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Father's Occupational Exposure to Radiation and the Raised Level of Childhood Leukemia near the Sellafield Nuclear Plant

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The first indications that childhood leukemia rates may be raised near the Sellafield nuclear plant in West Cumbria, England, came from largely anecdotal evidence in a television program "Windscale: The Nuclear Laundry" shown during 1983. During subsequent years, various epidemiological studies have investigated the claim in more detail. Geographical analyses of childhood leukemia incidence in the northern region and mortality in England and Wales using routinely available data made the first contribution. As a result, it was confirmed that leukemia rates in the area, particularly the neighboring village of Seascale, were high compared to other districts, although not totally extreme.

Cohort studies of children born in Seascale or attending schools in Seascale were carried out to resolve some of the difficulties of interpretation of geographical analysis. Cohort studies indicated that the excess of leukemia was concentrated among children born in Seascale and was not found among those moving in after birth and suggested that any causal factors may be acting before birth or very early in life. A case-control study of leukemia (and lymphoma) among young people in West Cumbria has examined potentially important individual factors in detail. The study demonstrated a relationship between the raised incidence of leukemia in children and father's recorded external radiation dose during work at Sellafield before his child's conception. The association can effectively explain statistically the observed geographical excess.

Introduction

Some concern that radioactive emissions from nuclear installations could be a health hazard to local communities had existed for many years, but substantial interest in the United Kingdom was raised only with the airing on national network of the Yorkshire television documentary "Windscale: the Nuclear Laundry" in 1983. The program had originally intended to discuss the health effects on workers of occupational exposure to radiation in the nuclear industry but was reorientated to the local children when the producer was told by residents in the area near Sellafield (Windscale) of cases of childhood leukemia and other cancers that seemed to them to occur at an unusually high rate for a rare disease. The suggested excess was said to be concentrated in the village of Seascale, which is on the coast about 3 km south of Sellafield.

Awareness of the scale of radioactive discharges from the nuclear waste reprocessing operation at Sellafield resulted in the possible linkage by the television program of the childhood cancer cases with environmental contamination from the site. The screening of the program resulted the following day in an announcement by the British government of an independent inquiry into the allegations to be chaired by Sir Douglas Black. A report was subsequently published (*1*).

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Geographical Studies

Because of the nature of the medical evidence produced by the television program, one of the first concerns of the Black inquiry was to establish whether the alleged increase in childhood leukemia could be supported by using routinely available sources (death certificates and cancer registrations). This was examined in two analyses.

First, it was shown (Table 1) that in Millom Rural District (the administrative area containing Seascale) there had been a raised leukemia mortality rate among persons under 25 years of age during 1968–78 but not during 1959–67, and not in the adjacent area of Ennerdale Rural District (containing Sellafield) for either period of time (*2*). These years cover the Seventh and Eighth revisions of the International Classification of Diseases and are relevant as Sellafield started operations around 1950. When examined in the context of the 151 other similar rural districts of England and Wales, to adjust for population size and urban/rural status, it was found (Table 2) that during 1968–78, Millom had the second highest standardized mortality ratio (435).

Table 1. Mortality from leukemia in persons under 25 years of age during 1959–78 in rural districts of England and Wales: Millom and Ennerdale (containing Sellafield area).

Rural district	1959–67		1968–78	
	Observed	Expected[a]	Observed	Expected[a]
Millom	1	1.6	6	1.4
Ennerdale	3	3.3	4	3.3

[a]At age, sex, and calendar period specific rates for England and Wales.

Table 2. Mortality from leukemia in persons under 25 years of age during 1959–78 in England and Wales: 152 rural districts similar in size to Millom.

Standardized mortality ratio	Number of rural districts	
	Observed	Predicted[a]
0–99	78	85.9
100–199	52	48.4
200–299	19	14.6
300–399	1	2.7
400+	2	0.4

[a]On the basis of the Poisson distribution.

This was second from top, but not extreme (*1*), and overall the mortality distribution was not markedly different from that expected by chance.

Second, data from the children's malignant disease register for the northern region of England and Wales were examined (*3*). Cancer registration started for under 15 year olds in 1968, and analyses covered 675 electoral wards for the years 1968–82. Seascale had four cases of lymphoid malignancy compared to 0.25 expected at registration rates for the region overall. This put it third highest in the ranking of registration rates, although in terms of associated Poisson probability ($p = 0.0001$), it was the most extreme (*1*).

These two investigations thus tended to support the allegations of the television program in terms of a raised childhood leukemia rate near the nuclear plant, although making no contribution to examination of the effects, if any, of radioactive discharges. Geographical analyses of this nature have a number of limitations: for example, the scale of areas used, the potential inclusion of cases after only a short residential period and exclusion of cases diagnosed soon after moving away, and the use of census enumerated populations as denominators when high levels of population change are possible. Thus, other epidemiological methods have their place in elucidating further the nature of the observed area excess and were recommended in the Black report (*1*).

Cohort Studies

Cohort studies have been carried out including as far as possible all children born since 1950 who have at some age lived in Seascale village (*4,5*). Their names and other particulars were identified from birth and school registers, and the cohorts comprised 1068 children born in Seascale and 1546 more children who attended schools in Seascale after having been born elsewhere. The records of mortality and cancer registration on these children, including after moving away from Seascale, were obtained by the usual follow-up methods incorporating the National Health Service Central Register.

The findings of these studies confirmed the geographical analyses, indicating a raised level of leukemia among Seascale children. However, the excess appeared to be concentrated among children born in Seascale in contrast to those attending the local schools (Table 3). Thus, there was a 10-fold excess for leukemia and a 2- or 3-fold excess of other cancers among the births. There was also a suggestion that this excess was found after the children had left Seascale, although the numbers involved are small (*4*). The conclusion of these studies suggested that one or more factors may be acting on a locality-specific basis before birth or early in life to produce the contrasting outcomes.

Table 3. Leukemia and other cancer cases during 1950–86 in Seascale birth and school cohorts.

Diagnosis	Cohort	Number of cases	
		Observed	Expected[a]
Leukemia	Birth	6	0.6
	Schools	0	0.6
Other cancer	Birth	6	2.2
	Schools	4	3.4

[a]At age, sex, and calendar period specific rates for England and Wales.

Case-Control Study

A case-control study has been carried out including all cases of leukemia and lymphoma diagnosed at under 25 years of age in the West Cumbria Health Authority area between 1950 and 1985 (*6,7*). This area was chosen to include coastal and inland areas where concern had been raised about potential risks from radiation contamination due to discharges from the nuclear plant to sea or air and also to cover the places of residence of the Sellafield workforce.

The aim was to obtain information on individual cases and controls that might help to explain the excesses found in the anecdotal, geographical, and cohort studies. Factors examined included prenatal X-ray exposure as the known risk factor for childhood leukemia; various other suspected risk factors such as viral illnesses, social class and maternal age; behavioral habits such as eating fresh seafood and playing on the beach that might have enhanced exposure to radionuclides released from Sellafield; and parental occupation and radiation exposure at Sellafield. The control children for the study were taken from the same birth registers into which the cases' births were entered. For each case, two sets of eight controls were identified, taken to be of the same sex and adjacent in date of birth, with one set covering the total birth registration area (area controls) and the other set confined to the same local village where the case was born (local controls).

The identifying details on the parents of the cases and controls were cross-linked with the past and present Sellafield workforce file, and, where matches were found, individual external radiation exposure records were obtained from the company (internal radiation exposure data are not yet available). It was in this respect that the most important result was found, although the expected geographical distribution of leukemia and association with prenatal X-rays were also identified (*6*).

The relationship between accumulated preconceptual external radiation dose of the fathers during their employment and leukemia in their children is shown in Table 4 for local controls, where a high relative risk is found for exposures over 100 mSv, albeit based on small numbers. Three of the four cases in this range were born in Seascale, and each of the four fathers had higher radiation doses than all their matched control fathers. Of the remaining three Seascale cases of leukemia shown in Table 3, the father of one case had an accumulated preconceptual radiation dose of 96 mSv and another has not yet been linked to the Sellafield workforce file, whereas the third case was diagnosed after leaving West Cumbria and hence excluded from this case-control study. Comparable findings were shown for area controls and for estimated external radiation dose during the 6 months before conception. Data from questionnaires to parents did not suggest any relationship of childhood leukemia to potential sources of enhanced exposure to radionuclides discharged

Table 4. Relative risks for childhood leukemia by father's external ionizing radiation dosimetry during employment at Sellafield before child's conception.

Radiation dose, mSv	Cases	Local controls	Odds ratio	95% confidence interval
0	38	236	1	
> 0-49	3	26	0.8	0.2 - 3.0
50-99	1	11	0.8	0.1 - 7.7
≥ 100	4	3	8.4	1.4 - 52.0

from the nuclear site. Similar results were also found for non-Hodgkin's lymphoma, although the number of cases was smaller, but not for Hodgkin's disease, which is as would be expected for a nonradiation related condition.

Conclusions

Epidemiological methods have been used to examine a media-suggested excess of childhood leukemia near a nuclear waste reprocessing plant. Geographical, cohort, and case-control studies have contributed to confirming the excess and showing a strong statistical association with father's exposure to external radiation at work in the plant before their child's conception sufficient to explain the excess cases. Thus, what was perceived as possibly an environmental health problem has resolved into what is probably an occupational health matter.

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