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Lung Cancer Among Navajo Uranium Miners*

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Lung cancer has been a rare disease among the Indians of the southwestern United States. However, the advent of uranium mining in the area has been associated with an increased incidence of lung cancer among Navajo uranium miners. This study centers on Navajo men with lung cancer who were admitted to the hospital from February 1965 to May 1979. Of a total of 17 patients with lung cancer, 16 were uranium miners, and one was a nonminer. The mean value of cumulative radon exposure for this group was 1139.5 working level months (WLMs). The predominant cancer type was the small cell undifferentiated category (62.5 percent). The low frequency of cigarette smoking in this group supports the view that radiation is the primary cause of lung cancer among uranium miners and that cigarette smoking acts as a promoting agent.

The association between uranium mining and lung cancer is well established today. The relationship between lung disease and mining was recognized in European studies as early as the 16th century.[1] Subsequent reports confirmed those early observations and attributed pulmonary malignancies to high radiation levels found in the mines.[2,3]

With the onset of intensive uranium mining in the United States in 1946, a similar risk of lung cancer associated with radiation was suspected. The risk was especially enhanced when excessive radon concentrations existed in the mine air.[4] Other research data on the miners have indicated that their risk of lung cancer is related to the magnitude of exposure to radon daughters.[5,6] Moreover, a recent study clearly demonstrated an excess of lung cancer among the white and Indian uranium miners of the southwestern United States.[7]

Numerous reports have largely attributed the etiology of lung cancer among uranium miners to radiation.[7,8] Another study, however, has suggested that the leading cause of lung cancer in uranium miners is cigarette smoking, since the incidence of lung cancer in noncigarette smokers is "insignificant."[9]

To cast more light on the controversy of cigarettes vs radiation in the causation of lung cancer, a number of Navajo uranium miners were studied, since they represent a singular group who smoked few cigarettes and had a very low rate of lung cancer before the advent of uranium mining.

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Materials and Methods

The Shiprock Indian Health Service Hospital and the Navajo Family Health Center are situated in the Four Corners area (New Mexico, Arizona, Utah, and Colorado). These facilities provide medical care to approximately 25,000 Navajos. This population includes many former and present uranium miners.

All male Navajo miners and nonminers with lung cancer admitted to the hospital between February 1965 and May 1979 constitute the basis for this report. Verification of occupation, radiation exposure records, and time spent in the mines was furnished by the National Institute for Occupational Safety and Health and the Center for Disease Control at Salt Lake City. Smoking histories were obtained from patients' charts. Diagnosis of lung cancer and cell type were established by biopsy, bronchoscopy, thoracotomy, or autopsy. The induction-latent period (time from onset of mining to diagnosis of cancer) was determined for each miner. Age at and date of death were obtained from hospital records and death certificates.

Data on cumulative radon daughter exposure are expressed as working level months (WLMs). One working level (WL) is equivalent to 1.3×10^5 MeV of potential α energy from radon daughters per liter of mine air. WLMs are the cumulative underground exposure in working months (170 hours) times concentration of radon daughters in WL specific for mine and calendar year.

Results

Tables 1 and 2 summarize the data for each miner. Of the 17 male Navajo patients with lung cancer admitted during the period February 1965 to May 1979, 16 (94.1 percent) were uranium miners; one (5.8 percent) was a nonminer (a former carriage-maker). Most of the uranium miners had also worked intermittently as shepherds and farm laborers.

The mean value of cumulative radon daughter exposure for the miners was 1,139.5 WLM, ranging from 58.8 to 2,125 WLM. The values for WLM were partly based on estimates. The mean length of time of exposure in the mines was 11.9 years, ranging

Table 1—*Data on Navajo Uranium Miners with Cancer of the Lung*

Case No.	Age at Death, yr	Date of Death	Time in Mines, yr	Working Level Months	Induction-Latent Period, yr
1	43	06-15-72	16	1,424.5	16
2	39	05-21-72	13	955	19
3	70	04-14-72	10	1,984.9	14
4	61	03-04-72	8	1,207.3	08
5	33	10-12-71	14	1,450	16
6	31	02-12-71	5	103	05
7	45	01-11-71	20	988.3	20
8	43	01-19-70	20	1,215.4	20
9	55	03-14-65	8	1,157.4	12
10	56	02-22-65	10	1,260	12
11	48	01-25-67	8	767	08
12	40	01-21-73	20	1,280	20
13	53	03-30-72	1/2	58.8	17
14	40	01-09-78	6	1,143	13
15	NA*	NA*	23	1,113	30
16	34	07-30-68	9	2,125	11

*Still alive, aged 52 years.

from six months to 23 years. The mean induction-latent period was 15 years, ranging from five to 30 years. The predominant cancer type found in this group was the small cell undifferentiated category (2A and 2B under the WHO classification scheme). The small cell undifferentiated type constituted ten of the 16 cases (62.5 percent); one cell type was unknown. Three cases were of the epidermoid type (19 percent), and two were of other types.

The smoking histories showed that 14 miners were nonsmokers, and two were light to moderate cigarette smokers (quantity not specified). The mean age at death of the miners was 46.1 years, ranging from 31 to 70 years. Six miners (38 percent) were aged 40 years or younger at time of death. One miner with lung cancer is still alive at age 52.

Discussion

Prior to 1946, the Navajo population was chiefly engaged in agricultural and handicraft activities: farming, shepherding, working with silver, sand-painting, and weaving rugs. Significantly low Indian morbidity and mortality rates for lung cancer, compared with both whites and blacks, were reported during this period.[10-13] The scarcity of lung cancer was attributed to the salubrious climate, absence of occupational and environmental carcinogens, and the infrequency of cigarette smoking.

Extensive uranium mining in the Four Corners area began about 1946, stimulated by the urgent demand for atomic weaponry. This led to large-scale employment of Navajo Indians to work in underground and milling operations. About 1968, uranium mining activities were curtailed because adequate stockpiles of uranium existed. Between the years 1946 and 1968, underground miners were exposed to high levels of radiation in the mine air.[14]

Radiation in a uranium mine results from the decay of uranium into radon gas whether the ore is mined or not. Radon gas diffuses through the atmosphere as radioactive radon daughters (polonium 218, lead 214, bismuth 214, polonium 214), which have a short half-life of about 30 minutes. The radon daughters become adsorbed to dust particles in the air, which are inhaled and deposited on the tracheobronchial epithelium. Radiation is emitted to the lung tissue from the radionuclides in the form of α-particles.

The onset of intensive uranium mining in 1946 introduced respiratory occupational hazards to the Navajos. Poorly ventilated mines, inadequate radiation detection, and deficient inspection allowed dangerously high levels of radiation in the mine air. The levels of radiation often exceeded established

Table 2—*Data on Navajo Uranium Miners with Cancer of the Lung*

Case No.	Method of Diagnosis	Cell Type	Survival Time	Smoking History
1	Pneumonectomy	Small cell	24 mo	No
2	Sputum cytology	None	14 mo	No
3	Lobectomy	Squamous cell	2 mo	No
4	Liver biopsy	Undifferentiated	9 mo	Light to moderate
5	Scalene node biopsy	Undifferentiated	10 mo	No
6	Thoracotomy	Squamous cell	8 mo	No
7	Pneumonectomy	Oat cell	13 mo	No
8	Thoracotomy	Undifferentiated	9 mo	No
9	Autopsy	Alveolar cell	1 day	No
10	Bronchoscopy	Undifferentiated	21 mo	No
11	Thoracotomy	Undifferentiated	5 mo	Light
12	Autopsy	Oat cell	17 mo	No
13	Thoracotomy	Adenocarcinoma	9 mo	No
14	Bronchoscopy	Squamous cell	24 mo	No
15	Thoracotomy	Small cell	Still alive	No
16	Mediastinotomy	Small cell	4 mo	No

standards in the early days of the uranium mining industry.[6]

The hazardous levels of radiation existed until American scientific studies, concurring with European data, reported the association of lung cancer with high radiation levels in uranium mines. Wagoner and his associates[15] in 1965 reported that the incidence of lung cancer increased from 3.1 per 10,000 miners per year to 116.1 per 10,000 miners per year over six exposure categories, ranging from fewer than 120 WLM to more than 3,720 WLM. Lundin and his group[5] described an excess of lung cancer in uranium miners within the range 120 to 359 WLM. The doubling dose for the induction of lung cancer among uranium miners has been estimated at 120 WLM or 240 rads (1 WLM is equivalent to between 1 and 5 rads).

In this study, the mean cumulative radiation exposure was 1,139.5 WLM. Previous reports[5-15] have shown a notable excess in incidence of lung cancer associated with high radiation levels at this range. The highest incidence of lung cancer is occurring now in those miners who were exposed to cumulative radiation levels of 1,000 WLM or more. In this series, 11 miners had total cumulative radiation exposures in excess of 1,000 WLM.

The mean length of time spent in the mines for this group was 11.0 years. Wagoner and his group[16] reported a tenfold increase in lung cancer among long-term uranium miners. Each of 13 miners in this study spent ten years or longer in the mines.

The induction-latent period in this study ranged from five to 30 years, with a mean of 15 years. Long induction-latent periods have previously been reported. Saccomanno and his group[17] reported an average induction-latent period of 15.9 years in their study of lung cancer among uranium miners. In our study, lung cancer did not appear sooner than five years from onset of exposure.

The predominant cancer appearing in this series was the small cell undifferentiated type, composing 62.5 percent. Small cell undifferentiated carcinomas occurred in excess in uranium miners,[17] which is in accord with our study.

Cigarette smoking has been accepted as a major etiologic factor in the causation of lung cancer.[18] Cigarette smoking also plays an important role in the excess of lung cancer among uranium miners.[6-8,9] However, in this study, of the 16 miners with lung cancer, 14 were nonsmokers; two miners were light to moderate smokers. Archer and his group[19] reported that lung cancer in cigarette-smoking uranium miners has a shorter induction-latent period than lung cancer in nonsmoking miners. We also observed a shorter induction-latent period in the two cigarette-smoking miners, of eight years each (mean induction-latent period for the group was 15 years). The foregoing data imply that the nonsmoking miners still have an increased risk of lung cancer, and their tumors take longer to develop.

A recent study has observed a high lung cancer risk among nonsmoking miners; that smoking seems to offer some protection against lung cancer.[8] The study suggests that there might be a decreased α-radiation dose to the epithelium in smokers because of a protective thick mucous sheath, since underground miners are prone to the development of bronchitis.

Information on smoking habits obtained from hospital records tends, at times, to be obscure. The smoking history data for this series appeared to be credible. Also, the Navajos are traditionally nonsmokers.

The early age at death in this group was noteworthy. The average age at death was 46.1 years. Six miners were aged 40 years or younger at death. One miner with lung cancer is still alive at age 52.

Conclusions

1. Features of the lung cancers observed among the 16 Navajo uranium miners are consistent with those observed by others among whites, which are largely attributed to radiation exposure.

2. The minimal use of cigarettes among this group of uranium miners is a strong argument that cigarette smoking is not a major factor in the lung cancers of uranium miners. Our data indicate that cigarettes act as a promoting agent, and that radiation is the major cancer initiating agent.

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