Pergamon

Ann. occup. Hyg., Vol. 38, Supplement 1, pp. 783–789, 1994
Elsevier Science Ltd

0003-4878/94 $7.00+0.00
Inhaled Particles VII

RADIOGRAPHIC APPEARANCES OF SMALL OPACITIES AND THEIR CORRELATION WITH PATHOLOGY GRADING OF MACULES, NODULES AND DUST BURDEN IN THE LUNGS*

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Abstract—Radiographic appearances of small opacities were correlated with pathological assessments of whole lung sections in a series of autopsy cases from southern West Virginia. The results revealed correlations between the radiographic and pathologic data, mainly between micro- and macro-nodules and X-ray category (Pearson correlations close to 0.5), but reveal that moderate to severe pathologic abnormality has to be present before radiographic detection is at all certain. The presence of macules tended to be associated with the smallest radiographic opacities (type p), while nodules were often manifested as type q or r. Macule profusion was related to overall levels of total retained dust, while nodules and X-ray category were associated with both coal and silica fractions of the retained dust weights. Weight-for-weight, silica dust was 20 times more important than coal dust in the latter relationship.

INTRODUCTION

GOUGH *et al.* (1950) found that there was a moderate correlation between the profusions of pathologic and radiographic abnormality. However, it was evident that what they termed slight degrees of pneumoconiosis could be present on lung sections without concomitant appearances on the radiograph. CAPLAN (1962) subsequently showed that radiographic appearances were most closely related to the profusion of fibrotic nodules rather than all types of dust foci.

RIVERS *et al.* (1960) and others have shown that radiographic category correlates with both mineral and carbon dusts retained in the lung, although weight-for-weight, mineral dust appears to be considerably more responsible than carbon for the radiographic appearances. More recent work by RUCKLEY *et al.* (1984) and FERNIE and RUCKLEY (1987) confirmed the above findings. They have, however, stressed that both coal rank and type of opacity must be taken into account when attempting to understand the retained dust–pathologic–radiographic relationship.

The preliminary analysis presented here of lung sections from a large autopsy series of U.S. coal miners was undertaken to obtain additional information on these relationships, particularly with regard to opacity type.

*This paper was included in Poster Session 1 and the discussion included in the summary presented in Section 12.

METHODS

Cases

The cases were collected systematically by a pathologist in central West Virginia (Dr W. Laqueur). The coal mined in this area is largely high volatile bituminous 'A', with some low volatile bituminous. The cases analysed in this report consisted of 423 male former underground coal miners having both radiographic and pathological data. The mean age at death for the group was 68 years (90% between 53 and 82 years), and they had worked an average of 35 years in mining.

Pathology data

Consensus determinations were taken of assessments of whole lung sections by two pathologists. Macules, micro-nodules, macro-nodules and silica nodules were identified following the guidelines of KLEINERMAN *et al.* (1979). All lesions apart from silica nodules were graded on a four-point scale (absence, slight, moderate and severe profusion). Silica nodules were noted if present in the lung parenchyma or lymph nodes.

Retained dust analysis

Gravimetric measurement of the weight and composition of the dust present in substantial tissue samples was made for 96 cases. Data obtained for total, coal, non-coal and silica dust were expressed as percentages of the total tissue weight and input as independent variables to regression analyses of pathologic variables (model I—total only; model II—coal, non-coal and silica).

Chest radiographs

The chest radiographs, taken an average of 1 year before death (90% within 3 years) were classified for pneumoconiosis using the 1971 ILO classification (1972) by three B readers (MORGAN, 1979), and median determinations of small combined opacity profusion derived. If small rounded opacities were more profuse than irregular opacities based on median determinations, the opacity type was based on agreement between two of the three readers on rounded opacity type (p, q, r). The corresponding procedure was followed when irregular opacities were more profuse. Where equal profusions were reported, or where there was no consensus on opacity type, the code 'm' (for mixed) was assigned.

RESULTS

Figure 1 shows the distributions of macule, micro-nodule, macro-nodule and silica nodule profusions, and median category of pneumoconiosis. Macules were found in virtually all (97%) of the lung sections. In contrast, micro-nodules were seen in 70% of the cases, and macro-nodules in 45%. Silica nodules were the least common (30%). Sixty-six per cent of the films had evidence of category 1 or greater small opacities. Among those with category 1 or greater, mixed types of opacities were the most common (36%), followed by type q (30%), r (17%) and p (8%). Irregular opacities were the predominant type in 9% of the cases.

The following correlation coefficients of median X-ray determinations of small

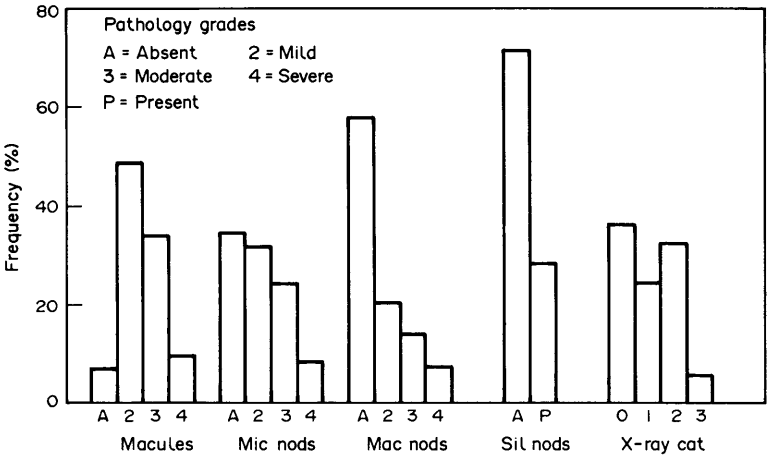

FIG. 1. Overall distributions of macules, micro-, macro- and silica nodules, and X-ray category.

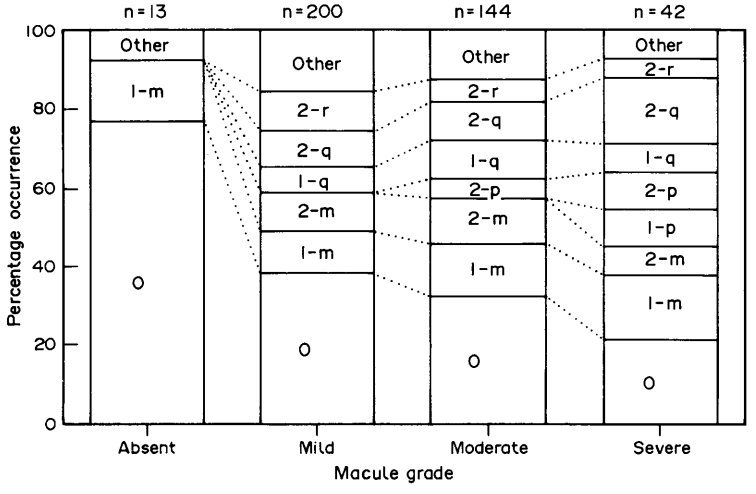

FIG. 2. Relationship between macule grade and radiographic profusion and type of small opacity.

opacity profusion with the pathological data were found: micro-nodules, 0.52; macro-nodules, 0.48; silica nodules, 0.14; and macules, 0.10.

Figure 2 shows that increasing grade of macules is associated with a greater likelihood of an abnormal radiograph being reported, with the predominant types being m (mixed), p and q, indicating mostly small to medium-sized rounded opacities. Importantly, however, there was a distinct chance of a category 0 radiograph being reported even when moderate and severe grades of macules were present (33 and 21%, respectively).

The corresponding results for micro-nodules are shown in Fig. 3. Again, there is a distinct correlation between the pathological and radiographic findings. In contrast to the results for macules, p type opacities occurred rarely, while type r opacities were

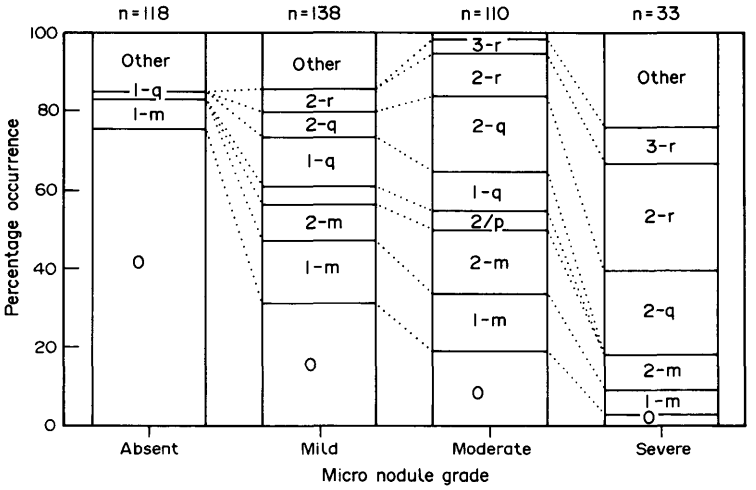

FIG. 3. Relationship between micro-nodule grade and radiographic profusion and type of small opacity.

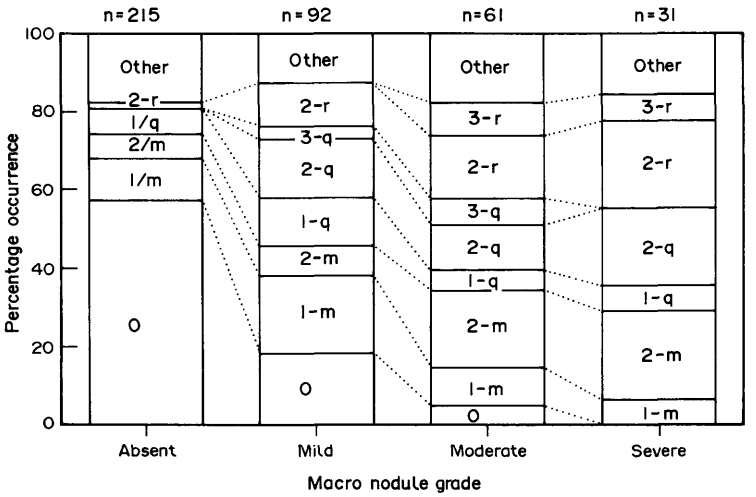

FIG. 4. Relationship between macro-nodule grade and radiographic profusion and type of small opacity.

more frequent, particularly for the severe profusion of nodules. Compared to macules, fewer of the cases with micro-nodules had category 0 radiographs, particularly for moderate and severe grades (9 and 3%, respectively), although 31% of those with mild grade of micro-nodules had category 0 radiographs.

The findings for macro-nodules were similar to those for micro-nodules, although the presence of macro-nodules was generally associated with greater profusion of small opacities and also more frequent occurrence of type q and r opacities (Fig 4). In addition, cases with macro-nodules were more likely to be said to have small opacities on the radiographs than those cases with other types of lesion (category 0 reported in 5 and 0% of moderate and severe grades, respectively).

TABLE 1. REGRESSION COEFFICIENTS AND t VALUES FOR PATHOLOGIC VARIABLE TYPES AND MEDIAN SMALL COMBINED OPACITY PROFUSION (FOUR-POINT SCALE) AGAINST RETAINED DUST WEIGHTS EXPRESSED AS A PERCENTAGE OF TOTAL TISSUE WEIGHT

	Regression coefficients							
	Model I			Model II				
Pathology variable	Intercept	Total dust	R^2	Intercept	Coal dust	Non-coal dust	Silica dust	R^2
Macules								
Regression coefficent	2.12	0.055	0.09	2.05	−0.032	0.044	0.829	0.07
t		3.3			1.6	1.1	1.3	
Micro nodules								
Regression coefficent	1.77	0.080	0.12	1.70	0.071	−0.009	1.353	0.13
t		3.8			2.8	−0.2	1.8	
Macro nodules								
Regression coefficent	1.11	0.099	0.16	0.939	0.090	0.036	1.800	0.20
t		3.8			3.5	0.7	2.3	
Silica nodules								
Regression coefficent	1.30	0.008	0.00	1.20	0.001	0.009	0.595	0.03
t		0.7			0.0	0.3	1.4	
Median X-ray category								
Regression coefficent	0.81	0.064	0.07	0.70	0.062	−0.022	1.622	0.11
t		2.9			2.4	−0.4	2.0	

Compared to those without silicotic nodules, those with silicotic nodules were more likely to be classified as showing pneumoconiosis on the radiograph (77% abnormal compared to 58%). The presence of silicotic nodules on pathologic examination doubled the likelihood that type r opacities would be reported for radiographs said to show pneumoconiosis (24% compared to 12%).

In the 96 cases for which retained dust measurements were available, total dust as a percentage of the weight of the tissue sample averaged 6.9%. Most of the retained dust was found to be coal dust (4.5%), while silica dust comprised 0.2% of the tissue weights. Table 1 shows the results of regression analysis based on two models: one with just total dust (model I), and one with coal, non- coal and silica dust (model II). For macule grade, total dust was the best correlate. On the other hand, the best correlates of micro- and macro-nodule grade were combinations of coal dust percentage and silica dust percentage. In this respect, the coefficients for silica dust were 20 times those for coal dust. Non-coal dust had little relationship to any of the pathologic variables. No statistically significant correlates with silicotic nodules were seen among the dust variables, although silica dust had the highest t value. Regression of median X-ray category of small opacities on retained dust revealed a relationship very similar to that for micro-nodules and retained dust.

COMMENT

These findings on U.S. bituminous coal miners echo those reported for British coal miners. First, it is clear that moderate to severe levels of pathological abnormality have to be present before radiographic detection of pneumoconiosis is likely. Second, presence of micro- and macro-nodules considerably increases the probability that radiographic pneumoconiosis will be detected. More importantly, p type opacities tend to occur in association with high grades of macules, while types q and r are found more when micro- and macro-nodules are present. Fourth, macule grade seems to be related more to the general amount of total dust in the lung tissue, while the profusion of micro- and macro-nodules relates to both coal and silica levels. All in all, the results support the concept that macules result from mixed dust deposition and aggregation, with the consequence that the lung dust burden has to be relatively high before the effects are visible on the radiograph. In contrast, the much greater regression coefficients for silica dust compared to coal dust in relation to micro- and macro-nodule grade, suggests that less total retained dust may be needed for nodule development than for macules. This suggestion, taken in conjunction with the fact that nodules appear to be more readily detectable on the radiograph than are macules, supports the observation by RUCKLEY et al. (1984) that radiographic signs of type q or r opacities are associated with lower lung dust burdens than are X-rays with predominantly type p opacities.

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