical and radiographic appearances of 12 boiler scalers, all of whom had sought medical advice on account of chest symptoms such as pain and dyspnoea. Small haemoptyses occurred in two cases. The clinical picture resembled that of chronic bronchitis and emphysema. In no case were tubercle bacilli found in the sputum. The x-ray appearances were comparable with those illustrated in Williams' paper and were of three types. The first showed a uniform mottling over both lung fields resembling either 'chronic' miliary tuberculosis or if the nodules were larger, the 'snowflake' mottling of silicosis. The second type had, in addition to the uniform mottling found in the first group, larger irregular shadows due apparently to confluence of the individual foci. The third type showed 'a diffuse fibrosis.' In none of these cases were the radiographic changes correlated with histological studies of the lung nor were full occupational histories given. It might be remarked in passing that the range of x-ray appearances illustrated in the article showed a close resemblance to that described by Hart and Aslett (1942) in their studies of the pneumokonioses of South Wales coal miners. Todd and Rice (1944) gave clinical and x-ray details of a man 40 years of age who had worked in his early life for 14 years as a boiler scaler and who later developed shortness of breath. The radiograph showed a 'snowstorm' type of infiltration of both lungs equal in intensity from the hila to the periphery of the lungs.

It will be seen that the subject of lung disease in boiler scalers has not yet had much attention and that up to the present time only two autopsies have been published. We think, therefore, that the following case of a boiler scaler in which clinical, radiographic and pathological studies have been made can usefully be recorded.

Case History

G.T., aet. 61 in 1943. He had been employed as a boiler scaler all his working life, from 14 years of age to within a few weeks of his death, that is, for 47 years. He had worked always on marine boilers. On 26.4.38 he was admitted to the Anlaby Road Hospital, Hull, complaining of cough, slight dyspnoea, slight sweating at night, expectoration, some loss of weight, and pain in the left side of his chest. He had had a cough for some years but his acute symptoms had begun 15 weeks before his admission to hospital. Pulmonary tuberculosis was suspected but there was no family history of the complaint. During his month's stay in hospital

he was found to be afebrile; no tubercle bacilli were found in the sputum on nine examinations and the erythrocyte sedimentation rate was normal. His weight increased from 8 st. to 8 st. 4 lb. Clinical examination of the chest revealed few abnormal signs except the presence of râles at both bases. X-ray examination (see fig. 1) at that time showed the presence of nodular shadows throughout both lungs more marked in the upper zones. The lower lung fields showed stippling and reticulation. These changes were first interpreted as being caused by broncho-pneumonic tuberculosis but later they were ascribed to the presence of pneumokoniosis ? silicosis. On 24.5.38 he was discharged from the hospital and went back to work.

On 20.12.43, 5½ years later, he was readmitted to hospital. On this occasion he had been ill for 5 weeks and had complained of pain in the left side of the chest with a cough which made the pain worse. His sputum was whitish, fairly copious and not blood-stained. He had rapidly lost a good deal of weight. On examination he was found to be emaciated, cyanosed and markedly short of breath on exertion. The percussion note was impaired over the right upper lung field and over the left base. Numerous moist sounds, coarse in quality, were heard over both these areas, more marked over the left base. At rest in bed the temperature fluctuated between 97° and 98° F., the pulse rate between 80 and 106 per minute, and the respiration rate between 24 and 28 per minute. The blood pressure was 120/84. A further x-ray film of the chest (see fig. 2) showed shadows similar to those seen in 1938, but in addition there was a ground-glass opacity involving the whole of the right upper lobe. A provisional diagnosis of pneumokoniosis complicated by carcinoma of the lung was made. His general condition rapidly deteriorated and he died on 29.12.43, that is nine days after his second admission to hospital.

Autopsy

An autopsy was made on 30.12.43. The body was extremely emaciated. There was slight clubbing of the fingers. In the line of the sixth left rib in the mid-axillary line a small hard mass could be felt.

Thorax.—Dense pleural adhesions were present on both sides, particularly over the upper lobes. About 1 inch of the right main bronchus showed a white, mottled, nodular appearance. When the rings of the bronchus were divided a firm carcinomatous growth was found to be invading the upper lobe of the right lung. Numerous secondary deposits were present in the mediastinum. Metastases were also present in the sixth left rib and in the seventh right rib just in front of its angle, in the muscle of the left ventricle near the apex of the heart, in the right lobe of the liver, in both kidneys and in the wall of the rectum. Further details about the pathological appearances of the lungs are given below.

The lymph nodes about the lesser curvature of the stomach were enlarged and pigmented. The stomach, spleen, gall bladder, skull and brain showed no abnormality. Apart from the secondary deposit in its muscle the heart was normal and the valves were healthy.

Laboratory Investigation

Right Lung.—There was a cream coloured growth in and around the uppermost main bronchus continuous with considerable tumour in the region of the hilar lymph nodes. The upper lobe was covered by thick, fibrous pleura, was heavy and almost entirely solid; it sank in water. The cut surface of this lobe (see fig. 3) was marbled black and grey and had a hard rubbery toughness. The black nodules were shiny and varied in size up to ½ inch in diameter. Much of the intervening lung substance, particularly near the apex, was infiltrated with tumour: deep in the lobe were one or two small ragged cavities that did not suggest a tuberculous origin. The pleura of the middle and lower lobes was blue-black, shining and not evidently thickened. There was moderate emphysema with some small bullae at the anterior border; the cut surface was black with

scattered nodules of two distinct kinds—(a) soft creamy nodules of tumour up to ½ inch in diameter; (b) more numerous smaller hard black nodules. The emphysematous areas in the cut surface appeared more pigmented than the surrounding lung.

Left Lung.—The pleura was blue-black; there was some fibrous thickening over the apex and some fibrinous deposit at the base. The cut surface was black with numerous solid shining jet-black nodules especially in the upper lobe, in the lower portion of which some reached a diameter of ½ inch. The lower lobe showed a moderate emphysema most marked along the anterior border; deeper in the lung the emphysematous areas were more pigmented than the surrounding lung. In both lobes were scattered nodules of tumour varying in size up to ½ inch in diameter.

Other Organs.—Tumour was present in almost all of the available tissues: it was found in lymph nodes along the lower half of the trachea, around the hilum of the lung, and along the lesser curvature of the stomach. There were nodules of growth in the thyroid, heart, liver and kidney.

Microscopical Appearances.—In all its sites the tumour appeared as a partially differentiated squamous cell carcinoma. Sections of the upper lobes (see figs. 4 and 7) showed typical solid, collagenous, 'silicotic nodules' that were as pigmented as those seen in the lungs of coal miners. A few such nodules were also found in the lower lobes (see figs. 5 and 6). Pigment was found in abundance also in all lobes, in the pleura, and in aggregates around pulmonary vessels and bronchi as well as in some phagocytic cells free in alveoli or contained in alveolar walls. The smallest of these aggregates closely resembled the reticulation described by Belt and Ferris (1942), but collagen fibrils were produced in increasing amount as the area grew larger. Many of the medium sized aggregates were rounded and markedly collagenous, but the collagen fibrils showed a tendency to be radial rather than to produce a whorl.

None of the pigment that was black and opaque stained with potassium ferro-cyanide and hydrochloric acid. Incinerated sections viewed by reflected light showed that perhaps a third of this pigment consisted of iron. This iron pigment occurred around the nodules of silicotic fibrosis but not within them; the pigment included in the nodules was presumably carbon since it disappeared on incineration. It has been our experience in this case and with many other lungs that it may be impossible in ordinary stained sections to distinguish between carbon pigment and some iron pigments. Incinerated and acid-treated sections viewed in polarized light showed silica particles as a fine dusting throughout the nodules and scattered in smaller amounts in the lung tissue. Although considerably more silica was visible than in normal lungs, there did not appear to be as much as we have often seen in other silicotic specimens.

The emphysema seen naked-eye was confirmed microscopically. No evidence of tuberculosis was found but there was an acute patchy pneumonia in the left upper lobe.

Chemical Findings.—Incinerated at 500° C., the previously dried lung yielded 5.1 per cent. tawny ash. Iron, reckoned as metal, formed 0.6 per cent. and silica 0.17 per cent. of the dry weight of the lungs. These figures relate to the lungs as a whole: presumably they would all be greater for the upper lobes alone, especially if tumour-free portions were chosen.

A sample of boiler scale taken from the type of ship's boiler usually scaled by this man contained 10.1 per cent. of iron calculated as metal, and 8.6 per cent. total silica probably present largely as silicate. A sample of flue dust contained 48.3 per cent. of iron and 6.1 per cent. total silica; combustible material (soot) formed 27 per cent. of this dust.

Death resulted from wide-spread metastases of a squamous cell carcinoma of the bronchus. There was marked pneumokoniosis, with typical silicotic fibrosis particularly in the right upper lobe where it could be described as massive.

FIG. 2.—Radiograph of chest (29.12.43), showing ground-glass shadow in right upper region of the lung. Appearances in rest of lung fields comparable with those seen in Fig. 1. Note fracture of 7th right rib due to tumour metastasis.

FIG. 1.—Radiograph of chest (28.4.38), showing nodulation in outer portions of upper lung fields and reticulation in the rest of the lung fields.

FIG. 3.—Photograph of slice of R. upper lobe $\times \frac{1}{2}$, showing bronchial carcinoma, pigmentation, nodules of silicotic fibrosis.

FIG. 4.—Photomicrograph, R. upper lobe, H. and E., $\times 4$. Nodular fibrosis and pigmentation.

FIG. 5.—Photomicrograph, R. lower lobe, H. and E., $\times 32$. Nodule of radial fibrosis and pigmentation.

FIG. 6.—Photomicrograph, R. lower lobe, H. and E., $\times 32$. Nodule showing early whorled fibrosis in centre with radiating fibrosis at periphery.

FIG. 7.—Photomicrograph, R. upper lobe, H. and E., $\times 12$. Subpleural silicotic nodulation.

Discussion

Scalers or cleaners of ships' boilers are exposed to the inhalation of dusts of variable composition. The boiler scale varies according to the hardness or other impurities in the water used in the boilers and the composition of the flue dust varies with the type of fuel used, e.g. coal or oil. This variation can be seen by comparing the analyses of Cooke's samples of boiler scale and flue dust with those of our samples:—

Cooke's samples		Boiler scale	Flue dust
Total silica	..	10.3 per cent.	32.4 per cent.
Iron (oxide)	..	3.42 „ „	27.17 „ „
Our samples			
Total silica	..	8.6 per cent.	6.1 per cent.
Iron (metal)	..	10.1 „ „	48.3 „ „

We have selected silica and iron for comparison, because these two substances in dust form probably have most effect in producing abnormal appearances in the x-ray films of boiler scalers' lungs. The dust of free silica (SiO_2) when inhaled by workers in fairly high concentrations over a period of years produces silicosis with characteristic x-ray and pathological appearances. These may be modified if the dust of free silica is mixed with other dusts. Abestosis, another form of pneumokoniosis, can be set up by the inhalation of the dust of asbestos which is a silicate or combined silica. Aggregates of iron dust in the lung tissues are opaque to x-rays. Studies of the effects of iron on the lungs [McLaughlin, Grout, Barrie and Harding (1944); Enzer and Sander (1938); Sander (1944)] have shown that iron oxide in its pure form does not set up a fibrotic reaction in the lung tissues, but that aggregates of it cause abnormal x-ray shadows which are difficult to distinguish from those thrown by early silicotic nodules, other pneumokonioses or miliary tuberculosis. It is probable that many of the abnormal

x-ray shadows in our case, particularly in the lower lung fields, were caused by iron deposits in the lungs, and were not due to fibrosis. It is noteworthy that the flue dust contained as much as 48.3 per cent. of iron (the boiler scale containing 10.1 per cent.) and that the dried lung contained 0.6 per cent. of iron as compared with 0.17 per cent. of silica. In our experience the x-ray shadows thrown by iron deposits do not become confluent, i.e. they do not advance much beyond the stage of reticulation. Examination of the x-ray film (fig. 1) shows that the nodulation and early massive shadows are confined to the upper halves of the lung fields, whereas the lower lung fields show reticulation. The histological studies of sections of the lungs more or less confirm that the nodular shadows mainly correspond to silicotic nodules, and that many of the reticular shadows are thrown by iron aggregates in the lung tissues (see fig. 8). Some of the latter are no doubt also due to early silicotic fibrosis (see figs. 5 and 6).

It is possible that the carcinoma from which the man died was initiated by a carcinogenic agent in the flue dust or soot. This point is being further investigated.

Summary

(1) The clinical, radiographical and pathological features of the lungs of a boiler scaler are described. Short notes are given of the processes in the scaling of marine boilers. Analyses of the silica and iron contents of the lungs are recorded and also of samples of boiler scale and flue dust.

(2) Well-marked silicosis was found in the lungs, together with marked pigmentation due to iron. Death was due to dissemination of tumour from a carcinoma of the bronchus.

(3) It is suggested that the abnormal shadows seen in the x-ray films of boiler scalers' chests are due partly to areas of silicotic fibrosis and partly to deposits of iron dust which is opaque to x-rays.

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FIG. 8.—Photomicrograph, R. lower lobe, H. and E., $\times 40$. Pigmentation without fibrosis around vessels.