A commonly used classification of the pneumoconioses is that devised by the UICC Committee (Cooperative study by UICC Committee, 1970). Simple pneumoconiosis is categorized by the type and profusion of small opacities present in the chest radiograph. In this classification small opacities are separated into rounded and irregular varieties. The former are subdivided into p, q, and r types according to their size, 'p' opacities being those less than 1.5 mm, 'q' those between 1.5 mm and 3 mm, and 'r' those between 3 mm and 10 mm in diameter. Irregular opacities are similarly divided into fine (s), medium (t), and coarse or blotchy (u).

The small rounded type of opacity is most commonly recorded in the radiographs of miners with coalworkers' pneumoconiosis (CWP). Moreover, previous studies have demonstrated a relationship between their profusion and the coal dust content of the lungs (Liddell, 1972; Rossiter, 1972). In contrast, irregular opacities are unusual in CWP and some authors have questioned whether their presence is related to coal dust retention (Gilson and Morgan, 1974). Furthermore some observers have reported the finding of small irregular opacities in cigarette smokers who have not had significant exposure to coal dust. Thus Carilli, Kotzen, and Fischer (1973) noted that irregular opacities were frequently present on the chest films of female cigarette smokers. Similarly, Theriault, Peters, and Johnson (1974) observed that, while a direct relationship existed between small rounded opacities and dust exposure in Vermont granite shed workers, the presence of irregular opacities was predominantly associated with cigarette smoking.
While numerous studies have failed to show a relationship between the common indices of ventilatory capacity and radiographic category of simple CWP (Morgan et al., 1974; Amandus et al., 1974a), Lyons et al. (1974) in a sample of miners claiming compensation demonstrated a lower FEV₁ (forced expired volume in one second) in those with irregular opacities as compared with those without radiographical evidence of CWP. We therefore decided to see whether we could confirm these observations, and if so, identify those factors that are associated with the presence of irregular opacities in the chest films of coalminers.

**Material and methods**

The sample included in this study was drawn from the National Study of Coalworkers’ Pneumoconiosis. Complete details of the method and sample selection are to be found in earlier publications (Morgan et al., 1971; Morgan et al., 1973). Each of the 9076 miners who was examined in the first round of the National Study had some simple tests of ventilatory capacity performed. In addition a modified version of the British Medical Research Council’s questionnaire on respiratory symptoms (Medical Research Council’s Committee on the Aetiology of Chronic Bronchitis, 1960) was administered as well as a detailed occupational and smoking history. Posteroanterior and left lateral chest radiographs were taken and interpreted by members of the US Public Health Service’s panel. Total lung capacity (TLC) was calculated according to the technique of Barnhard (Barnhard et al., 1960). This method has been shown to yield comparable values to the plethysmograph in miners with CWP (O’Shea et al., 1970). Residual volume (RV) was derived by subtracting FVC (forced vital capacity) from TLC.

The study sample of 6166 coalminers was selected using the following criteria:

1. They were either current cigarette smokers or were life-long non-smokers (ex-smokers were excluded).
2. Their chest film showed either small opacities with a profusion of subcategory 1/0 or greater, or was read as completely clear, (subcategories 0/- and 0/0). Subjects whose films were reported as showing large opacities (progressive massive fibrosis) or were classified as 0/1 were excluded. Because of interobserver variation, both in regard to profusion and type of opacity, we relied upon the radiographic interpretations of one interpreter.

The study sample was subdivided into four groups:

(a) Those without radiographic evidence of CWP.
(b) Those with small irregular opacities.
(c) Those with small rounded opacities.
(d) Those with both small rounded and irregular opacities (mixed opacities).

The statistical analysis of the study sample was performed in two phases. In phase 1, the relationship between the percentage of each type of opacity and smoking, bronchitis, age, and years underground was determined by multiple regression techniques. Bronchitis was defined as persistent phlegm, or moderate phlegm and persistent cough. A persistent symptom was defined as that occurring on most days and nights for at least three months, and a moderate symptom as that occurring on most days and nights but for less than three months.

In phase 2, the mean lung volumes for the four study groups were compared separately for smokers and non-smokers using multiple regression and analysis of covariance techniques. For each group the necessary criteria were evaluated before an analysis of covariance was performed, namely that there was the same variation in lung volume and a gaussian distribution of lung volume across age and height in each group and that the same linear relationship existed between lung volume and age and height within each group. The 5% level of probability was used to test the statistical significance of the results obtained.

A description of the method used in phase 1 is as follows:

1. The study group of 6166 coalminers was divided according to category of smoking, bronchitis, age, and years underground, that is, divided into smokers and non-smokers, those with and without bronchitis, those younger and older than 30 years of age, and into 10 categories according to years worked underground. The intervals of years underground were 0, 1-5, 6-10, 11-15, etc. The percentage of miners whose radiographs showed only irregular opacities was then determined for all cross-classifications of smoking, bronchitis, age, and years underground. Similarly, the percentage of miners with rounded opacities was calculated for each cross-classification. Age was not further subdivided since sample sizes would have been too small to yield reliable estimates of the percentages.

2. For purposes of statistical computation, smokers were coded as 1 and non-smokers as 0, those with bronchitis as 1 and those without bronchitis as 0, those older than 30 as 1 and those younger than 30 as 0, and each interval of years underground was coded with the midpoint of the interval, for example, 0, 3, 8, 13, etc.

3. Multiple least squares regression equations were developed via the forwards stepwise regression technique. The equations predicted the percentages of each type of opacity from category of smoking, bronchitis, age, and years underground. In this way the relationship between the percentages and the independent variables could be evaluated by the regression coefficients. All linear and cross-product terms of smoking, bronchitis, age, and years underground, as well as the square and cubic terms of years underground, were inputs into the stepwise procedure. The procedure was performed twice. In the first analysis, the linear terms were forced to remain as the significant cross-product terms were added to the equations. However, several of the linear terms were of little value in predicting the percentages. These terms were then deleted and a second analysis was performed during which only the significant linear terms remained.

**Results**

**Relationship of type of opacity with smoking, bronchitis, age, and years underground**

The multiple regression equations calculated by the stepwise regression procedures are presented in Tables 1 and 2. It was found that smoking, age, and years underground were independent factors which
had irregular lesions. A similar percentage of smokers had irregular lesions than did non-smokers, a finding which was independent of bronchitis, age, and years underground. Similarly, a higher percentage who were over the age of 30 years had irregular opacities than did those under 30, a finding which was independent of smoking, bronchitis, and years underground.

Bronchitis alone was not found to be significant; but, in combination with smoking, age, and years underground it contributed markedly to the prevalence of irregular opacities. The complete equation in Table 1 shows two significant cross-product terms. The product of smoking, bronchitis, and age accounted for a marked proportion of irregular opacities. Thus the largest percentage of irregular lesions was found among smokers with bronchitis who were over 30 years. The product of bronchitis, age, and years underground had a slight negative effect. Thus the contribution of years underground was least among bronchitics who were over 30 years.

The prevalence of the rounded opacities was generally unrelated to bronchitis and age, but strongly influenced by smoking and years underground. A significant cross-product term of smoking and years underground was present as well as a significant linear effect due to years underground. The rounded opacities occurred more frequently in non-smokers than in smokers and this finding was independent of years underground.

Although the results are not presented, several transformations of the percentages were performed which included the probit, logit, log, and arcsin transformations. The results from these transformations were not appreciably different from the results of the least squares procedure. When using the arcsin (sin⁻¹ √percentage) transformation the results were similar to those of the least squares procedure, however, age was not present in the cross-product terms in Table 1. Thus the arcsin transformation tended to reduce the contribution due to age.

### Table 2

**Multiple Regression Equation Calculated by the Stepwise Regression Procedure to Predict the Percentage of Rounded Opacities**

Complete equation*

\[
\% R = 0.60 + 0.61 Y - 0.23 S Y \text{SEE} = 0.058
\]

Equations by category of smoking†

- Smokers
  - Complete equation: \( \% R = 0.60 + 0.38 Y \)
- Non-smokers
  - Complete equation: \( \% R = 0.60 + 0.61 Y \)

*\( \% R \) = percentage of miners with only rounded opacities on their chest radiograph.

S = smoking category: 0 for non-smokers and 1 for smokers

Y = years underground

A = age: 0 for age < 30 and 1 for age > 30 years

B = bronchitis: 0 for those with bronchitis and 1 for those without bronchitis

SE = standard error of the estimate

†The complete equation was broken down by category of smoking, age, and bronchitis, that is values of S, Y, and B were substituted into the equation.

### Table 3

**Multiple Regression Equation Calculated by the Stepwise Regression Procedure to Predict the Percentage of Irregular Opacities**

Complete equation*

\[
\% IR = -1.22 + 2.08 S + 0.13 Y + 2.58 A + 6.65 S \cdot B \cdot A
- 0.12 B \cdot Y \cdot A \text{SEE} = 0.030
\]

Equations by category of smoking, bronchitis, and age†

Smokers

- Complete equation: \( \% IR = 0.86 + 0.13 Y \)
- Complete equation: \( \% IR = 10.09 + 0.01 Y \)

Non-smokers

- Complete equation: \( \% IR = -1.22 + 0.13 Y \)
- Complete equation: \( \% IR = 1.36 + 0.01 Y \)

*\( \% IR \) = percentage of miners with only irregular opacities on their chest radiograph.

S = smoking category: 0 for non-smokers and 1 for smokers

Y = years underground

A = age: 0 for age < 30 and 1 for age > 30 years

B = bronchitis: 0 for those with bronchitis and 1 for those without bronchitis

SE = standard error of the estimate

†The complete equation was broken down by category of smoking, age, and bronchitis, that is values of S, Y, and B were substituted into the equation.

Each contributed significantly to the prevalence of irregular opacities. A higher percentage of smokers had irregular lesions than did non-smokers, a finding which was independent of bronchitis, age, and years underground. Similarly, a higher percentage who were over the age of 30 years had irregular opacities than did those under 30, a finding which was independent of smoking, bronchitis, and years underground.

**Discussion**

This study shows that there is a statistical association

*These results can be supplied by the authors on request.
between cigarette smoking and the presence of irregular opacities. The results also suggest that other factors such as bronchitis, age, and exposure to coal dust are involved in the development of these lesions.

It is recognized that both cigarette smoking and the inhalation of coal dust are associated with chronic bronchitis (Kibelstis et al., 1973; Ulmer and Reichel, 1972). It has also been observed that irregular lesions, although found infrequently, are associated with chronic bronchitis (Fraser and Paré, 1970; Bates et al., 1966; Simon, 1959). It is possible that coal dust deposited in the parenchyma of a lung which is structurally damaged by emphysema or bronchitis might modify the radiographic appearance and predispose to the development of irregular rather than rounded opacities.

Our results indicated that the presence of irregular lesions was markedly associated with bronchitis among smokers older than 30 years. However, a negligible relationship was noted between the percentage of irregular opacities and bronchitis in non-smokers. Since smoking is a far more potent stimulus in the induction of bronchitis than coal dust, the association between irregular opacities and bronchitis will be more pronounced among smokers than non-smokers.

While it is apparent that bronchitis, age, and dust exposure are associated with the presence of irregular opacities, emphysema may also be concerned. Lyons et al. (1974) demonstrated a relationship between the presence of irregular opacities and the degree of emphysema shown at necropsy. If this association is accepted, there might well be a similar relationship between the presence of irregular opacities and cigarette smoking, as the presence of emphysema is closely related to smoking.

Definite conclusions as to the role played by factors in the induction of irregular opacities are hampered by lack of agreement among observers as to their presence in the radiograph (Amandus et al., 1974b). Although considerable interobserver error exists, the results of our study indicate that the presence of irregular lesions in the chest films of coalminers is associated with cigarette smoking. In smokers with irregular opacities, the FEV1, FVC and (FEV1/FVC) % were reduced, while in non-smokers with irregular opacities no such decrements were present. Smokers

---

**TABLE 3**

**Average Ventilatory Capacities and Lung Volumes Adjusted for Age and Height (Non-Smokers)**

<table>
<thead>
<tr>
<th>Adjusted</th>
<th>Category 0</th>
<th>Irregular opacities</th>
<th>Rounded opacities</th>
<th>Mixed opacities</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEV1 (litres)</td>
<td>3.67</td>
<td>3.74</td>
<td>3.70</td>
<td>3.63</td>
</tr>
<tr>
<td>FVC (litres)</td>
<td>4.78</td>
<td>4.83</td>
<td>4.78</td>
<td>4.80</td>
</tr>
<tr>
<td>(FEV1/FVC) %</td>
<td>76-90</td>
<td>77-30</td>
<td>77-50</td>
<td>75-90</td>
</tr>
<tr>
<td>RV (litres)</td>
<td>2.27</td>
<td>2.34</td>
<td>2.39</td>
<td>2.60</td>
</tr>
<tr>
<td>TLC (litres)</td>
<td>7.05</td>
<td>7.18</td>
<td>7.16</td>
<td>7.41</td>
</tr>
<tr>
<td>Group sizes</td>
<td>1467</td>
<td>31</td>
<td>161</td>
<td>28</td>
</tr>
</tbody>
</table>

*Statistical differences were not found among the x-ray groups

**TABLE 4**

**Average Ventilatory Capacities and Lung Volumes Adjusted for Age and Height (Smokers)**

<table>
<thead>
<tr>
<th>Adjusted</th>
<th>Category 0</th>
<th>Irregular opacities</th>
<th>Rounded opacities</th>
<th>Mixed opacities</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEV1 (litres)*</td>
<td>3.46</td>
<td>3.32</td>
<td>3.49</td>
<td>3.55</td>
</tr>
<tr>
<td>FVC (litres)</td>
<td>4.73</td>
<td>4.70</td>
<td>4.69</td>
<td>4.84</td>
</tr>
<tr>
<td>(FEV1/FVC) %*</td>
<td>73-00</td>
<td>70-50</td>
<td>74-40</td>
<td>73-30</td>
</tr>
<tr>
<td>RV†</td>
<td>2.63</td>
<td>2.85</td>
<td>2.64</td>
<td>2.76</td>
</tr>
<tr>
<td>TLC‡</td>
<td>7.36</td>
<td>7.55</td>
<td>7.32</td>
<td>7.60</td>
</tr>
<tr>
<td>Group sizes</td>
<td>3898</td>
<td>191</td>
<td>294</td>
<td>96</td>
</tr>
</tbody>
</table>

*Averages were statistically lower among those with irregular opacities than among those in the other groups
†Averages were statistically higher among those with irregular opacities than among those in the other groups
‡Averages were statistically higher among those with irregular and mixed opacities than among those with category 0 and irregular opacities
were shown to have more airways obstruction and hyperinflation when only irregular opacities were present than when only rounded nodules were present.

References

Received for publication 13 May 1975.
Accepted for publication 30 August 1975.
Significance of irregular small opacities in radiographs of coalminers in the USA.

H E Amandus, N L Lapp, G Jacobson and R B Reger

doi: 10.1136/oem.33.1.13

Updated information and services can be found at:
http://oem.bmj.com/content/33/1/13

Email alerting service

These include:
Receive free email alerts when new articles cite this article.
Sign up in the box at the top right corner of the online article.

Notes

To request permissions go to:
http://group.bmj.com/group/rights-licensing/permissions

To order reprints go to:
http://journals.bmj.com/cgi/reprintform

To subscribe to BMJ go to:
http://group.bmj.com/subscribe/