Increased Leukemia, Lymphoma, and Spontaneous Abortion in Western New York Following a Flood Disaster

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THE NEW YORK STATE DEPARTMENT OF HEALTH was asked in September 1978 to investigate four cases of leukemia and lymphoma in a small rural village (Almond) in the western part of the State. The village is on the boundary of Allegany and Steuben Counties, but most of its population and most of its geographic area are within the boundaries of Allegany County. The four cases had been diagnosed during the preceding 10 months among the approximately 2,000 residents of the Almond area. They were initially investigated by the Epidemiology Unit of the University of Rochester Cancer Center. Local government officials expressed concern to State health department officials about the high rate of disease that these cases represented. The persons with the index cases were not related through personal, occupational, or residential association. The only apparent characteristic they all shared was that they were long-term residents of Almond.

There were no industrial activities in the area which would suggest that the cluster of cases was caused by an obvious occupational carcinogenic exposure. Local industry is diverse and typically rural. At a town meeting called by local authorities, residents had expressed general concern about the high natural background radiation in the region from indigenous surface rock deposits (*1*), radiation from a nuclear processing plant in a neighboring county (*2*), and suspected radiation from a new town water well that had been drilled about 5 years before.

We provide here a preliminary description of en-

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vironmental and epidemiologic investigations of cases of cancer and fetal death among residents of the area surrounding Almond. Cancer registry reports and death records were used to determine temporal trends in cancer rates for this town and the surrounding communities. The investigation was eventually expanded to include an examination of reproductive events, based on existing live birth and fetal death records.

We used the leukemia (ICDA 204–208) and lymphoma (ICDA 200–202) rates for upstate New York (New York State exclusive of New York City) to compute the estimated number of cases of these diseases that might be expected in the population of the Almond area. Compared with the four cases per annum observed in this population of 2,000, 0.46 per annum would have been expected on the basis of the cancer registry rates. By extending our investigation, we found that the four cases were part of a regional rise in leukemias and lymphomas of at least 4 years' duration, which resulted in an excess of 30 to 35 malignancies. Combined leukemia and lymphoma mortality rates for this region of New York State had not been high between 1950 and 1969 (*3*).

Environmental Investigations

Our environmental investigations were designed to respond to the residents' specific concerns as well as to examine the suspected environmental hazards. Water samples were taken over several months in 1978–79 from the two sources of supply serving the Almond population, the village's public well and the Almond High School well. These radiological samples were analyzed by the New York State Department of Health's Division of Laboratories and Research. The residents were particularly concerned about the village well, which had been drilled in 1972. Their previous water supply, a natural spring, had been destroyed in June 1972 by a major flood resulting from the tropical storm Agnes (*4*). The town had then built a new well-house and pumping station, as well as a new storage facility, at a higher elevation just outside the village. The radiation levels of this facility, which were determined by analysis of gross particle activity and of radon, were found to be well within acceptable limits as defined by Federal standards.

Background radiation levels were measured during a radiological survey of the elementary school, the high school, the village's roads and creek, and a local

dump site, where it was believed a small amount of radioactive waste material had been buried. The survey was conducted during October 1978 by regional radiological health specialists from the Buffalo Area Office of the State health department and by the Allegany County radiological officer. Acceptable levels of 5–8 micro *R* per hour were found in both schools, along the roads and creek, and along the access road to the dump.

Discussions with the owner-operator of the suspect dump site and with maintenance people from a local college revealed that in 1966 several glass containers of waste had been buried in the landfill. Since the nature of the buried materials could not be determined because of the vagueness of available records, extensive measurements of radiation levels at the burial site were made. All readings were negative. Analyses of water samples taken at the dump site also produced negative readings. Inquiries at the Bureau of Radiological Health of the State health department and at the Bureau of Radiation of the New York State Department of Environmental Conservation revealed that there were no known unusual natural or manmade (including nuclear material disposal) sources of radiation in Allegany County.

Epidemiologic Investigations

At the same time that the radiological survey of the Almond area environment was being done, we were also conducting an epidemiologic survey of cancer rates in the towns of the surrounding counties (Allegany and Steuben). From 1966 on, the New York State Department of Health has maintained a uniform cancer registration program that is based on the date of diagnosis, and data from this program became the basis of our epidemiologic investigation. We examined the rates for all cancers from 1966 through the most recent year for which we had complete data, 1977. In table 1 the incidence rates for leukemia and lymphoma for upstate New York are compared with those from other major cancer reporting systems in the United States. Since mortality rates for these tumors are not higher in New York than the rest of the country and there is no reason to believe that incidence rates for these tumors should be higher, these data suggest that our case reporting in New York is essentially complete and is comparable to that of other major reporting systems in the United States. Similar comparability was found for the other major cancers.

Almond lies at the headwaters of the Canisteo River, which begins in Allegany County and flows through Steuben County. Our epidemiologic survey showed high rates of leukemia and lymphoma in towns in the river valley, starting in 1974. The Canacadea Creek begins in the mountains of rural Allegany County above Almond, flows through Almond, crosses into Steuben County, and joins the Canisteo River in the nearby city of Hornell. In the vicinity of Corning and Elmira, the Canisteo then becomes part of the Susquenhanna River, which eventualy enters and flows through Pennsylvania. The entire Canisteo River valley was severely affected by the floods that accompanied the tropical storm of June 1972.

Table 1. Incidence rates per 100,000 population for lymphomas and leukemias

Sources of rates and years	Lymphomas (ICDA 200–202)	Leukemia (ICDA 204–208)	Both
New York State Department of Health cancer registry, 1972–76 [1] ...	12.9	9.8	22.8
Third National Cancer Survey, 1969–71 [1]	9.7	9.5	19.4
SEER (surveillance, epidemiology, and end results) program of the National Cancer Institute, 1973–76	11.7	9.5	21.2
Connecticut State Department of Health cancer registry, 1973–76 [1] ...	11.8	9.9	21.7

[1] Rates are age adjusted for 1970.

The timing and location of the increased rate of leukemia and lymphoma suggested that something related to the flooding of the river valley during the 1972 storm may have been responsible for the high rate. To examine this hypothesis, we extended our geographic area of investigation to include the adjacent Cattaraugus and Livingston Counties, as well as the Allegheny and Genesee River valleys, which are included in these counties.

Table 2 shows the rates of leukemia and lymphoma during 1966–77 for the river-valley towns and the nonriver-valley towns in the four counties and for the remainder of upstate New York. Before 1974 the combined rates were similar for all three river valleys, for the nonriver valleys, and for the rest of the upstate area. In the 1974–77 period, there was a small increase in rates in the nonriver valleys and the remainder of upstate New York, but there was a much larger increase in the river-valley towns. The z test showed that the difference in the 1974–77 rates between river-valley towns and the rest of upstate New York was significant ($P < 0.05$). The rates for other malignant tumors were unaffected during this period; therefore, changes in medical care or reporting artifacts were unlikely to explain the increases that occurred

Table 2. Incidence rates per 100,000 population and numbers of cases of lymphomas and leukemia in river-valley and nonriver-valley towns in a 4-county area of New York, 1966–77

Years	Study and comparison areas with 1970 populations					
	Combined river valleys in 4-county area 102,201		Nonriver valleys in 4-county area 179,510		Remainder of New York State 10,118,200	
	Rates	Cases	Rates	Cases	Rates	Cases
1966–77	25.5	..	22.0	..	22.5	..
1966–73	22.3	..	21.1	..	21.5	..
1974–77	[1]32.0	..	[2]23.7	..	[3]24.4	..
1966	18.6	19	24.5	44	19.5	..
1967	29.4	30	20.6	37	20.0	..
1968	23.5	24	18.9	34	20.0	..
1969	21.5	22	21.7	39	20.6	..
1970	22.5	23	17.3	31	21.3	..
1971	11.7	12	21.7	39	22.2	..
1972	24.5	25	20.6	37	23.2	..
1973	26.4	27	23.4	42	25.3	..
1974	35.2	36	24.0	43	24.5	..
1975	29.4	30	30.6	55	24.0	..
1976	30.3	31	27.9	50	24.0	..
1977	33.4	34	12.3	22	25.1	..

[1] 95 percent confidence level (26.5–37.5). [2] 95 percent confidence level (20.1–27.3). [3] 95 percent confidence level (23.9–24.9).

after 1973. The distribution of leukemia and lymphoma cases by age, sex, or the kind of tumor diagnosed was not noticeably different in the river-valley towns after 1973 from that in the previous period.

These cancer data seem to indicate that the increase in leukemia and lymphoma rates occurred in all three river valleys and that the rates for these approximately 100,000 people were about 35 percent higher than would be expected, starting from about 2 years after the flood.

The explanation for the high rates of leukemia and lymphoma in the river-valley towns is not clear. There is no evidence of a reporting bias; nor is there any reason why an unknown reporting bias should favor the river valleys. The rate calculations are based on 1970 U.S. Census data for the counties and the State. Based on U.S. Census Bureau estimates, between 1970 and 1977, the population of upstate New York increased by 2.8 percent, and the population of the four counties increased by 4.9 percent, but the population of the river-valley towns increased by only 1.0 percent. Therefore, we concluded that the cancer rate increases and the rate differences shown in table 2 were limited to leukemia and lymphoma.

Table 3. Ratio of spontaneous abortions per 1,000 live births in Allegany, Cattaraugus, Livingston, and Steuben Counties and in the remainder of upstate New York, 1970–77

Period	4 counties	Remainder of upstate New York	Difference
1970	39.7	48.4	−8.7
1971	51.4	52.1	−0.7
January–December 1972	52.2	53.8	−1.2
January–March	43.8	...	..
April–June	50.9	...	..
July–September	42.8	...	..
October–December	71.4	...	..
1973	60.9	58.4	+2.5
1974	50.9	56.0	−5.1
1975	47.5	57.1	−9.6
1976	51.6	58.1	−6.5
1977	54.7	56.3	−1.6

Examination of the incidence rates for birth defects in the four counties failed to show anything unusual. We next examined spontaneous abortion rates (defining spontaneous abortion as the spontaneous expulsion from the mother's body of dead products of conception of all gestational ages). Examination of reproductive statistics for the four counties for 1970–77 (table 3) showed that there had been a statistically significant ($P < 0.01$) excess of spontaneous abortions in 1973 as compared with the average of the other yearly rates. Except for 1973, the year following the flood, the spontaneous abortion rates in these four

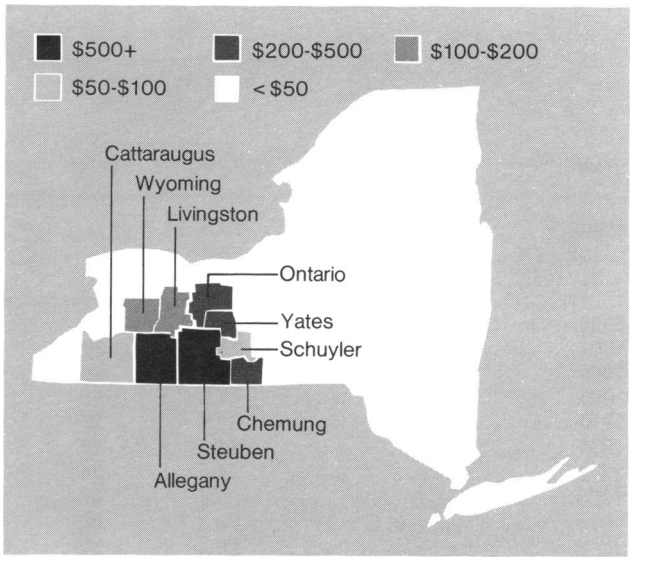
counties were consistently lower than for the rest of upstate New York. It can be seen that the upswing rates began during the last quarter of 1972. The excess was greatest in the river-valley towns.

Studies of Exposure

The observation of increased rates of leukemia and lymphoma from 1974 to 1977 and the patterns of excess spontaneous abortions in 1973 in the four counties focused our attention on the possibility of a connection with the June 1972 flood that followed Hurricane Agnes. To assess the severity and scope of the flood in the four counties, we obtained information from the U.S. Army Corps of Engineers and from the Federal Disaster Assistance Administration. These organizations reported that the 1972 storm had produced the most widespread flooding on record in the eastern United States (*4*). The hardest hit communities in upstate New York were in the river valleys. During a 3-day period, these towns suffered millions of dollars worth of damages and their residents underwent inestimable personal hardship. We obtained estimates prepared for the Federal Disaster Assistance Administration of the financial loss for each county. These estimates included the costs for the repair or replacement of roads, bridges, and public buildings, and costs for debris removal and for similar activities. Essentially, all the damage that occurred in upstate New York was concentrated in Allegany and Steuben Counties and the two surrounding counties (see map); Allegany and Steuben Counties, which the village of Almond straddles, were the most severely damaged.

Through the cooperation of the Hornell Chapter of the American Red Cross, we assembled a list of the names of 915 residents of towns in the Canisteo River valley who had been evacuated from their homes because of the 1972 flood. With this list we tested the hypotheses that evacuation was associated with an increased risk of leukemia and lymphoma or with an increased risk of spontaneous abortion. Using the New York State tumor registry, we compiled a list of all residents of towns in the Canisteo River valley who from 1972 to 1977 had been diagnosed as having leukemia or lymphoma. These people constituted the study subjects. Similarly, a list was compiled of residents who had been diagnosed as having any other malignant tumor; these residents comprised the control pool. Because of the influence of age and sex on both the likelihood of evacuation and of cancer incidence, an age- and sex-matched control was chosen for each resident with a diagnosed case. When we matched the names of these residents and of the controls with names on the list of evacuees, we found no evidence of an association between leukemia and lymphoma and evacuation. However, our failure to find an association may have been due to the small numbers involved.

Estimated per capita flood damage in counties of New York State due to 1972 Hurricane Agnes



For subjects in the spontaneous abortion comparison, we used residents of towns in the Canisteo River valley who had experienced a spontaneous abortion between 1972 and 1973. Their controls were age-matched residents of towns in this valley who had delivered a live infant during the same period. When names of these matched pairs were compared with names on the evacuation list, there was no evidence of an increased risk of spontaneous abortion associated with the evacuation, but again, this conclusion is based on small numbers. Investigations of unusual clusters of disease in relatively small populations such as this have inherent limitations. In most instances, only the most dramatic associations can be detected in epidemiologic studies of case-versus-control populations. In such instances, causative agents that are widespread but cause disease in only a few susceptible people will probably not be identified. Cancer registry data for 1978 and 1979 were not sufficiently complete at the time of our study to indicate whether the high rate of leukemia and lymphoma for the river valleys continued beyond 1977. The high spontaneous abortion rates may not be related to the high leukemia and lymphoma rates, but if they are, the evidence suggests that the etiological event has passed and was short lived.

Discussion

There have been previous reports of clusters of leukemias, lymphomas, and abnormal reproductive out-

comes. In most instances, the etiological agents were not clearly identified. The cluster that we have described is unique in that it involved a large number of excess cases and also comprised both cancers and fetal deaths.

We could find no evidence that any source of radiation was responsible, although we cannot rule out the possibility of an undetected transient evironmental contamination. The short time in which the changes in the disease rate occurred seems to exclude the possibility, suggested by local residents, that background radiation from indigenous rocks might have caused the leukemia. Studies of the environment and water supply provided no evidence of abnormal radiation levels. Although the residents of Almond were concerned about a nuclear reprocessing plant to the west of them in Cattaraugus County, we could find no link between the plant and the epidemiologic data we examined. The plant had stopped reprocessing in 1972, and moreover, it was located 50 miles to the west of the Canisteo River valley. Also, the watershed surrounding the plant drains to the northwest into Lake Erie and does not make a major contribution to the Allegheny, Genesee, or Canisteo Rivers.

The sequence of events seems to identify the flood as a possible etiological event in leukemia and lymphoma. These diseases are thought to be associated with outdoor occupations like farming and lumbering (*5,6*). The reasons for this association are unknown, but the diseases may be due to etiological agents in the outdoor rural environment. In addition, acquaintance networks among leukemia and lymphoma patients have been reported (*7*), and specific clusters of lymphoma have been described among groups of acquaintances (*8*). Another etiological possibility is a sylvatic or wild life virus. The 1972 flood caused the human and wildlife populations of the area to retreat from rising waters (*4*), and the movement of animals and people to higher ground to escape the flood waters may have caused people to be exposed to the viruses of other human beings or of displaced animals.

Another possibility is that the excess occurrence of neoplasia and spontaneous abortions may have been caused by the substantial psychological or physical (neuroendocrine) stress (*9–11*) that affected these people at the time of the flood. Many studies, both retrospective and prospective, have linked stressful life events (including natural disaster) with the onset of various diseases, both emotional and physical, and have shown significant correlations (*12,13*). Greene has carried out a series of long-term studies (*14*) to investigate the relationship of the onset of leukemia and lymphoma to the severe psychological stress that patients had previously undergone, studies in which he has paid particular attention to the stresses generated by loss situations. Some specific features of the post-Agnes cluster of cases that should be examined in the light of a stress-as-cause hypothesis are: (*a*) the concentration of excess leukemia and lymphoma cases in the valley towns within the affected counties, (*b*) the apparent latency period of 1 year or more between the flood disaster and a substantial increase in disease, and (*c*) the prolongation of the elevated incidence rate for new cases for 5 years after the disaster.

Although the river-valley towns were the only ones that showed a significant increase in tumor rates in the mid-1970s, there was evidence of a smaller increase in the rates both for tumors and spontaneous abortions also in the nonriver-valley towns. If the cause of these increases was stress, which perhaps was expressed through a neuroendocrine mechanism (*15*), it would not be unreasonable to expect that the effect would extend to a lesser degree beyond the towns that were actually flooded. The acute stress experienced at the time of the flood could have been expected to produce an effect over a widespread area and to be felt even where damage was relatively light and of short duration. However, long-term or chronic stress would be more likely to occur in the river-valley towns, where damage was severe and the recovery period protracted —in other words, where the stressors were more intense, more prevalent, and more persistent.

Neither the short latency of the disease, nor the prolonged high incidence rates, have clear explanations, but both phenomena are consistent with Greene's observations about stress events in the prodromal period of adult-onset leukemia and lymphoma (*14*). At the time of diagnosis, a majority of the patients in Greene's study were experiencing a severe phychological sense of loss or hopelessness, which was generated by stress events that had occurred as long as 4 years before the appearance of clinical disease. Greene observed that the median interval between the stress event and a confirmed diagnosis was 1 year and that a large cluster of such events occurred between 11 and 13 months before the diagnosis of disease. A latent period of about 1 year from the stress event to diagnosis would thus not appear to be unusual. Greene noted that this period of latency would in part be explained as the time that had elapsed between initiation of the neoplastic process and its progression to symptoms requiring medical attention.

Further environmental and epidemiologic investigations will need to be done before anything more than a speculative explanation can be offered. Other areas of the northeastern United States were also severely

affected by the 1972 floods. Logue and associates (*16*) have described the emotional and physical distress in the Wyoming Valley of Pennsylvania following Hurricane Agnes. Although these authors did not report on particular disease entities, they found strong relationships between physical and emotional health problems and flood-related stress.

If stress was responsible for the high rates of leukemia, lymphoma, and spontaneous abortion that we observed, similar outcomes will likely occur at the site of other phenomena that are perceived as disasters, even if no physical damage is sustained. It will be of interest in the coming months and years to monitor the rates for spontaneous abortion, leukemia, and lymphoma in the vicinity of the Three Mile Island nuclear plant. Increases in these rates might inaccurately be attributed to radiation when the causal mechanism could be, in fact, related to stress.

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SYNOPSIS

JANERICH, DWIGHT T. (New York State Department of Health), STARK, ALICE D., GREENWALD, PETER, BURNETT, WILLIAM S., JACOBSON, HERBERT I., and McCUSKER, JANE: *Increased leukemia, lymphoma, and spontaneous abortion in western New York following a flood disaster. Public Health Reports, Vol. 96, July–August 1981, pp. 350–356.*

The New York State Department of Health was asked in September 1978 to investigate a cluster of leukemias and lymphomas in a rural town in western New York State of less than 1,000 people. Four cases of these diseases had been diagnosed in the town's population in the previous 10 months. Residents were concerned about environmental hazards such as background radiation and contamination of their water supply. A total environmental study of the area was not feasible or warranted, but certain environmental studies of the area were conducted. No environmental health hazards were identified.

Incidence rates for towns in the four-county area (population 281,000) surrounding the study town were analyzed, based on data from the New York State Cancer Registry. These four counties had been severely affected by the flood following the 1972 Hurricane Agnes. Examination of annual leukemia and lymphoma incidence rates for these counties for 1966–77 revealed that the rates for towns in the river valley (population 102,000), but not for nonriver-valley towns, were 20 to 50 percent above the statewide rates for 1972–77. All other cancer rates remained level throughout both periods. An analysis of spontaneous abortion rates for the four counties for 1968–77 showed a significant peak in 1973, but not for the rest of upstate New York. The peak was concentrated in the towns in the river valley. The apparent time-space cluster of leukemias and lymphomas in conjunction with a marked increase in the spontaneous abortion rate suggests an unidentified flood-related environmental exposure.