

# Relation between progressive massive fibrosis, emphysema, and pulmonary dysfunction in coalworkers' pneumoconiosis

J P LYONS AND H CAMPBELL

*From the Pneumoconiosis Medical Panel, and the Department of Medical Statistics, Welsh National School of Medicine, Cardiff, UK*

**ABSTRACT** The correlations between progressive massive fibrosis (PMF), emphysema, and impairment of ventilation were studied in 108 dead coalminers, all of whom had suffered with complicated coalworkers' pneumoconiosis (radiological category B or C) during life. The findings indicated that both factors were contributing to impairment of ventilation in proportion to their size or extent, but these contributions were in the main independent of one another. A joint opinion on the types of emphysema found to be present in a random 50 out of the 108 cases was given by two pulmonary pathologists. They found that most of the emphysema was of the centrilobular variety, which appeared to be unrelated to the PMF. The distribution of the PMF throughout the lungs both radiologically and anatomically is shown.

Although it is generally acknowledged that coalworkers' pneumoconiosis accompanied by progressive massive fibrosis (PMF) is a significant cause of disablement and premature death in the coal mining industry in Britain,<sup>1</sup> the relative contributions to disablement by the massive fibrosis and accompanying factors, such as emphysema and additional fibrotic disease in the lung fields, have not, to our knowledge, hitherto been separately investigated. In many substantially disabled cases who exhibit PMF it seems unlikely that the mere space-occupying effects of the mass in itself would be sufficient to give rise to the accompanying disablement, whereas patients are often encountered who, despite the presence of extensive bilateral PMF, are leading normal lives and are not significantly disabled; clearly the size of the PMF in itself is not the only, nor perhaps even the main, determinant of disablement. We decided to explore this aspect in a group of dead miners who suffered from PMF during life in all of whom radiological, physiological, and pathological findings including large lung sections are available.

The group consisted of dead miners with PMF with radiological changes amounting to category B or category C of the ILO classification extracted

from a larger group of 247 dead miners with both simple and complicated pneumoconiosis, previously reported on by Ryder *et al.*<sup>2</sup> Both extent of emphysema and radiological category of PMF were separately positively correlated to impairment of FEV<sub>1</sub>,<sup>3,4</sup> and we therefore considered that it would be interesting to attempt to establish the relative roles of both these factors in determining disability in PMF cases together with their relation to one another. We also decided to determine the distribution of the PMF lesions throughout the lung fields; it seems to be generally well recognised<sup>1,5</sup> that the tumour occurs more often in the upper lobes and in the posterior lung segments, but the precise order of frequency and the radiological and anatomical situations have not, to our knowledge, been documented.

## Material and method

A detailed description of the miners concerned and of the methods of investigation have already been given, so only brief relevant details are included here. In our earlier studies<sup>2-4</sup> we reported on 247 miners who had died and lived in a defined area of South Wales. In the present study we studied only those cases whose final radiographs were read as category B or category C PMF; all had attended the Cardiff Pneumoconiosis Panel at least once in the

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four years preceding death; had had a final radiograph before death; had detailed contemporaneous pulmonary function tests; and had had postmortem whole lung sections prepared and a quantitative assessment of emphysema according to the method of Ryder *et al.*<sup>6</sup> To determine more accurately the relation between PMF and impairment of ventilation, the area of PMF present in the final radiograph of each case was measured as follows by W J Clarke, who had had previous experience in this field.

The outlines of the PMF shadows in each case were traced on to transparent plastic sheets, which were placed over the radiograph. Each sheet had two horizontal lines spaced so as to indicate upper, mid, and lower radiological zones. These outlines were then measured using squared paper; they ranged in area from 5 to 82 cm<sup>2</sup> with an average of 26.5 cm<sup>2</sup>. Because of lack of clarity in many of the shadows it was not always possible to obtain absolute accuracy, but all the areas were measured twice using both 1-cm and 2-cm squared paper. A random sample of the shadows was retraced when it was found as might be expected that the largest errors were in the tracing of the ill-defined shadows. On the whole, the remeasurement proved to be surprisingly comparable, being within plus or minus 0.5 cm<sup>2</sup> of the first measurement.

The total area of PMF in each case was then related to the fall in FEV<sub>1</sub> below that expected of a man of the same age and height, to FEV/FVC ratio, and to the emphysema count. The distribution of the PMF in radiological and anatomical terms was also recorded by comparing the radiograph and the sagittal whole lung section. To ascertain so far as possible the nature of the emphysema two pulmonary pathologists (R Seal and J C Wagner) undertook jointly to study and report on a random selection of 50 large lung sections out of the total of 108.

Two possible biases may have occurred. Firstly, the method of emphysema counting assumes that the total area of large section will be available for counting whereas if gross PMF were to occupy a large area the emphysema count may be reduced. Since the average area of PMF in the left lung section studied amounted to only 11 cm<sup>2</sup> and in only 15 cases exceeded 20 cm<sup>2</sup>, we consider that the effect on the emphysema count was unlikely to be more than marginal. The second possible source of bias arises from the fact that the emphysema count is based on the finding from one lung only whereas the PMF estimation includes both lungs. Although it would be reasonable to assume that the emphysema count in both lungs would be roughly similar, this might not be so where different sizes of PMF were present in each lung, particularly if the PMF was

Table 1 *Distribution of PMF by radiological zone in 108 dead miners. (Percentages in parentheses)*

Lung	Radiological zone			All zones
	Upper	Mid	Lower	
Right lung	94 (87.0)	47 (43.5)	45 (41.7)	186 (57.4%)
Left lung	72 (66.7)	46 (42.6)	33 (30.6)	151 (46.6)
Both lungs	166 (76.9)	93 (43.1)	78 (36.1)	337 (52.0)

contributing substantially to the emphysema formation.

## Results

There were 108 cases included by our terms of reference; 59 were category B (mean age 62.9 years) and 49 were category C (mean age 61.5). Of 89 cases who had bilateral PMF, 41 were category B (69.5%) and 48 category C (98.0%). Thus unilateral category C is probably rare.

Table 1 shows the distribution of PMF in each of six radiological zones as ascertained by the final radiography in life; 337 (52.0%) out of a possible 648 zones were affected. The right lung zones were more often affected (57.4%) than the left (46.6%), and this difference was statistically significant ( $\chi^2_1 = 7.15$   $p < 0.01$ ).

The upper zones (76.9%) were affected more often than the middle (43.1%) or lower (36.1%) ( $\chi^2_2 = 71.0$   $p < 0.001$ ); of the individual zones 94 out of 108 upper right zones (87.0%) were affected whereas only 33 (30.6%) of the lower left zones were.

The segmental distribution at necropsy was estimated from the sagittal sections, and as, due to possible distortion, it was difficult in some cases to be certain whether a lesion was in the posterior or anterior segment only approximate percentage figures are given. Sixty per cent of all lesions were in the posterior segment, but 75% of the lesions in the upper zone were posterior whereas only 30% of those in the middle and 60% of those in the lower zones were posterior. When there was mid-zone involvement the PMF had usually spread downwards and anteriorly from the upper zone.

Table 2 shows the correlations between area of PMF, emphysema count, fall in FEV<sub>1</sub>, and FEV/FVC

Table 2 *Correlation coefficients between measures of disability*

Measure of disability	Emphysema count	Fall in FEV	FEV/FVC
Area of PMF	-0.045	0.266**	-0.068
Emphysema count	-. . .	0.275**	-0.200*
Fall in FEV		-. . .	-5.75***
FEV/FVC			-. . .

Statistical significance: \*  $p < 0.05$ ; \*\*  $p < 0.01$ ; \*\*\*  $p < 0.001$ .

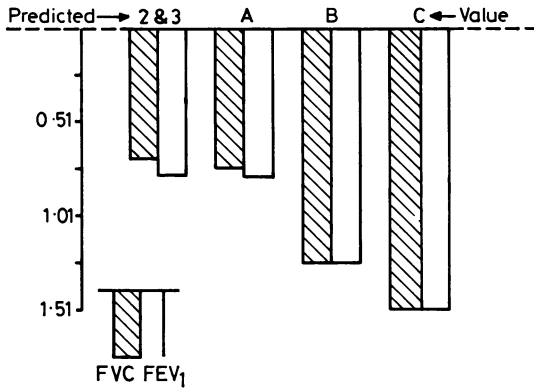


Fig 1 Impairment of FEV<sub>1</sub> and of FVC in 190 dead coal miners with simple pneumoconiosis and with PMF categories A, B, and C below that predicted by age.

ratio. Both area of PMF and emphysema count were positively correlated with fall in FEV<sub>1</sub>, and these correlations are statistically significant ( $p < 0.01$ ). They are negatively associated with the FEV/FVC ratio, although these associations are weaker ( $p < 0.05$ ); tumour size is not correlated with emphysema count. The weak negative association between PMF or emphysema and FEV/FVC ratio is presumably due to the restrictive effect of PMF, but the stronger association with fall in FEV<sub>1</sub> indicates that the general impairment in pulmonary function is obstructive in type.

Figure 1 shows that the association between emphysema and fall in FEV<sub>1</sub> is largely confined to PMF tumours of less than 15 cm, and that in the larger tumours there is little association. Figure 2 examines the association between tumour size and

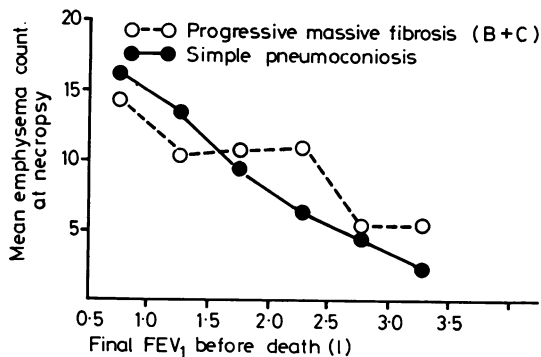


Fig 2 Association between mean emphysema count at necropsy and FEV<sub>1</sub> at last examination before death in coal miners with simple pneumoconiosis and miners with PMF category B or C.

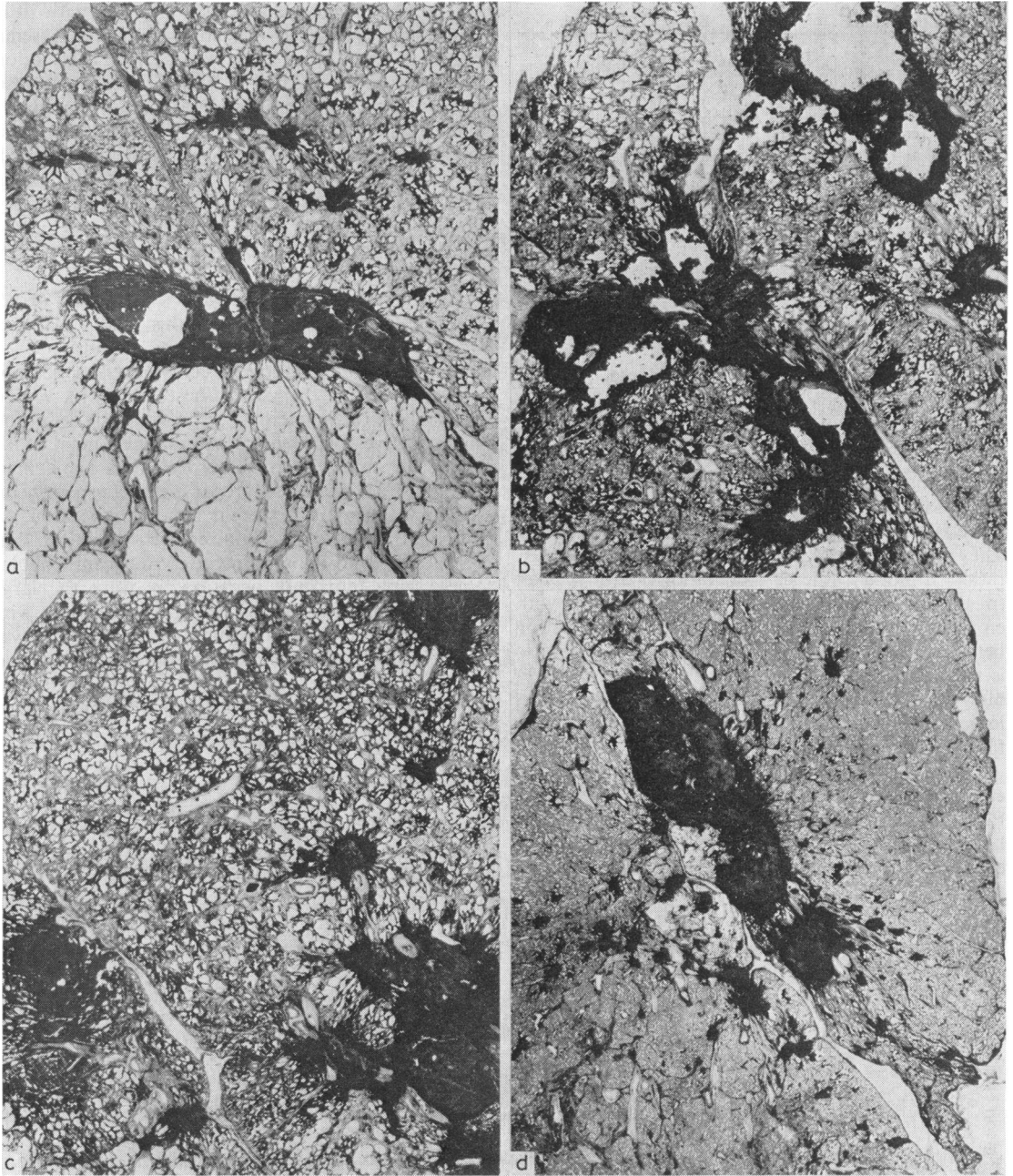
fall in FEV, which is stronger in lungs with little emphysema whereas in lungs with emphysema counts of 10 and over there is almost no association between tumour and fall in FEV<sub>1</sub>. These figures also suggest that emphysema and PMF act independently in causing impairment of FEV<sub>1</sub>. Possibly the method of estimating emphysema, as previously mentioned, may contribute to this lack of relationship tending, as it does, to make PMF and emphysema mutually exclude one another at their higher levels, but we consider that this lack of relationship is probably genuine.

The report of the pathologists (RMES and JCW) goes some way to explaining this lack. "When a significant degree of emphysema is present, in simple and in complicated coalworkers' pneumoconiosis, by far the commonest variety is centrilobular (centriacinar) emphysema, which by definition is destructive. When severe and affecting most of the lobule, it might be misinterpreted as panacinar, but in 2 × 2 projected preparations the peripheral surviving normal paraseptal zone can be seen. In the PMF cases we scrutinised we concluded that here too the most common variety was centrilobular emphysema and only occasionally were the large irregular emphysematous lesions associated with the masses. Rarely, destructive emphysema was segmental or lobular in distribution and was considered in some way related to involvement of lobular or segmental bronchi by the parenchymal or lymph node mass."

### Discussion

The overall findings seem to indicate that both PMF and emphysema usually make largely separate, independent contributions to impairment of ventilation in proportion to their size and extent. In cases where compensatory emphysema related to PMF is present in substantial degree the roles of both may be interdependent, but such cases it would seem are the exception according to the pathologists; fig 3A is probably an example of this type of emphysema. The possible bias referred to earlier concerning differing areas of PMF in both lungs should not operate significantly in these circumstances, since the amount of emphysema would not be dependent on the area of the PMF in most cases.

The pathologists' report indicating that most of the emphysema is centrilobular in type and distributed in relation to the smaller dust foci similar to that found in coalworkers' pneumoconiosis without PMF, is well shown in figs 3(b) and (c). These figures also show that despite the presence of large areas of PMF, there is little significant shrinkage of the lung and the outline is well preserved; and even



**Fig 3** *Sagittal sections of whole left lungs showing: (a) compensatory emphysema with both types of lesions; (b) centrilobular emphysema associated with smaller dust foci; (c) centrilobular emphysema associated with dust foci and with some destructive lesions; and (d) PMF category B with little emphysema.*

those areas of lung adjacent to the PMF are not unduly distorted. It is well recognised that PMF is not always a homogenous mass of fibrous tissue,

but in many cases has a soft core with substantially reduced collagenous material.<sup>7</sup> In such cases the mass may act only as little more than a space-

occupying lesion in so far as its contribution to disablement is concerned. This type of case, particularly if there is no significant emphysema or other parenchymal involvement, probably accounts for those cases of PMF exhibiting dramatic radiological changes but with little or no accompanying disablement. Figure 3(d) exhibits such a condition, there being little evidence of disablement found during life, although the radiograph displayed bilateral PMF category B. The condition of the lung parenchyma is obviously as important, if not more so, than the size of the PMF in determining disablement in such cases.

The coefficients of correlation (table 2) would seem to indicate that the contributions made by emphysema and PMF both separately and together to impairment of ventilation were rather less than might have been anticipated from our previous findings.<sup>2-4</sup> It would seem, therefore, that other factors affecting the airways and the lung parenchyma—for example, small airways disease and interstitial fibrosis—must also contribute to disablement in coalworkers' pneumoconiosis with PMF.

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- <sup>1</sup> International Steering Committee of Medical Editors. Uniform requirements for manuscripts submitted to biomedical journals. *Br Med J* 1979;1:532-5.
- <sup>2</sup> Soter NA, Wasserman SI, Austen KF. Cold urticaria: release into the circulation of histamine and eosinophil chemotactic factor of anaphylaxis during cold challenge. *N Engl J Med* 1976;294:687-90.
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