Surveillance Data on US Coal Miners' Pneumoconiosis, 1970 to 1986

ABSTRACT

Objectives. Statistics on prevalence of pneumoconiosis among working underground coal miners from data collected as part of a large national radiographic surveillance program between 1970 and 1986 are presented. The main intent was to examine the time-related trend in prevalence over this period, which coincides with historically low dust levels mandated by federal act.

Methods. Tenure-specific prevalence rates and summary statistics derived from them for four consecutive time intervals within the 16-year period were calculated and compared.

Results. The results indicate a reduction in pneumoconiosis over the life of the program. This trend is similar to that seen in epidemiologic studies undertaken concurrently.

Conclusions. Although low participation in the surveillance program and other problems complicate the findings, it appears that reductions in dust exposure mandated by federal act in 1969 have led to lower prevalence of pneumoconiosis among underground coal miners. (*Am J Public Health.* 1992;82:971–977)

Michael D. Attfield, PhD, and Rochelle B. Althouse, BS, MS

Introduction

As part of a lung disease prevention program mandated by the Federal Coal Mine Health and Safety Act,[1] radiographic examinations of the chest are made available to underground coal miners every 5 years. If an x-ray shows certain signs of coal workers' pneumoconiosis (CWP), a miner is given the right to work in a low-dust environment. This procedure, combined with a general control of dust levels mandated by the law, is intended to prevent or slow down the progression of CWP in underground miners and thus reduce the risk of progressive massive fibrosis (PMF).

The administration of these x-rays and of related quality control procedures occurs under the Coal Workers' X-ray Surveillance Program (CWXSP), which is overseen by the National Institute for Occupational Safety and Health (NIOSH). Although primarily serving as a medical monitoring program for underground miners, the CWXSP also provides data that are pertinent to assessing CWP prevalence and to determining the effectiveness of the mandated dust control measures in reducing and eliminating CWP.

This paper provides statistics on the more than 250 000 x-rays collected in the CWXSP since 1970. Information by tenure group is provided, as are various adjusted summary rates reflecting prevalence of CWP among program participants. To permit valid comparisons of data for different periods, details on operational changes are given.

Operation of the CWXSP

Past and present regulations governing the operation of the CWXSP are described in Title 42 of the Code of Federal Regulations.[2–5] In summary, the program is overseen by NIOSH, which, by referring to records on active mines maintained by the Mine Safety and Health Administration, notifies mine operators when its employees are due to be examined. The operator must then file a mine examination plan, which provides information on when and where miners can get their x-rays and on who will do the initial x-ray reading. On receipt of this information, NIOSH determines whether the designated medical facilities and readers are qualified, among other requirements. If a mine operator does not supply a plan, NIOSH prepares one and notifies the operator.

After a plan is approved, it must be posted at the mine site when the time comes due for the examinations. Miners may then present themselves to the designated facility to get an x-ray on their own time and at no cost to themselves. While the miner is at the facility, a brief occupational history is taken using a standard form. The x-ray is classified by the first reader (usually an A reader, but sometimes a B reader [see below]), who typically resides locally. After this, the x-ray film, form, and initial reading must be sent to NIOSH; the x-ray is then sent to a B reader for a further reading. If the two readings are sufficiently similar (definitions of agreement have varied somewhat over time but basically consist of agreement within the same major category of

The authors are with the Division of Respiratory Disease Studies at the National Institute for Occupational Safety and Health in Morgantown, WV.

Requests for reprints should be sent to Michael D. Attfield, PhD, MS 234, ALOSH, 944 Chestnut Ridge Road, Morgantown, WV 26505.

This paper was submitted to the Journal July 1, 1991, and accepted with revisions March 20, 1992.

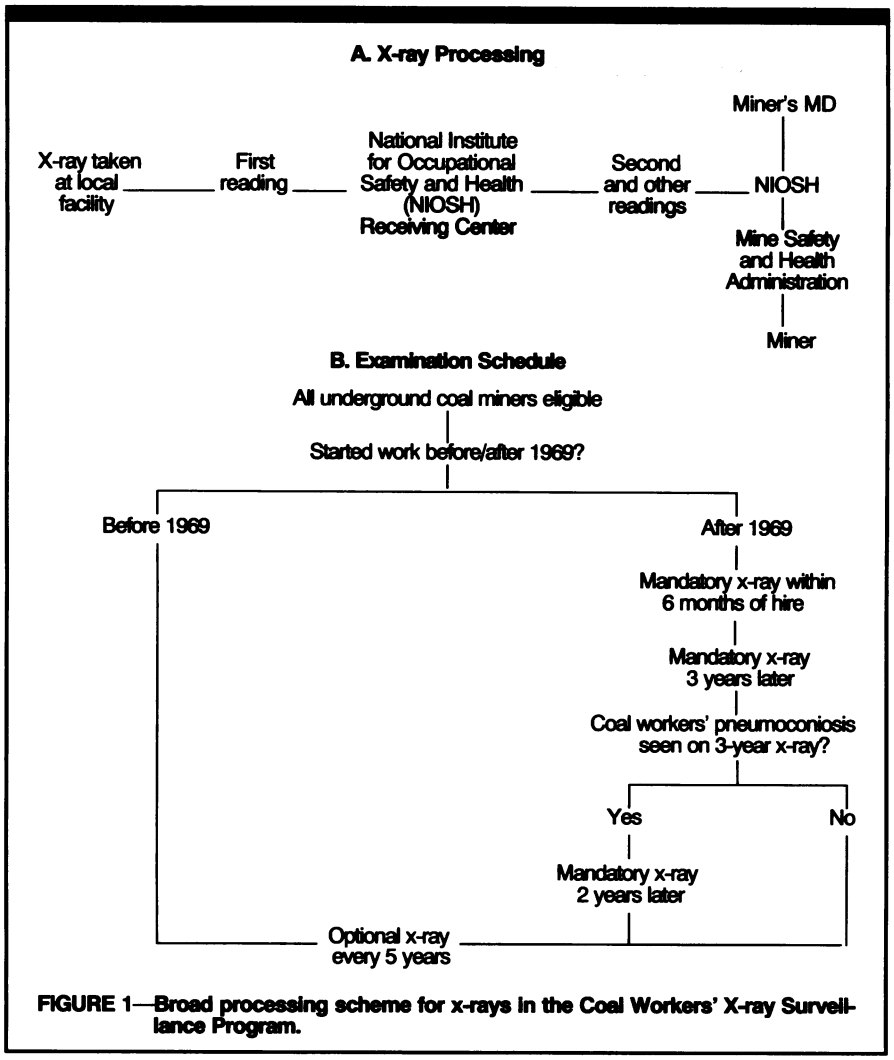

FIGURE 1—Broad processing scheme for x-rays in the Coal Workers' X-ray Surveillance Program.

small opacity profusion), the "final determination" is set equal to the maximum profusion category of the two. If there is greater disagreement than this, further readings are made until sufficient agreement is obtained. The miner is awarded the right to work in a job with a dust exposure of 1 mg/m^3 or less if the final determination is category 1/0 or greater. All program participants have the opportunity to have the results of their x-ray readings (negative or positive) sent to their personal physician. See Figure 1A for details of the x-ray processing.

As a part of a quality control program, the x-ray readers who participate must satisfy certain tests of their competence. Currently, both A and B readers are certified by NIOSH. To become an A reader, the applicant must either attend a special NIOSH seminar or submit six correctly classified chest x-rays. B readers must have passed a special test administered by NIOSH and must undergo regular reexamination to maintain certification.[6] Hundreds of readers have been involved in the program since its inception. As a result, the statistics given in this report should not, in the main, be influenced unduly by individual idiosyncrasies among the readers.

All coal miners working at underground mines are eligible for the periodic x-rays. Currently, miner participation is optional except for new miners, who must have an x-ray within 6 months of starting work at an underground mine and another x-ray 3 years later. A third x-ray, to be taken 2 years later, is mandatory if the second shows signs of CWP. Figure 1B shows the examination schedule schematically.

Between August 1970 and August 1981, the CWXSP was organized into three so-called rounds. Each round was made up of two parts: an initial period when all active mines had to complete examination plans, and a follow-up period when x-rays—mostly those for new miners and for others receiving mandatory x-rays—were being taken. However, logistical problems incurred by the large influx of x-rays at the start of each round led NIOSH to discontinue this administration procedure. Instead, to smooth out processing, mine plans were filed on a continuous basis after 1981. In this report, for convenience, the period between August 1981 and December 1986 will be referred to as round 4, although it is not a round in the same sense as were the previous three. Details pertinent to each round are given in Table 1.

Film Readings

The results presented here are confined to data based on the first and second x-ray readings. (Results are not given for the final determinations because the procedures by which they were obtained differed between the rounds.) At least two readings were made on the films from rounds 1, 3, and 4. Because of logistical problems at round 2, the decision was made not obtain a second reading if the first reading had been made by a B reader (10% of all films). In rounds 3 and 4, the second reading was always made by a B reader, but both A and B readers performed the first reading. Three sets of x-ray standards were used over the four rounds: the Union Internationale Contre le Cancer (UICC)/Cincinnati standards of 1968[7] (round 1), the 1971 International Labour Office (ILO) standards[8] (rounds 2 and 3), and the 1980 ILO standards[9] (round 4). Results are presented on prevalences of small rounded and small combined opacity profusions of progressive massive fibrosis. (For details pertaining to the definition of CWP and the derivation of small rounded opacity scores, see the report in this Journal on epidemiological findings.)[10]

In the following analysis, there are fewer readings than participants owing to the unavailability of data for films said to be unreadable. In some cases, multiple films for the same person were available within the same round; in these cases, only readings of the last film are included.

Results

The following analysis provides information on tenure-specific prevalences among the participants, and on summary statistics computed to facilitate the comparison of prevalences over the different rounds.

Tenure Distribution Data

Table 2 provides detailed information on the tenure distribution of participants at each round. Occupational history information was obtained from the miners by

interview at the time of examination. Note that the data from each round are probably weighted toward younger miners; this is owing to the dual mandatory/voluntary nature of the program. New miners, who must have initial and 3-year x-rays, tend to be younger. The experienced miners, who are generally older and not required to obtain regular x-rays, have participated less in the program. As a result, the tenure distributions of CWXSP participants might be expected to be different from those that would have resulted from a census of the work force held at the same time.

Furthermore, selective participation may have occurred, with the healthier miners having been more likely to choose to attend. Lastly, the age structure of the mining work force has been changing dramatically since 1969. In particular, there was a large reduction in the average age between 1969 and 1979 as older men retired from the generally elderly work force, and young men were hired to fill the deficit and to man mines newly opened or expanded in response to the energy crisis of the mid-1970s.

The table also includes a projected tenure distribution for the 1986 work force for underground and surface workers at underground coal mines; this distribution was derived from a mail survey of coal mine operators.[11]

TABLE 1—Background Information on Each Round

	Round 1	Round 2	Round 3	Round 4
Dates	1970–1973	1973–1978	1978–1981	1981–1986
X-ray classification system	1968[7]	1971[8]	1971[8]	1980[9]
Number of participants	77 758	122 625	63 519	40 634
Average total population in underground coal mining employment	103 000	128 000	144 000	110 000

Note. Work force estimates are from MSHA reports, such as that for 1986.[13]

TABLE 2—Tenure Distributions for Miners Who Attended the Four Completed Rounds of the Coal Workers' X-ray Surveillance Program and for Those Included in the 1986 Survey of Coal Miners[11]

Tenure in Mining Group	% Round 1 Miners (n = 71 404)	% Round 2 Miners (n = 107 031)	% Round 3 Miners (n = 58 282)	% Round 4 Miners (n = 34 953)	% 1986 Survey Miners[a] (n = 78 741)
0[b]	22.1	46.7	24.9	17.1	2.0
1	7.4	7.2	6.4	3.5	2.0
2–4	11.6	14.6	20.7	16.2	8.9
5–9	9.4	10.8	24.3	28.9	29.2
10–14	6.2	4.4	9.1	19.8	35.0
15–19	6.6	2.9	3.7	6.6	14.1
20–24	10.2	2.8	2.6	2.6	3.6
25–29	8.8	4.0	2.2	1.6	1.6
30+	17.8	6.5	6.1	3.7	3.7

[a]The tenure figures for the 1986 survey were computed from data supplied by the Bureau of Mines. Because the original data were rounded up to the nearest integer, 1 year was subtracted from the tenure to make the data consistent with the radiological data (in which the figures were rounded down).
[b]The zero tenure group includes all those with less than 1 year.

Tenure-Specific Prevalences: Small Rounded Opacities

Figures 2 and 3 show tenure-specific prevalence rates of category 1 or greater small rounded opacities for the first and second readers, respectively. Comparison of these tenure-specific rates across rounds reveals several interesting points. The first readings (Figure 2) show a consistent decline in prevalence over all four rounds in virtually every tenure group. In comparison, the second readings (Figure 3) reveal higher prevalences in round 2 for longer-tenured miners; otherwise, the trends are similar. Comparison of the two figures reveals that, at all four rounds, the second readers tended to report fewer cases of abnormality than the first readers, an effect that is most obvious in round 1.

Figures 4 and 5 provide corresponding statistics for category 2 or greater small rounded opacities. Both the first and second readings show a consistent reduction in prevalence over time; however, the general prevalence levels are higher for the first readings.

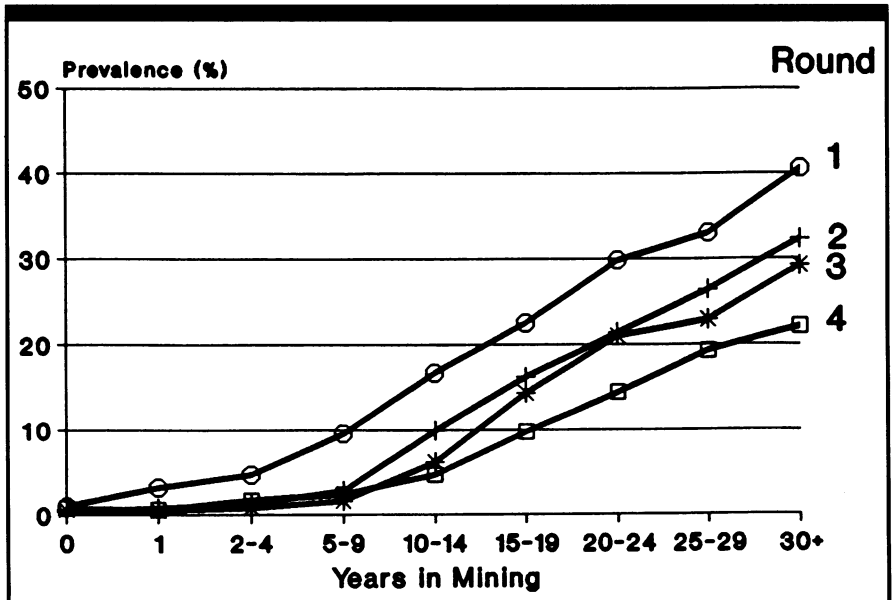

FIGURE 2—Tenure-specific prevalences of category 1 or greater small rounded opacities by round of the Coal Workers' X-ray Surveillance Program, based on the first readings only.

Summary Statistics for Small Rounded Opacities

The data given in Figures 2 through 5 were used to derive certain summary statistics. First, summation of the products of tenure-specific prevalence shown in those figures with the tenure distribution proportions from Table 2 for each round gave rise to crude prevalence rates for all participants by round (see Table 3). How-

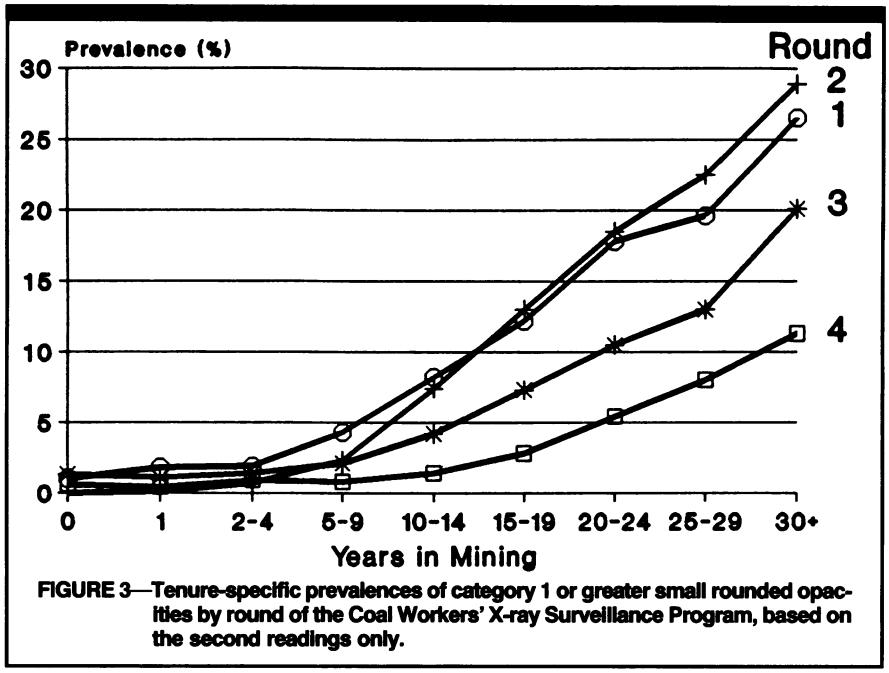

FIGURE 3—Tenure-specific prevalences of category 1 or greater small rounded opacities by round of the Coal Workers' X-ray Surveillance Program, based on the second readings only.

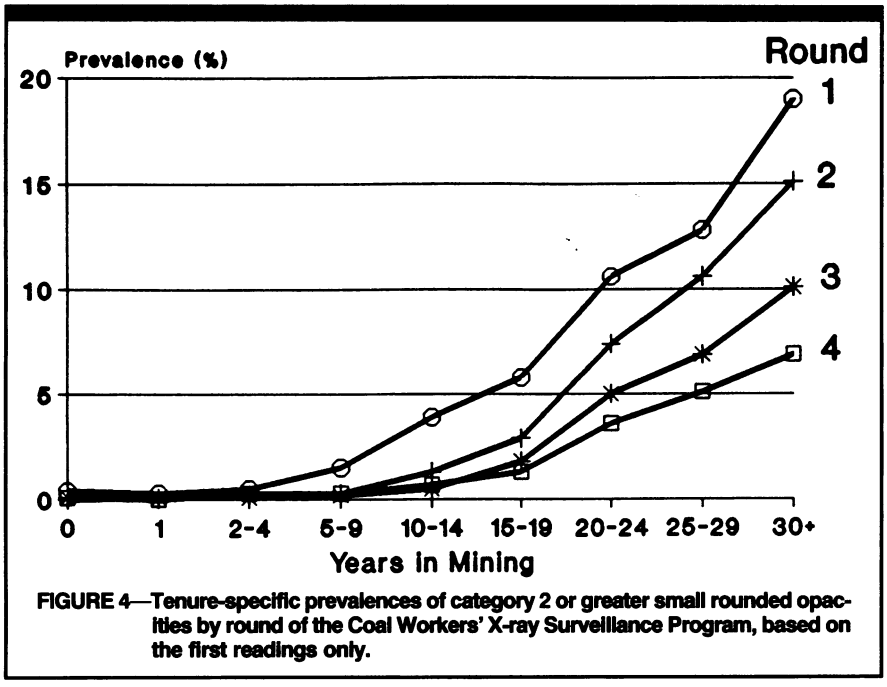

FIGURE 4—Tenure-specific prevalences of category 2 or greater small rounded opacities by round of the Coal Workers' X-ray Surveillance Program, based on the first readings only.

ever, these rates are naturally heavily weighted by the zero tenure group and, to some extent, by the 3-year x-rays. Thus, to eliminate the spurious and misleading weighting caused by the mandatory preemployment and 3-year x-rays, the above approach was modified by omitting the 0- to 4-year tenure group from the summation and adjusting to account for the fact that the tenure proportions no longer add to 100%. Not surprisingly, these statistics are all larger than the crude rates (see Table 3). They tend to reflect the influence of changes in both employment patterns and dust control, while removing the effect of the mandatory films.

The question of whether dust control brought about a reduction in prevalence after 1969 was tackled by standardizing the rates for each round to a constant tenure distribution. A summary statistic was formed by multiplying tenure-specific prevalences from Figures 2 through 5 for each round by the proportions of miners in the tenure groups given by the Bureau of Mines survey.[11] Note that these statistics were generated for interround comparison and should not be regarded as estimates of prevalence at any particular round of the CWXSP, except perhaps the fourth. Other tenure distributions could obviously have been used for standardization.

Overall, the summary statistics reveal that the first readers consistently reported more abnormality than did the second readers. The summary rates also show that, once the weighting effect of the new miners is removed (e.g., by restricting the calculations to those miners with 5 or more years of tenure), the prevalences show a much more gradual and uniform drop from round 1 to round 4. Hence, large temporal changes in tenure distribution were clearly responsible for large variations in the crude summary prevalence statistics. Lastly, standardization to a common tenure distribution leads to the smallest drop in prevalence from round 1 to round 4 of the three summary statistics, although clear downward trends over the rounds are still evident.

Small Combined Opacities

Although most research into the radiographic appearances of CWP has concentrated on rounded opacities, there have been some recent indications that irregular opacities are also associated with dust exposure.[12] For completeness, the prevalences of both rounded and irregular opacities (i.e., combined opacities) have been tabulated, with the resulting adjusted rates shown in Table 4. As expected, the rates are all higher but otherwise follow the same trends seen in Table 3.

Prevalence of Large Opacities

Standardization for tenure was not undertaken on the data for large opacities because there were too few cases. However, tenure-specific prevalences of progressive massive fibrosis by round and reader are given in Figures 6 and 7. The data exhibit similar tendencies to those seen for small opacities—namely, a rise in prevalence with tenure and a trend toward lower prevalences of disease at the later rounds.

Participation

Participation is obviously an important issue with these data: if it is not 100%, self-selection and, hence, bias might be suspected. Unfortunately, assessing bias in the CWXSP to any detailed extent is very difficult owing to a paucity of data by age, region, etc., on the baseline population of miners eligible for the program at any time.

Some very rough rates of participation pertinent to miners eligible for the vol-

untary aspect of the program were derived. This was done by dividing the numbers of examined miners with 1 or more years of tenure at each round by average work force estimates applicable to each round obtained from annual Mine Safety and Health Administration reports on injuries, such as that for 1986.[13] The results indicate that participation of miners with 1 or more years of tenure at rounds 1 through 4 was 50%, 44%, 32%, and 30%, respectively.

Some indication of tenure-specific participation can be gained for round 4 of the CWXSP by using some Bureau of Mines survey data[11] (shown in Table 2 of this report). Tenure-specific participation rates based on these data were 44%, 25%, 21%, 32%, 44%, and 44% for the 5–9, 10–14, 15–19, 20–24, 25–29, and 30+ groups, respectively. It is interesting that participation appears to improve among miners with longer tenure in mining.

Comparison with Epidemiological Data

Undertaken concurrently with the coal miner surveillance program was a large-scale, nationwide epidemiological study of underground coal miners. Results from that research are described in a companion report.[10] Summary rates of small opacity profusion standardized to the Bureau of Mines survey tenure distribution were derived (see Tables 3 and 4); these reveal trends similar to those noted here for the surveillance data, although the reported prevalences appear to be generally lower.

Discussion

The information reported here reveals a clear downward trend in CWP prevalence among program participants over time. The decline parallels that observed over a series of medical surveys undertaken as part of a long-term epidemiological study of US underground coal miners[10] (see Tables 2 and 3 of this report). Both sets of data suggest that prevalences of category 1 or greater small opacities at round 4 (1981 to 1986) were about one-third of their levels at round 1 (1970 to 1973). Reductions in reported prevalence of category 2 or greater small opacities were somewhat larger.

These reductions in prevalence coincide with lower dust exposure limits mandated by the 1969 Federal Coal Mine Health and Safety Act.[1] Under the regulations promulgated by that legislation, permissible airborne respirable dust concentrations in underground coal mines are currently limited to 2 mg/m^3. This contrasts to levels of 6 mg/m^3 or more existing before 1969.[14] Documented trends of dust concentrations in underground mines indicate a substantial decline over the 10 years from 1968,[15] although there is some evidence that the reductions have not been as great as reported.[16,17]

Because the 1986 underground coal mining work force was fairly young, use of this distribution for standardization leads to rates reflecting prevalence among the less experienced miners. This is appropriate if preliminary evidence on the efficacy of the current federal dust limit is being sought, for it is only those with limited tenure who have, to date, been working under the lower dust

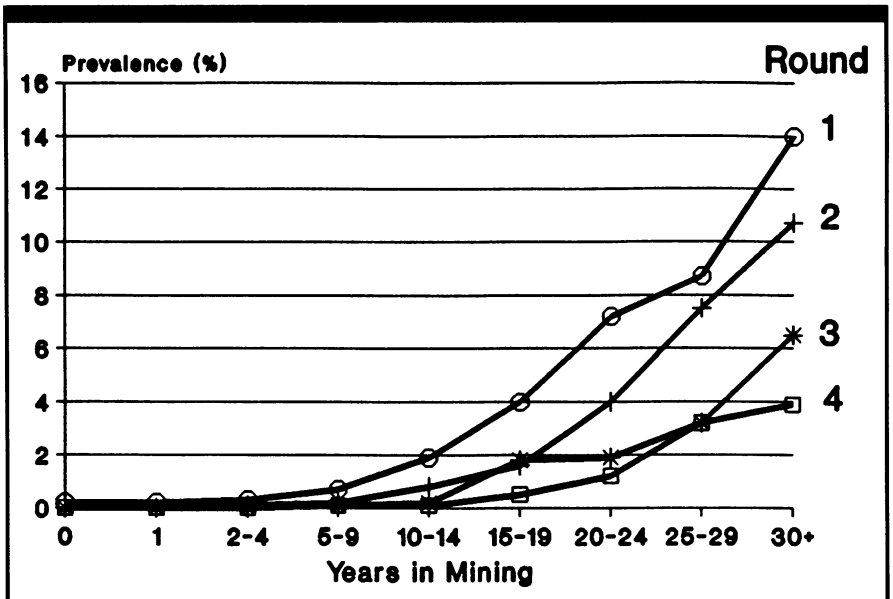

FIGURE 5—Tenure-specific prevalences of category 2 or greater small rounded opacities by round of the Coal Workers' X-ray Surveillance Program, based on the second readings only.

TABLE 3—Adjusted Summary Prevalence Estimates for Small Rounded Opacities by Round of the Coal Workers' X-ray Surveillance Program, Separately by First and Second Readers, and by Data from a Large Concurrent Epidemiological Study[10]

		Adjusted Summary Prevalences, %			
	Category[a]	Round 1	Round 2	Round 3	Round 4
First readers					
All participants[b]	1+	17.7	5.4	4.7	4.2
	2+	5.5	1.5	0.9	0.7
Tenure >4 years[c]	1+	28.2	15.8	9.0	6.0
	2+	9.2	4.7	1.7	1.1
Common tenure distribution[d]	1+	15.4	9.1	6.9	5.5
	2+	3.4	1.5	0.9	0.9
Second readers					
All participants[b]	1+	10.5	4.4	3.6	1.6
	2+	3.7	0.9	0.5	0.2
Tenure >4 years[c]	1+	16.9	13.5	6.1	2.2
	2+	6.2	3.0	1.1	0.4
Common tenure distribution[d]	1+	8.0	7.3	4.6	2.0
	2+	2.0	1.0	0.5	0.3
Epidemiological data					
Common tenure distribution[d]	1+	4.5	4.1	1.8	1.3
	2+	1.2	1.0	0.4	0.1

[a]1+ means category 1 or greater; 2+ means category 2 or greater.
[b]All participants = summary rates based on all mandatory and voluntary x-rays.
[c]Tenure >4 years = summary rates based on all miners with more than 4 years tenure in mining.
[d]Common tenure distribution = summary rates standardized to data in right-most column of Table 2.

TABLE 4—Adjusted Summary Prevalence Estimates for Small Combined Opacities by Round of the Coal Workers' X-ray Surveillance Program, Separately by First and Second Readers, and by Data from a Large Concurrent Epidemiological Study[10]

		Adjusted Summary Prevalences, %			
	Category[a]	Round 1	Round 2	Round 3	Round 4
First readers					
All participants[b]	1+	22.4	7.1	6.0	5.5
	2+	6.5	1.8	1.1	0.8
Tenure >4 years[c]	1+	35.0	20.3	11.4	7.8
	2+	10.8	5.7	2.2	1.2
Common tenure distribution[d]	1+	19.5	11.7	8.7	7.2
	2+	4.0	2.0	1.2	1.0
Second readers					
All participants[b]	1+	13.8	5.9	5.7	3.0
	2+	4.5	1.2	0.6	0.3
Tenure >4 years[c]	1+	22.1	18.2	9.2	4.0
	2+	7.5	3.8	1.3	0.5
Common tenure distribution[d]	1+	10.7	9.9	7.3	3.6
	2+	2.4	1.2	0.7	0.4
Epidemiological data					
Common tenure distribution[d]	1+	6.6	5.1	3.6	2.3
	2+	1.5	1.2	0.5	0.3

[a]1+ means category 1 or greater; 2+ means category 2 or greater.
[b]All participants = summary rates based on all mandatory and voluntary x-rays.
[c]Tenure >4 years = summary rates based on all miners with more than 4 years tenure in mining.
[d]Common tenure distribution = summary rates standardized to data in right-most column of Table 2.

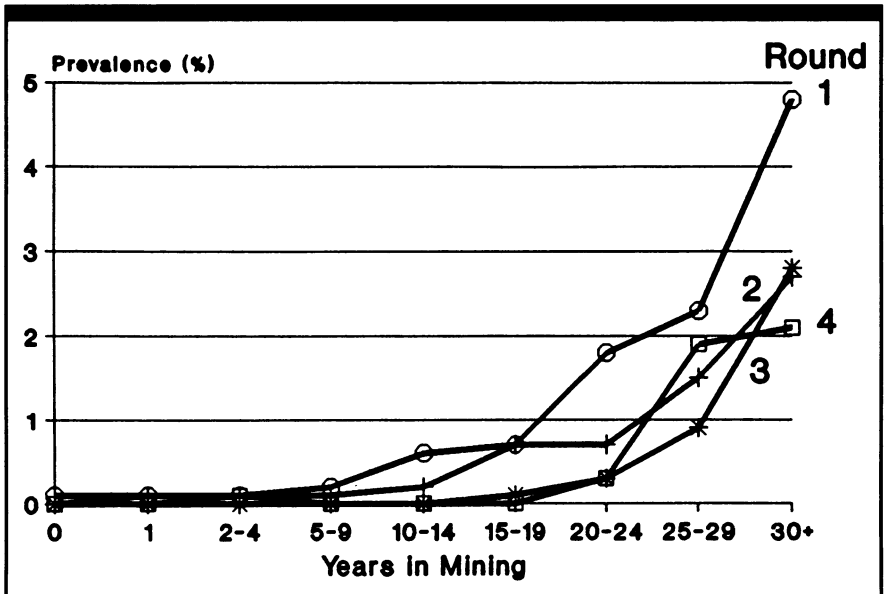

FIGURE 6—Tenure-specific prevalences of large opacities by round of the Coal Workers' X-ray Surveillance Program, based on the first readings only.

limits mandated by the 1969 law. However, this distribution is inadequate for estimation and comparison of prevalence levels and changes in older miners. Simple averages of the tenure-specific rates for miners with 20 or more years of work in mining indicate drops for category 1 or greater small rounded opacities from 34.5% to 23.3% for the first readers and from 12.1% to 5.7% for the second readers. Corresponding figures for category 2 or greater small rounded opacities were from 24.4% to 8.2% for the first readers and from 6.2% to 2.2% for the second readers. As might be expected, the reductions in prevalence (as measured by the ratios of the prevalences) are not so marked as those obtained using the 1986 work force distribution (Table 3, common tenure distribution). This may be because many of the older miners in round 4 had substantial lung dust burdens that were gained from exposures received before 1969.

In general, the prevalences estimated from the surveillance data are greater than those from the epidemiological study. It is not clear why this occurred. Possible reasons for the difference may lie with x-ray reader effects or with systematic differences in prevalence associated with the types and sizes of the mining operations feeding into the two programs. The epidemiological study has always involved large operations, which may have better dust-control procedures and thus lower levels of CWP than the smaller mines. Smaller mines form a large part of the input to the CWXSP.

Prior reports on the CWXSP have generally concentrated on certain restricted aspects of the data.[18–21] The findings from those papers are essentially the same as those presented here and are not discussed further.

There are obviously many problems in interpreting data from successive cross-sectional surveys. These include exodus of workers with ill-health, self-selection bias, changes in the x-ray classification standards, and interreader variability. There is also the possibility that readers' perceptions of CWP have been changing over time. Some reading exercises involving large amounts of film are planned. These should provide more reliable information on trends in prevalence of CWP in underground coal miners.

Longitudinal study approaches can control for many of the factors that interfere with interpreting cross-sectional data. In such studies, a specific cohort of workers is followed over time, with the x-rays being read at one time in a controlled reading environment. Althouse et al.[22] conducted one such study using films from the CWXSP and looking at x-ray changes over 10 years in new miners. Of 1825 miners studied, a net total of 15 developed category 1 opacities from category 0; no category 2 or greater readings were reported. While these reported incidence levels are encouraging, they should be regarded as only preliminary; further studies are needed owing to the relatively short observation period and to the fact that CWP is often not manifested until after more than 10 years of exposure.

In conclusion, despite methodological limitations, the results presented here demonstrate a temporal reduction in prevalence of CWP that is consistent with results from concurrent epidemiological investigations and coincides with reductions

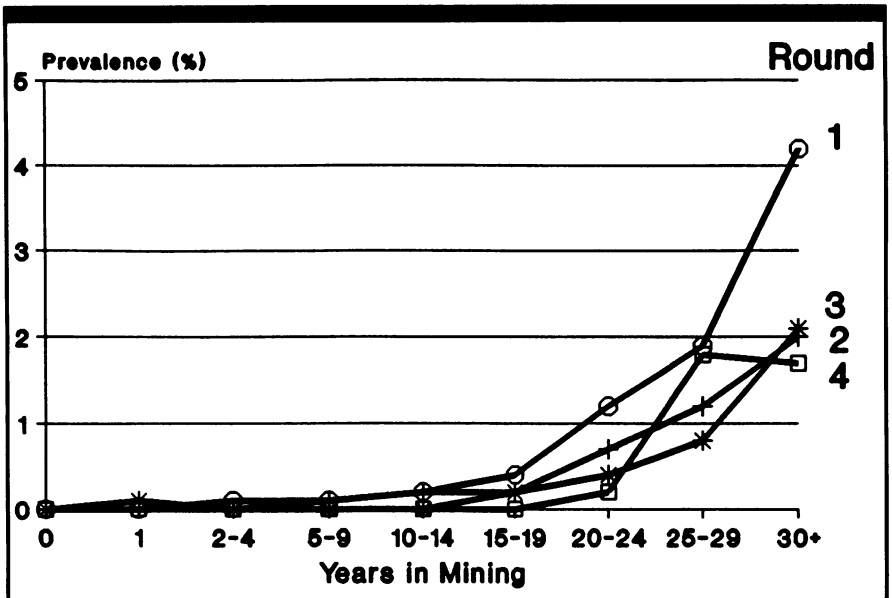

FIGURE 7—Tenure-specific prevalences of large opacities by round of the Coal Workers' X-ray Surveillance Program, based on the second readings only.

in dust levels mandated after 1969. Continual vigilance in dust control is necessary to ensure that these gains are maintained and, it is hoped, advanced. Emphasis on dust control is especially important with regard to the increasing use of mining techniques that tend to cause greater dust generation, such as longwall methods.[23] In addition, the implications of coal mine dust exposure for lung diseases other than pneumoconiosis must be fully determined. □

Acknowledgments

Thanks are due to Barbara Bonnett for help in preparation of the figures and in other programming, and to the many who have helped in preparing and reviewing the manuscript.

References

1. Coal Mine Health and Safety Act. US Pub L No. 91–173, Stat 2917.
2. 42 CFR PT 37. Specifications for medical examinations of underground coal miners. 35 Fed Reg 13 206-13 208 (1970).
3. 42 CFR PT 37. Specifications for medical examinations of underground coal miners. 38 Fed Reg 20 076-20 081 (1973).
4. 42 CFR PT 37. Specifications for medical examinations of underground coal miners. 43 Fed Reg 33 713-33 720 (1978).
5. 42 CFR PT 37. Specifications for medical examinations of underground coal miners. 44 Fed Reg 23 084-23 085 (1979).
6. Morgan RH. Proficiency examination of physicians for classifying pneumoconiosis chest films. *Am J Radiol.* 1979;132:803–808.
7. Bohlig H, Bristol LJ, Cartier PH. UICC/Cincinnati classification of the radiographic appearances of categories of simple pneumoconiosis: a cooperative study by the UICC committee. *Chest.* 1970;58:57–67.
8. International Labour Office. ILO U/C international classification of radiographs of pneumoconioses 1971. Occupational Safety and Health, Series no. 22 (Rev). Geneva, Switzerland: International Labour Office; 1972.
9. International Labour Office. *International Classification of Radiographs of Pneumoconiosis.* Rev ed. Occupational Safety and Health, Series no. 22 (Rev 80). Geneva, Switzerland: International Labour Office; 1980.
10. Attfield MD, Castellan RM. Epidemiological data on US coal miners' pneumoconiosis, 1960 to 1988. *Am J Public Health.* 1992;82:964–970.
11. Butani SJ, Bartholomew AM. *Characterization of the 1986 Coal Mining Work Force.* Washington, DC: US Bureau of Mines; 1988. Bureau of Mines Information Circular 9192.
12. Collins HPR, Dick JA, Bennett JG, et al. Irregularly shaped small shadows on chest radiographs, dust exposure, and lung function in coalworkers' pneumoconiosis. *Br J Ind Med.* 1988;45:43–55.
13. Mine Safety and Health Administration. *Injury Experience in Coal Mining, 1986.* Washington DC: US Govt Printing Office; 1987. Information Report 1157.
14. Jacobson M. Respirable dust in bituminous coal mines in the US. In: Walton WH, ed: *Inhaled Particles III.* Old Woking, England: Unwin Brothers; 1971:745–756.
15. Parobeck PS, Jankowski RA. Assessment of the respirable dust levels in the nation's underground and surface coal mine operations. *Am Ind Hyg Assoc J.* 1979;40:910–915.
16. Boden LI, Gold M. The accuracy of self-reported regulatory data: the case of coal mine dust. *Am J Ind Med.* 1984;6:427–440.
17. Mine Safety and Health Administration. Peabody Coal Company pleads guilty to dust sample tampering. Washington DC: Mine Safety and Health Administration; January 17, 1991. Press release USDL 91–23.
18. Felson B, Morgan WKC, Bristol LJ, et al. Observations on the results of multiple readings of chest films in coal miners' pneumoconiosis. *Radiology.* 1973;109:19–23.
19. Merchant JA. Coal workers' pneumoconiosis surveillance in the United States. In: *Proceedings of the Fifth International Conference on Pneumoconiosis.* Caracas, Venezuela: 1978.
20. Millar JD. *Statement before the House Subcommittee on Oversight, Committee of Ways and Means,* July 27, 1981.
21. Althouse RB. Ten years experience with the national coal workers health surveillance program. *MMWR CDC Surveill Summ.* 1985;34/1SS:33–37SS.
22. Althouse RB, Attfield MD, Kellie S. Use of data from the x-ray surveillance program for underground coal workers to evaluate the efficacy of the dust standard, presented at Conference on Medical Screening and Biological Monitoring for the Effects of Exposure in the Workplace, Cincinnati, July 1984. *J Occup Med.* 1986; 28:741–745.
23. Watts WF, Niewiadomski GE. Respirable dust trends in coal mines with longwall or continuous miner sections. In: *Proceedings of the Seventh International Pneumoconiosis Conference, Pittsburgh, USA, 1988.* Washington, DC: US Department of Health and Human Services; 1990:94–99. DHHS (NIOSH) publication 90–108, part I.