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An ecologic study of skin cancer and environmental arsenic exposure

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Summary. We conducted an epidemiologic study of skin cancer incidence rates for four counties in Montana. The two counties considered to be exposed to arensic were Deer Lodge, containing the former Anaconda copper smelter, and Silver Bow, containing an open pit copper mine. Residents in these counties had potential exposure to arsenic and other heavy metals. Gallatin and Park counties served as controls. All histologically proven skin cancer cases during the period January 1980 through June 1986 were collected from pathology services and dermatologists in these four counties. In addition, all skin cancer cases from four dermatologists practicing in urban referral areas outside the counties were reviewed. Results were analzyed by individual as well as by two different definitions of anatomically distinct lesions: the National Cancer Institute (NCI) definition and the study definition. There were 1616 individuals with skin cancer in the four counties during the period under consideration, yielding 2252 (NCI definition) and 2451 (study definition) cases. The clinical features of the skin cancers in the exposed counties were not similar to those described for arsenic-related skin cancer. The age-adjusted annual skin cancer rates were higher for the two control counties as compared to either the county with the former smelter, Deer Lodge, or the county with the mine, Silver Bow. Our results cannot be explained by differences in ascertainment, latitude, or altitude. They can be partially explained by differences in both outdoor employment and medical practice. The overall skin cancer incidence rates for the exposed counties were well within the range of skin cancer rates observed for other locations in the United States.

Key words: Skin cancer – Arsenic – Heavy metal – Outdoor occupations – Copper smelter – Environmental contamination – Superfund site

Introduction

The Anaconda copper smelter adjacent to the town of Anaconda, Montana, operated for more than nine decades until plant closure in 1980. The Anaconda open pit copper mine in Butte, Montana, had been the primary supplier of copper ore to the Anaconda smelter. In the copper-smelting process, arsenic trioxide, a natural contaminant of the copper ore deposits, was separated from the copper and became a constitutent of the tailings from the smelting operations. Arsenic trioxide was also liberated into the air from the smelter stacks. The areas in Butte and Anaconda are a part of the Clark Fork Superfund sites extending for more than 120 miles downstream from Butte and Anaconda. In the Butte and Anaconda areas alone, there are more than 6500 acres considered to be contaminated at levels of arensic in the soil above 90 ppm. In addition, there are about 27 million cubic yards of furnace slag and 300000 cubic yards of flue dust located in and around Anaconda. The arensic concentration can run as high as 10% in these wastes (U.S. Environmental Protection Agency 1990). The Anaconda smelter site and surrounding area have been contaminated with significant and varying amounts of arsenic trioxide, cadmium, copper, lead, zinc, and possibly beryllium (Clement Associates 1986).

Cohort mortality studies of smelter workers, including workers at the Anaconda site, have clearly demonstrated a dose-dependent increase in respiratory cancer among arsenic-exposed workers (Lee and Fraumeni 1969; Lee-Feldstein 1983, 1986; Welch et al. 1982; Enterline and Marsh 1982; Enterline et al. 1987). Skin cancer (usually a nonfatal condition) was not the focus of these occupational mortality studies. Skin cancer has been documented among residents of Taiwan consuming arsenic-contaminated well water (Tseng et al. 1968). The U.S. Environmental Protection Agency (EPA) has used the Tseng et al. data from Taiwan to estimate the cancer risk for environmental arsenic exposures. Based on calculations in the Anaconda and Butte areas, EPA considers the environmental pollution associated with the mining and smelting operations in two counties containing these operations to pose a considerable cancer risk to the residents of the two counties. At the time of this study, there were no epidemiologic data that demonstrated an association or lack of association between skin cancer and community exposure to arsenic-contaminated soils in the Anaconda area.

Our study was initiated due to concern that arsenic from mining and milling smelting operations may have posed a substantial increase in skin cancer risk to the

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populations in the Anaconda and Butte areas. The two primary objectives of this study were: (1) to compare skin cancer incidence rates in two counties containing a former smelter and an open pit mine to rates in control counties, and (2) to compare clinical features of cases of skin cancer in these counties to previously described arsenic-related skin cancer in Taiwan (Tseng 1977; Yeh et al. 1968; Yeh 1973) and non-arsenic-related skin cancer in the United States (Scotto et al. 1974; Lynch et al. 1970).

Materials and methods

Residents of two counties – Deer Lodge County (city of Anaconda and the former smelter) and Silver Bow County (city of Butte and open pit copper mine) – were considered potentially exposed to arsenic and other heavy metals. Gallatin and Park Counties were selected as control counties.

Skin cancer incidence data were collected from: (a) consecutive surgical and biopsy specimen reports from pathologists' and hospital records, and (b) dermatologists' office records. As skin cancer is rarely a fatal disease, autopsy reports were not used.

We first identified and contacted all pathologists and dermatologists practicing full or part time in the four study counties as well as those dermatologists practicing in nearby urban referral areas (Missoula, Great Falls, and Helena). Trained researchers selected all designated primary skin malignancies from consecutive pathology reports on file at pathology laboratories and hospitals. Data from dermatologists were collected by the same researchers, identifying all skin cancers from log books or pathology reports. Two dermatologists collected the pertinent cases from their own log books because of their concerns about patient confidentiality.

Primary skin malignancies were coded by histology, using the Ninth Revision, of the International Classification of Disease-Oncology (ICD-O) codes (Table 1). The body location of skin cancer was coded to one of 18 sites. As skin cancer of the palms and soles has been reported among populations ingesting arsenic (Tseng 1977; Yeh et al. 1968; Yeh 1973), skin cancers involving the palms or soles were coded specifically to the pertinent area.

A case was defined as a histologically proven malignant skin cancer diagnosed during the period 1 January 1980 to 30 June 1986. Multiple skin cancers for a given patient were accepted only if there were two or more malignant lesions which were independent and distinct from each other anatomically and/or histologically. Anatomically distinct lesions were defined in two manners: the National Cancer Institute (NCI) definition (after Scotto et al. 1974) and our broader "study" definition.

According to the NCI definition, only cancers occurring in separate body site codes were considered anatomically distinct. Since site codes sometimes covered wide areas of the body, we also used a broader study definition. Cancers which were described on the pathology report as visually separate and distinct, even if they were within the same site code, were considered anatomically distinct. According to this study definition, two cancers of questionable distinction were considered to be the same if they occurred within the same site code within a 12-month period. Known recurrences of skin cancers were not included. Cancers which occurred more than 12 months after the previous diagnosis, and were not an obvious recurrence of a skin cancer previously diagnosed in the study period, were considered distinct cancers.

Demographic information (age, sex, occupation, address, city, zip code, and county of residence) was obtained from the patient's chart facesheet in the participating dermatologist's office. For those cancer patients identified from consecutive pathology reports, demograhic data were gathered via hospital records or follow-up with the referring physician. The remaining data were gathered with the assistance of the Helena Public Library, using city and zip code directories.

Age-race-sex-specific population data for the four counties (1980 census) were obtained from the U.S. Census Bureau. The U.S. Census Bureau estimates for the years 1982 and 1984 were also obtained. The State of Montana county data book (1980) provided county-specific demographic information.

The average annual age-sex-race-specific incidence rates of skin cancer for the four counties over the 6 1/2-year observation period were calculated. For comparison, directly adjusted rates were calculated for each of the four counties, with combined populations of the four counties as the standard.

Table 1. Skin cancer histology codes

Histology	ICD[a] code
Basal cell carcinoma	80903
Squamous cell carcinoma	80703
Basosquamous carcinoma	80943
Bowen's disease	80812
Carcinoma, in situ	80102
Melanoma	87203
Acral lentiginous	
Nodular	
Superficial spreading	
Lentigo maligna melanoma	
Lentigo maligna	87422
Other	
Carcinoma, NOS[b]	80103
Ceruminous adenocarcinoma	84203
Dermatofibrosarcoma, NOS	88323
Fibrous histiocytoma, malignant	88303
Sebaceous adenocarcinoma	84103
Skin appendage carcinoma	83903
Apocrine adenocarcinoma	84013
Sweat gland adenocarcinoma	84003
Spindle cell, epidermoid	80743
Pleiomorphic adenoma (adenosquamous carcinoma)	85603
Kaposi's sarcoma	91403

[a] ICD, International Classification of Disease-Oncology (Ninth Revision)
[b] NOS, Not otherwise specified

Results

Demographic data drawn from the State of Montana county data book revealed that the four study counties were predominately white (97%–99%). The combined population of the exposed counties was 50610, while the combined population of the control counties was 55525. The counties differed in urbanization, with 98%–100% of the population in the exposed counties being urban, versus 51%–55% of the population of the control counties. A total of 154 farms were recorded in the exposed counties, while 1135 farms were recorded in the control counties. All four counties are located at a similar latitude and the primary population centers are at similar elevations.

Two hospital pathology departments (21.8%), two physician laboratory services (38.2%), and six dermatologists (40.1%) served as sources of skin pathology reports.

Table 2. Number of skin cancer cases by county and gender

	Silver Bow		Deer Lodge		Gallatin		Park		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
Male										
NCI	411	54.65	76	47.20	528	52.69	204	60.53	1219	54.13
Study	430	54.36	80	45.98	583	52.15	223	60.60	1316	53.69
Female										
NCI	338	44.95	82	50.93	464	46.31	128	37.98	1012	44.94
Study	357	45.13	91	52.30	524	46.87	139	37.77	1111	45.33
Unknown										
NCI	3	0.40	3	1.86	10	1.00	5	1.48	21	0.93
Study	4	0.51	3	1.72	11	0.98	6	1.63	24	0.98
Total										
NCI	752	100.00	161	100.00	1002	100.00	337	100.00	2252	100.00
Study	791	100.00	174	100.00	1118	100.00	368	100.00	2451	100.00

Table 3. Distribution of skin cancer cases by histologic diagnosis and county[a]

	Silver Bow		Deer Lodge		Gallatin		Park		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
In situ carcinoma										
NCI	12	1.69	6	4.05	19	1.94	6	1.81	43	1.98
Study	12	1.60	6	3.82	21	1.92	6	1.66	45	1.91
Squamous cell carcinoma										
NCI	116	16.32	31	20.95	142	14.52	80	24.17	369	17.02
Study	123	16.44	31	19.75	154	14.09	89	24.65	397	16.83
Bowen's disease										
NCI	22	3.09	2	1.35	4	0.41	4	1.21	32	1.48
Study	23	3.07	2	1.27	4	0.37	4	1.11	33	1.4
Basal cell carcinoma										
NCI	510	71.73	100	67.57	755	77.20	227	68.58	1592	73.43
Study	534	71.39	105	66.88	851	77.86	248	68.7	1738	73.68
Basosquamous carcinoma										
NCI	12	1.69	0	0.00	14	1.43	1	0.30	27	1.25
Study	12	1.60	0	0.00	14	1.28	1	0.28	27	1.14
Malignant melanoma										
NCI	33	4.64	4	2.70	38	3.89	11	3.32	86	3.97
Study	34	4.55	4	2.55	39	3.57	11	3.05	88	3.73
Other										
NCI	5	0.70	4	2.70	5	0.51	2	0.60	16	0.74
Study	5	0.67	4	2.55	5	0.46	2	0.55	16	0.68
Diagnosis missing										
NCI	1	0.14	1	0.68	1	0.10	0	0.00	3	0.14
Study	5	0.67	5	3.18	5	0.46	0	0.00	15	0.64
Total										
NCI	711	100.00	148	100.00	978	100.00	331	100.00	2168	100.00
Study	748	100.00	157	100.00	1093	100.00	361	100.00	2359	100.00

[a] Excluding subjects with missing age and sex

Table 4. Histologic diagnosis of skin cancer cases by body location among males[a]

	In situ carcinoma		Other		Squamous cell carcinoma		Bowen's disease		Basal cell carcinoma		Basosquamous carcinoma		Malignant melanoma		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Head and neck																
NCI definition	21	72.41	6	75.00	186	80.17	7	43.75	729	86.68	13	92.86	22	52.38	984	83.25
Study definition	22	73.33	6	75.00	204	80.63	8	47.06	791	86.54	13	92.86	22	51.16	1066	83.35
Trunk																
NCI definition	4	13.79	0	0.00	8	3.45	3	18.75	76	9.04	0	0.00	14	33.33	105	8.88
Study definition	4	13.33	0	0.00	8	3.16	3	17.65	82	8.97	0	0.00	15	34.88	112	8.76
Genital perineum																
NCI definition	0	0.00	2	25.00	6	2.59	2	12.50	0	0.00	0	0.00	0	0.00	10	0.85
Study definition	0	0.00	2	25.00	6	2.37	2	11.76	0	0.00	0	0.00	0	0.00	10	0.78
Limbs																
NCI definition	4	13.79	0	0.00	30	12.93	4	25.00	28	3.33	1	7.14	5	11.90	72	6.09
Study definition	4	13.33	0	0.00	32	12.65	4	23.53	33	3.61	1	7.14	5	11.63	79	6.18
Skin appendage																
NCI definition	0	0.00	0	0.00	0	0.00	0	0.00	1	0.12	0	0.00	0	0.00	1	0.08
Study definition	0	0.00	0	0.00	0	0.00	0	0.00	1	0.11	0	0.00	0	0.00	1	0.08
Site not specified																
NCI definition	0	0.00	0	0.00	2	0.86	0	0.00	7	0.83	0	0.00	1	2.38	10	0.85
Study definition	0	0.00	0	0.00	3	1.19	0	0.00	7	0.77	0	0.00	1	2.33	11	0.86
Total																
NCI definition	29	100.00	8	100.00	232	100.00	16	100.00	841	100.00	14	100.00	42	100.00	1182	100.00
Study definition	30	100.00	8	100.00	253	100.00	17	100.00	914	100.00	14	100.00	43	100.00	1279	100.00

[a] Excluding subjects with missing age and sex

A total of 1616 skin cancer patients (individuals) were identified, yielding 2252 cases (NCI definition) and 2451 cases (study definition). The ratio of cases to individuals, a measure of multiple skin cancers in the same individual, was greatest for Park County (1.53 by NCI definition, 1.67 by study definition) and least for Deer Lodge County (1.24 by NCI definition, 1.34 by study definition).

The mean age at first diagnosis for all individuals was 64.9 years, with a median of 67 years. The distribution of ages at first diagnosis was similar among counties. Date of birth and/or gender was missing in 4.5% of individuals. The percent of individuals with missing date of birth and/or gender ranged from 1.4% (Park County) to 8.5% (Deer Lodge County).

The breakdown of cases by sex and county is shown in Table 2. Table 3 presents data by diagnosis and county. Basal cell carcinoma and squamous cell carcinoma were the two most predominate histologic diagnoses, with an overall percentage of 73.7% and 16.8%, respectively (study definition). Under both the NCI and the study case definition, Gallatin County (control) had the highest basal cell cancer percentage while Park County (control) had the highest squamous cell cancer percentage. Cases with missing data were similar in cancer diagnoses to those without missing age and/or sex information.

Histologic diagnosis by body location and gender are presented in Tables 4 and 5. Basal cell carcinoma was more frequent on the head and neck than was squamous cell carcinoma. The patterns of body location for basal cell carcinoma were similar for both sexes. Compared to males, females had considerably fewer squamous cell carcinomas of the head and neck but more of the limbs.

The age-adjusted skin cancer rates and the respective 95% confidence limits for each county are shown in Tables 6–8. Rates are shown per individual (Table 6), per NCI case definition (Table 7), and per study case definition (Table 8). For total rates and rates for males, Deer Lodge County had a significantly lower ($P<0.05$) rate than Silver Bow County. When Deer Lodge County was compared to either Gallatin or Park Counties, it had a significantly lower ($P<0.05$) rate for males, females, and total for all three definitions. Gallatin County had a significantly higher ($P<0.05$) rate for males, females, and total for all three definitions than either Silver Bow or Park Counties.

An examination of the occupations of the cases in our data base indicated that there were much higher proportions of individuals with outdoor occupations (agriculture, forestry, gardening, and logging) in both Gallatin and Park Counties than in Silver Bow and Deer Lodge Counties. Less than 1% (5/745) of the skin cancer cases in Silver Bow County and none of the cases in Deer Lodge County worked in "outdoor" occupations, whereas the corresponding percentages in Gallatin and Park

Table 5. Histologic diagnosis of skin cancer by body location among females[a]

	In situ carcinoma		Other		Squamous cell carcinoma		Bowen's disease		Basal cell carcinoma		Basosquamous carcinoma		Malignant melanoma		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Head and neck																
NCI definition	21	72.41	6	75.00	186	80.17	7	43.75	729	86.68	13	92.86	22	52.38	984	83.25
Study definition	10	71.43	4	50.00	83	60.58	8	50.00	641	85.35	10	76.92	11	25.00	767	77.79
Trunk																
NCI definition	4	13.79	0	0.00	8	3.45	3	18.75	76	9.04	0	0.00	14	33.33	105	8.88
Study definition	0	0.00	0	0.00	10	7.30	2	12.50	68	9.05	0	0.00	8	18.18	88	8.92
Genital perineum																
NCI definition	0	0.00	2	25.00	6	2.59	2	12.50	0	0.00	0	0.00	0	0.00	10	0.85
Study definition	0	0.00	2	25.00	7	5.11	2	12.50	5	0.67	0	0.00	0	0.00	16	1.62
Limbs																
NCI definition	4	13.79	0	0.00	30	12.93	4	25.00	28	3.33	1	7.14	5	11.90	72	6.09
Study definition	4	28.57	1	12.50	35	25.55	4	25.00	25	3.33	2	15.38	24	54.55	95	9.63
Skin appendage																
NCI definition	0	0.00	0	0.00	0	0.00	0	0.00	1	0.12	0	0.00	0	0.00	1	0.08
Study definition	0	0.00	1	12.50	0	0.00	0	0.00	1	0.13	0	0.00	0	0.00	2	0.20
Site not specified																
NCI definition	0	0.00	0	0.00	2	0.86	0	0.00	7	0.83	0	0.00	1	2.38	10	0.85
Study definition	0	0.00	0	0.00	2	1.46	0	0.00	11	1.46	1	7.69	1	2.27	15	1.52
Total																
NCI definition	29	100.00	8	100.00	232	100.00	16	100.00	841	100.00	14	100.00	42	100.00	1182	100.00
Study definition[b]	14	100.00	8	100.00	137	100.00	16	100.00	751	100.00	13	100.00	44	100.00	983	100.00

[a] Excluding subjects with missing age and sex
[b] Site missing in three study definition cases

Table 6. Age-adjusted annual skin cancer rates per 100000 by county and gender for individuals

Sex	Silver Bow	Deer Lodge	Gallatin	Park
Male				
Rate	203.1	119.9	342.3	230.0
95% C.I.	177.8–232.0	88.3–162.3	313.8–373.4	187.3–282.0
Female				
Rate	181.5	135.7	315.5	209.0
95% C.I.	158.3–207.9	101.1–181.5	287.2–346.6	168.7–258.6
Total				
Rate	192.3	127.7	329.0	219.6
95% C.I.	175.0–211.4	103.6–157.3	308.7–350.6	189.5–254.2

Counties were 9% and 15%, respectively. The difference in outdoor occupation between exposed and control counties was statistically significant by the chi-square test ($P < 0.01$).

Since no increased risk was found in the exposed counties, we considered the power of the study to detect a reasonable magnitude of increased risk. Using the average rate (NCI definition) for Gallatin and Park Counties as the comparison rate, the study had more than 80% power in detecting an increase of 20% in risk for Deer Lodge County (i.e., a relative risk of 1.20 at the 0.05 significance level). As Silver Bow County had a larger population, the corresponding power in detecting a 10% increase in risk in Silver Bow County was 89%. Therefore, we feel that the power of the study was sufficient in detecting a relatively small increase in skin cancer risk, if one existed.

Discussion

Deer Lodge County, site of the Anaconda smelter, had the lowest skin cancer rates while a control county (Gal-

Table 7. Age-adjusted annual skin cancer rates per 100000 by NCI case definition

Sex	Silver Bow	Deer Lodge	Gallatin	Park
Male				
Rate	287.6	150.7	498.5	390.3
95% C.I.	257.2–321.5	114.9–197.3	464.0–535.6	333.8–456.2
Female				
Rate	230.3	166.0	457.9	267.8
95% C.I.	204.1–259.8	127.3–215.9	423.6–494.9	221.8–323.1
Total				
Rate	259.1	158.3	478.3	329.4
95% C.I.	238.8–281.1	131.2–190.8	453.8–504.2	292.3–371.1

Table 8. Age-adjusted annual skin cancer rates per 100000 by study definition of case

Sex	Silver Bow	Deer Lodge	Gallatin	Park
Male				
Rate	301.6	159.1	551.4	425.7
95% C.I.	270.4–336.3	122.2–206.7	515.0–590.3	366.5–494.2
Female				
Rate	242.6	177.7	515.2	289.4
95% C.I.	215.7–272.8	137.5–229.0	478.8–554.4	241.5–346.6
Total				
Rate	272.3	168.3	533.4	358.0
95% C.I.	251.5–294.7	140.3–201.7	507.5–560.7	319.2–401.3

latin) experienced the highest rates. The differences in rates for the exposed and control counties were the reverse of what we would expect if arsenic were causing an increase in the skin cancer rate. In addition, the specific skin cancer type determined by the Environmental Protection Agency (EPA) as related to arsenic exposures (squamous cell carcinoma of palms and soles) was found only in Gallatin County (two cases). The ratio of skin cancer cases to individuals (a measure of the presence of multiple skin cancers in the same individual) was lowest in Deer Lodge County and highest in the control county of Park. Tseng et al. (1968), in the study of arsenic-related skin cancer associated with contaminated well water, noted multiple skin cancers in 99.5% of individuals with skin cancer.

Skin cancer rates for the exposed counties were well within the range of skin cancer rates observed for other locations in the United States. Our data (based on the NCI definition) can be compared to those in the Third National Cancer Survey (TNCS). For the eight areas surveyed, the annual age-adjusted incidence rates (1977–78) for non-melanoma skin cancer (more than 95% of all skin cancers) among white males ranged from 172.1 for Detroit to 562.9 for New Orleans, with an average of 310.4 for all areas. Both the Deer Lodge and Silver Bow male rates (150.7 and 287.6, respectively) compared favorably to these TNCS rates. For white females, the TNCS rates ranged from 108.0 for Detroit to 264.2 for New Orleans, with an average of 172.6 for all areas. The Deer Lodge and Silver Bow female rates (166.0 and 230.3 respectively) were well within the TNCS range.

We do not believe that the completeness of ascertainment of the skin cancer case data can explain county differences. Montana, a relativey sparsely populated state, has few hospitals and pathology laboratories in any one community. In the past, most of the individual physicians and smaller hospitals in this area sent pathology specimens to one of three pathology laboratories. We had full cooperation of all three laboratories. More recently there has been an influx of dermatologists into urban areas of Montana. The dermatologists tend to do their own pathology assessments of biopsies they obtain. Seven of nine dermatologists in Bozeman, Butte, Helena, and Missoula allowed us access. Patients in the exposed counties may have been seen by a dermatologist in Missoula. Two of the three Missoula dermatologist participated in the study. If the remaining one dermatologist in Missoula, who did not allow us access, had seen as many cases from Deer Lodge and Silver Bow Counties as the total of the two dermatologists who allowed us access, we would have missed 25 cases. If his number of patients was the average of the other two, we would have missed only 12–13 cases. Due to the distance, it would be highly unusual to expect a patient from either Gallatin or Park Counties to go to Missoula for specialty treatment of skin cancer, especially since two dermatologists practice in Gallatin County.

Previous epidemiologic studies have found that the dominant risk factor for skin cancer is ultraviolet radiation, which depends on latitude and altitude (Fears et al. 1977). Latitude and altitude were similar in the four study counties, and thus should not be confounding factors in comparing skin cancer incidence rates among the four

counties. However, individual behavior associated with ultraviolet radiation exposure might vary from county to county. Occupations with a considerable amount of time spent outdoors would entail a high degree of ultraviolet radiation exposure, and, thus, an associated higher risk for skin cancer. The available data do not allow us to adjust the skin cancer rates of occupation, as age distributions of population by occupation are not available by county. However, employment information was collected for study cases. An examination of the occupations of cases indicated that there were much higher proportions of farm or agricultural workers in both Gallatin and Park Counties than in Silver Bow and Deer Lodge Counties. The difference in outdoor occupation between the exposed and control counties was statistically significant and likely accounted for at least part of the difference in skin cancer rates observed between the exposed and control counties.

Additional issues that could help explain the differences in skin cancer rates include medical practice differences, diagnostic criteria differences, and migration. Bozeman (Gallatin County) had two practicing dermatologists during the study period; Butte (Silver Bow County) had only recently acquired a full-time dermatologist. In a community without dermatologists, the primary care practitioners may treat most skin disorders. Primary care practitioners and dermatologists may differ in the proportion of surgical specimens submitted for pathologic diagnosis.

While there can be diagnostic criteria differences among the pathologists and dermatologists, this should not be a major factor for the two most common types of skin cancer: basal cell and squamous cell.

Emigration could cause a deficit in skin cancer incidence rates if those at greatest risk left in disproportionate numbers. Silver Bow and Deer Lodge both have experienced emigration at least since the 1970s. In the 1980s the closing of the smelter and copper mine might have added to this migration out of the area. Conversely, Gallatin and Park Counties have had an increase in population during the same period. While population emigration can affect the results of a study such as this, it is usally the younger individuals of the population who leave an economically depressed area, not those over age 55, who are at highest risk for developing skin cancer.

Finally, limitations associated with the ecologic study design may have influence findings. Ecologic fallacy may be introduced when causal inference about an individual phenomenon or process is made on the basis of observations of groups. This limitation could be avoided only by using a different study design. An appropriate follow-up epidemiologic study design to investigate the skin cancer issue in Montana is a case-control study which includes analysis of individual residential and occupational histories.

To conclude, the age-adjusted annual skin cancer incidence rates were found to be higher in the control counties than in the two exposed counties. This finding can be explained at least in part by a higher proportion of residents in outdoor occupations in the control counties. The percentages of skin cancers due to squamous cell carcinoma of the palms and soles and basal cell carcinoma of the trunk (types of skin cancer frequently reported among those ingesting arsenic-contaminated well-water) were greater in Gallatin than in Deer Lodge County. The overall skin cancer incidence rates for the exposed counties were well within the range of skin cancer rates observed for other locations in the United States.

One of the primary concerns which initiated this study was the potential for a large excess of skin cancer among the smelter county residents. Based on the findings in this study, residents in the exposed counties of Deer Lodge and Silver Bow did not experience an increase in skin cancer incidence as compared to the residents in Gallatin and Park Counties.

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