CLINICAL RESEARCH

Childhood leukaemia in the West Berkshire and Basingstoke and North Hampshire District Health Authorities in relation to nuclear establishments in the vicinity

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Abstract

During the years 1972-85, 89 children aged 0-14 were registered with leukaemia in the West Berkshire and Basingstoke and North Hampshire District Health Authorities. Two nuclear establishments are located within the health authorities, and a third is situated nearby. Fifty of the 143 electoral wards in the two district health authorities lie wholly within, or have at least half their area lying within, a circle of radius 10 km around the establishments. In those 50 electoral wards 41 children aged 0-14 were registered with leukaemia, 28.6 registrations being expected on the basis of leukaemia registration rates in England and Wales (incidence ratio=1.4, $p<0.05$). This excess was confined to children aged 0-4, among whom there were 29 registrations of leukaemia, 14.4 being expected (incidence ratio=2.0, $p<0.001$). In the remaining 93 electoral wards there was a small and non-significant increase in the number of registrations of leukaemia at age 0-14 (48 observed, 40.8 expected; incidence ratio=1.2). There was no obvious trend in the incidence of childhood leukaemia over the 14 years and the overall occurrence of the malignancy in the 143 electoral wards was consistent with a random distribution. In the surrounding Oxford and Wessex Regional Health Authorities the

number of registrations of leukaemia at age 0-14 was virtually identical with that expected on the basis of registration rates in England and Wales (362 observed, 372.5 expected; incidence ratio=1.0).

These data indicate that in the two district health authorities studied there was an excess incidence of childhood leukaemia during 1972-85 in the vicinity of the nuclear establishments. In the West Berkshire and Basingstoke and North Hampshire District Health Authorities an average of 60 000 children aged 0-14 lived within a 10 km radius of a nuclear establishment each year. The normal expectation of leukaemia in these children was two cases a year, whereas the recorded incidence was three cases per year, representing one extra case of leukaemia each year among these 60 000 children.

Introduction

The incidence of childhood leukaemia around nuclear establishments has been a topic of public concern and scientific investigation, especially since the reported cluster of cases near the Sellafield plant in west Cumbria.¹⁻⁶ The West Berkshire District Health Authority contains two nuclear establishments: the Atomic Weapons Research Establishment at Aldermaston and the Royal Ordnance Factory at Burghfield. Both establishments lie in the south of the West Berkshire District Health Authority, close to its border with the Basingstoke and North Hampshire District Health Authority (see fig 1). The United Kingdom Atomic Energy Authority's establishment at Harwell lies less than 2 km to the north of the West Berkshire District Health Authority.

In 1985 we reported a preliminary analysis of the incidence of leukaemia for the years 1972-84 in children aged 0-9 living in the West Berkshire District Health Authority, noting that the incidence among the 0-4 year olds was increased by 63% ($p<0.01$).² At that time complete information was not available for children who, although resident in the West Berkshire District Health Authority, were referred elsewhere for diagnosis and treatment. In addition, we could not examine the incidence of childhood leukaemia in the

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immediate area surrounding the nuclear installations, as data from the neighbouring Basingstoke and North Hampshire District Health Authority had not been compiled, nor could we assess whether the excess incidence of childhood leukaemia was specific to the West Berkshire District Health Authority or characteristic of the general area in which the West Berkshire District Health Authority is situated. The preliminary data have now been extended to include children from the neighbouring health authority of Basingstoke and North Hampshire, children diagnosed as having leukaemia in 1985, those aged 10-14 years, and residents in the district health authorities who were referred elsewhere for diagnosis and treatment. The places of residence of the children with leukaemia have been investigated with specific reference to their proximity to the nuclear establishments in the vicinity.

FIG 1—Map of West Berkshire and Basingstoke and North Hampshire District Health Authorities, showing main towns (O) and nuclear establishments (■) in the area.

Subjects and methods

The West Berkshire District Health Authority forms part of the Oxford Regional Health Authority, constituting about one sixth of its population. The Royal Berkshire Hospital is situated in Reading, and a paediatric oncology and haematology clinic was established there in 1971.⁷ The Basingstoke and North Hampshire District Health Authority forms part of the Wessex Regional Health Authority, constituting almost one tenth of its population. The Basingstoke District Hospital serves this district health authority. The hospital was opened in 1972 and lies on the outskirts of Basingstoke. Figure 1 shows a map of the two district health authorities and the position of the main towns and the three nuclear establishments in the vicinity.

SUBJECTS

Children aged under 15 years who were first diagnosed as having leukaemia in 1972-85 and who were then living in either the West Berkshire District Health Authority or the Basingstoke and North Hampshire District Health Authority were identified. Fifty eight patients were first diagnosed at the Royal Berkshire Hospital, 56 being residents of the West Berkshire District Health Authority and two of the Basingstoke and North Hampshire

District Health Authority. Twenty seven patients were first diagnosed at the Basingstoke District Hospital, 25 being residents of the Basingstoke and North Hampshire District Health Authority and two of the West Berkshire District Health Authority. All diagnoses were confirmed histologically and were supported by documentary evidence in hospital records. Reliable hospital records were not available before 1972, because the oncology and haematology clinic at the Royal Berkshire Hospital was not fully operational until 1972 and the Basingstoke District Hospital was not opened until 1972. To ensure that ascertainment of cases for 1972-85 was as complete as possible consultants from hospitals in the surrounding district health authorities and staff of the Childhood Cancer Research Group in Oxford were approached for information that might identify additional subjects. As a result of these inquiries a further eight cases, six from West Berkshire and two from North Hampshire, were identified. All eight had been referred for diagnosis and treatment outside the district health authority in which they lived.

The completeness of registration of children with leukaemia was checked against national cancer registry data. This could be done only for the years up to 1982, as data were not complete beyond that year. All 48 patients identified by us as living in the West Berkshire District Health Authority and diagnosed as having leukaemia between 1972 and 1982 were also registered in the national scheme. For the Basingstoke and North Hampshire District Health Authority 24 of the 28 patients diagnosed between 1972 and 1982 were also registered in the national scheme. One of those not registered was a 6 year old boy, diagnosed as having lymphoblastic lymphoma in early 1979, who later that year developed acute lymphatic leukaemia. He was registered in the national scheme as having lymphoma but not leukaemia. The three other children who were not registered were aged 2, 3, and 8, respectively, and were all diagnosed as having leukaemia at the Basingstoke District Hospital in 1972. These children probably escaped registration in the reorganisation after the opening of the Basingstoke District Hospital in 1972 and the separation of the Wessex cancer registry from the South Thames registry in early 1973.⁸

METHODS

Yearly mid-year population estimates were provided for the 14 years 1972-85 for the West Berkshire District Health Authority, the Basingstoke and North Hampshire District Health Authority, the Oxford Regional Health Authority, and the Wessex Regional Health Authority by the population estimates department of the Office of Population Censuses and Surveys. Populations, by five year age groups, are available from the 1981 census for each of the 85 electoral wards in the West Berkshire District Health Authority and the 58 wards in the Basingstoke and North Hampshire District Health Authority. Population estimates for the electoral wards are not made yearly by the Office of Population Censuses and Surveys, and we estimated these by applying the 1981 ward proportions of the district health authority population to the yearly mid-year district health authority population figures supplied by the Office of Population Censuses and Surveys.

The address of each child when leukaemia was diagnosed was allocated to the appropriate electoral ward, using the ward boundaries that existed at the time of the 1981 census. The expected numbers of registrations of leukaemia (International Classification of Diseases (ICD) 8th revision 204-207, 9th revision 204-208^{9,10}) were estimated by applying the yearly age specific leukaemia registration rates for England and Wales for 1972-82 to the population estimates.¹¹ National incidence data were not available beyond 1982. As there was no significant trend in national registration rates for childhood leukaemia over the 11 years 1972-82, the mean age specific rates for 1972-82 were applied to 1983-5. Confidence intervals and tests of significance for the ratio of observed to expected cases (incidence ratio) were obtained from tables based on the Poisson distribution.¹² All tests of significance were two sided.

For each age group we compared the distribution of the incidence ratios for the 143 wards in the two district health authorities with the distribution that would have been expected, assuming that the observed numbers of cases in each ward followed a separate Poisson distribution. For these calculations the age specific incidence in the two health authorities was used as a standard. The expected number of cases in each ward was calculated as a fraction of the total cases observed, this fraction being the proportion of the total population that was contained in the respective ward in 1981. The probability distributions for the incidence ratio of each ward were summed to give a predicted distribution, assuming a random distribution of cases across the wards. Two additional methods were also used to examine for non-uniformity of leukaemia risk across the wards.^{13,14}

To study the relation between residence near a nuclear establishment and leukaemia risk, we divided the electoral wards according to whether half or more of their area lay within circles of specified radii from the three nuclear plants in the vicinity. A 10 km radius was chosen for the analyses before the geographical distribution of leukaemia was examined. In view of the findings

obtained when the 10 km radius was used, we made further divisions at 5 km and 15 km for subsidiary analyses. Incidence ratios were calculated separately for each category, and, where appropriate, linear tests for trend were carried out using a standard method.¹⁵

Results

Ninety three children aged 0-14 living in the West Berkshire District Health Authority or Basingstoke and North Hampshire District Health Authority were identified as having had leukaemia first diagnosed in the years 1972-85. Of these, 49 were boys and 44 girls and 5 (5%) also had Down's syndrome. Seventy eight children (84%) had acute lymphatic leukaemia, but complete information on the different subtypes was not available, as cell marker studies were not routinely performed until 1976. Four of the 93 children were not registered in the national cancer registration scheme (see methods) and were excluded from all analyses presented here. Table I shows the numbers of children registered with leukaemia in each district health authority, by age. The numbers of cases expected were based on leukaemia registration rates in England and Wales. Overall, there was a significant excess in the numbers of registrations of leukaemia in 0-14 year

registrations in these two district health authorities in the 11 years 1972-82. In contrast, childhood leukaemia rates in the surrounding areas were virtually identical with those in England and Wales in general. The incidence ratio at age 0-14 was 1.0 in the Oxford Regional Health Authority after the data for the West Berkshire District Health Authority were excluded. In the Wessex Regional Health Authority it was also 1.0 after the data for the Basingstoke and North Hampshire District Health Authority were excluded. Because the rates of childhood leukaemia in the remainder of the Oxford and Wessex regional health authorities were so similar to national rates, the expected numbers of registrations of leukaemia estimated for subsequent analyses were based on age specific rates in England and Wales as a whole.

Figures 2 and 3 show the distribution of childhood leukaemia in the 143 electoral wards making up the West Berkshire and the Basingstoke and North Hampshire District Health Authority for 1972-85. Figure 2 gives data for those aged 0-14 and figure 3 for those aged 0-4. Electoral wards with incidence ratios greater than one are shaded; the striped areas indicate wards with incidence ratios not significantly greater than one, and the darker areas indicate wards with incidence ratios significantly greater than one ($p < 0.05$). The distribution of observed incidence ratios within each ward was compared with that predicted when a random distribution of cases across wards was assumed (table III). For each five age group the observed

TABLE I—Incidence of childhood leukaemia in the West Berkshire and Basingstoke and North Hampshire District Health Authorities 1972-85, by age. (Expected numbers are based on leukaemia registration rates in England and Wales)

Age (years)	West Berkshire			Basingstoke and North Hampshire			Total		
	No of children with leukaemia		Incidence ratio* (95% confidence interval)	No of children with leukaemia		Incidence ratio* (95% confidence interval)	No of children with leukaemia		Incidence ratio* (95% confidence interval)
	Observed	Expected		Observed†	Expected		Observed†	Expected	
0-4	38	22.3	1.7 (1.2 to 2.3)	15	11.7	1.3 (0.7 to 2.1)	53	34.0	1.6 (1.2 to 2.0)
5-9	15	13.6	1.1 (0.6 to 1.8)	6	7.1	0.8 (0.3 to 1.8)	21	20.7	1.0 (0.6 to 1.6)
10-14	11	9.7	1.1 (0.6 to 2.0)	4	4.9	0.8 (0.2 to 2.1)	15	14.6	1.0 (0.6 to 1.7)
Total	64	45.6	1.4 (1.1 to 1.8)	25	23.7	1.1 (0.7 to 1.6)	89	69.3	1.3 (1.0 to 1.6)

*Ratio of observed to expected number of registrations.

†Excludes four children (aged 3, 4, 6 and 8, respectively) who were not registered in the national cancer registration scheme.

olds ($p < 0.05$), due almost entirely to the excess among 0-4 year olds ($p < 0.01$). The findings were similar in the West Berkshire District Health Authority and the Basingstoke and North Hampshire District Health Authority, but the incidence ratios were larger in West Berkshire and significant only in that health authority. The data were examined for evidence of a trend in incidence of leukaemia over time. Although this examination was limited by the small number of patients diagnosed each year, there was little suggestion of either an increase or a decrease in incidence over the 14 years 1972-85.

Table II contrasts the childhood leukaemia registration ratios in the West Berkshire and Basingstoke and North Hampshire District Health Authorities with those in the surrounding Oxford and Wessex Regional Health Authorities. The data relate to 1972-82 because registration data beyond 1982 were not available for the regional health authorities. The expected numbers of cancer registrations are based on registration rates for leukaemia in England and Wales. There was a significant excess in leukaemia

TABLE II—Incidence ratios (observed/expected registrations) for childhood leukaemia in the West Berkshire and Basingstoke and North Hampshire District Health Authorities compared with the rest of the Oxford and Wessex Regional Health Authorities 1972-82, by age. (Expected numbers are based on leukaemia registration rates in England and Wales)

Age (years)	West Berkshire and Basingstoke and North Hampshire District Health Authorities	Oxford and Wessex Regional Health Authorities (excluding West Berkshire and Basingstoke and North Hampshire District Health Authorities)	Total
0-4	1.7** (45/26.9)	1.0 (174/179.6)	1.1 (219/206.5)
5-9	0.8 (13/17.0)	1.0 (115/112.5)	1.0 (128/129.5)
10-14	1.2 (14/11.6)	0.9 (73/80.4)	0.9 (87/92.0)
Total	1.3* (72/55.5)	1.0 (362/372.5)	1.0 (434/428.0)

* $p < 0.05$.

** $p < 0.01$.

FIG 2—Map showing distribution of leukaemia incidence ratios at ages 0-14 in 143 electoral wards in West Berkshire and Basingstoke and North Hampshire District Health Authorities. Figures are numbers of cases. Circles of radius 10 km are drawn around each nuclear establishment (● = Atomic Weapons Research Establishment, Aldermaston, ■ = Royal Ordnance Factory, Burghfield, and ▲ = United Kingdom Atomic Energy Authority's establishment, Harwell).

FIG 3—Map showing distribution of leukaemia incidence ratios at ages 0-4 in 143 electoral wards in West Berkshire and Basingstoke and North Hampshire District Health Authorities. Figures are numbers of cases. Circles of radius 10 km are drawn around each nuclear establishment (●=Atomic Weapons Research Establishment, Aldermaston, ■=Royal Ordnance Factory, Burghfield; and ▲=United Kingdom Atomic Energy Authority's establishment, Harwell).

TABLE III—Observed and predicted distributions of childhood leukaemia incidence ratios in the 143 electoral wards of the West Berkshire and Basingstoke and North Hampshire District Health Authorities 1972-85, by age

Incidence ratio*	Age (years)					
	0-4		5-9		10-14	
	Observed No of wards	Predicted No of wards	Observed No of wards	Predicted No of wards	Observed No of wards	Predicted No of wards
0	100	102.3	125	124.1	130	129.1
-2.5	21	20.4	1	1.2	0	0.3
-5.0	12	12.3	8	7.2	2	2.3
>5.0	10	8.0	9	10.6	11	11.3
Total	143	143.0	143	143.0	143	143.0

*Ratio of observed to expected number of registrations.

and predicted distributions of incidence ratios were comparable. Although the data are not shown here, two other methods used to examine for non-uniformity of risk across the wards also suggested that the overall geographical distribution of the cases was not significantly different from that expected by chance.^{13 14}

Fifty of the 143 electoral wards had half or more of their area lying within 10 km of one of the three nuclear establishments at Aldermaston, Burghfield, and Harwell (see figs 2 and 3). There was a significantly increased incidence of leukaemia in these 50 electoral wards at ages 0-4 ($p<0.001$) and 0-14 ($p<0.05$), but not at ages 5-9 or 10-14 (table IV). The excess numbers of registrations at ages 0-14 may be attributed entirely to the excess in the under 5 age group. In wards further than 10 km from a nuclear establishment the incidence at ages 0-4 and 0-14 was still slightly higher than the national figures, but this excess was not significant at the 5% level. The incidence of leukaemia at ages 0-4 and 0-14 was examined further by dividing the electoral wards into those with at least half of their area lying within 5 km, 6-10 km, 11-15 km, and more than 15 km from a nuclear establishment (table V). At age 0-4 the incidence ratio in the 15 electoral

TABLE IV—Incidence of childhood leukaemia in the West Berkshire and Basingstoke and North Hampshire District Health Authorities 1972-85, by age and distance of the electoral ward of residence from a nuclear establishment. (Expected numbers are based on leukaemia registration rates in England and Wales)

Age (years)	Electoral wards within 10 km of a nuclear establishment			Electoral wards more than 10 km from a nuclear establishment		
	No of children with leukaemia		Incidence ratio* (95% confidence interval)	No of children with leukaemia		Incidence ratio* (95% confidence interval)
	Observed	Expected		Observed	Expected	
0-4	29	14.42	2.0 (1.3 to 2.9)	24	19.58	1.2 (0.8 to 1.8)
5-9	9	8.25	1.1 (0.5 to 2.1)	12	12.48	1.0 (0.5 to 1.7)
10-14	3	5.91	0.5 (0.1 to 1.5)	12	8.70	1.4 (0.7 to 2.4)
Total	41	28.58	1.4 (1.0 to 1.9)	48	40.76	1.2 (0.9 to 1.6)

*Ratio of observed to expected number of registrations.

wards lying within 5 km of these establishments was 2.3, significantly greater than the number of registrations expected ($p<0.05$), but at age 0-14 the excess was not significant at the 5% level. For electoral wards located 5-10 km from the establishments the incidence ratio was significantly increased both at age 0-4 and at 0-14. Two sided tests for linear trend across the four divisions of distance given in table V were not significant ($\chi^2=2.19$, $p=0.14$ for age 0-4; $\chi^2=1.10$, $p=0.29$ for age 0-14).

Table VI shows the incidence ratios and the observed and expected numbers of registrations of childhood leukaemia separately for each of the three nuclear establishments in the vicinity. The numbers are small, but broadly similar incidence ratios are found around both the Atomic Weapons Research Establishment at Aldermaston and the Royal Ordnance Factory, Burghfield. Nine electoral wards lie within 10 km of both of these establishments, and thus there is some overlap between the separate figures. In those nine overlapping electoral wards there was a significant excess in the number of children aged 0-4 years registered with leukaemia (five registrations observed, 1.08 expected; incidence ratio=4.6, $p<0.05$). Information for the area surrounding the United Kingdom Atomic Energy Authority's

TABLE V—Incidence of childhood leukaemia in the West Berkshire and Basingstoke and North Hampshire District Health Authorities 1972-85, by age and 5 km distances of the electoral ward of residence from a nuclear establishment. (Expected numbers are based on leukaemia registration rates in England and Wales)

Distance of the electoral ward of residence from nuclear establishment	Age (years)					
	0-4			0-14		
	No of children with leukaemia	Incidence ratio* (95% confidence interval)	No of children with leukaemia	Incidence ratio* (95% confidence interval)	No of children with leukaemia	Incidence ratio* (95% confidence interval)
≤5 km	9	3.85	2.3 (1.1 to 4.4)	10	7.68	1.3 (0.6 to 2.4)
-10 km	20	10.56	1.9 (1.2 to 2.9)	31	20.89	1.5 (1.0 to 2.1)
-15 km	14	12.96	1.1 (0.6 to 1.8)	35	27.07	1.3 (0.9 to 1.8)
>15 km	10	6.63	1.5 (0.7 to 2.8)	13	13.69	0.9 (0.5 to 1.6)
Total	53	34	1.6 (1.2 to 2.0)	89	69.33	1.3 (1.0 to 1.6)

*Ratio of observed to expected number of registrations.

TABLE VI—Incidence ratios (observed/expected registrations) of childhood leukaemia in electoral wards lying within 5 km and 10 km, respectively, for each of the three nuclear establishments in the vicinity of the West Berkshire and Basingstoke and North Hampshire District Health Authorities 1972-85, by age. (Expected numbers are based on leukaemia registration rates in England and Wales)

Age (years)	Distance from nuclear establishment	Atomic Weapons Research Establishment, Aldermaston†	Royal Ordnance Factory, Burghfield†	United Kingdom Atomic Energy Authority's establishment, Harwell
0-4	≤5 km	2.8 (3/1.08)	2.2 (6/2.77)	No data available
	≤10 km	2.2 (7/3.13)	2.2* (27/12.19)	0 (0/0.18)
0-14	≤5 km	1.4 (3/2.15)	1.3 (7/5.46)	No data
	≤10 km	1.2 (8/6.41)	1.6* (38/23.86)	0 (0/0.39)

* $p<0.05$.

†Includes data for nine electoral wards that lie within 10 km of both the establishment at Aldermaston and that at Burghfield where five registrations were observed at age 0-4, with 1.08 expected and five registrations were observed at age 0-14, with 2.38 expected.

establishment at Harwell is incomplete, no data having been examined for the district health authority in which Harwell is located. None of the electoral wards in the West Berkshire District Health Authority had half or more of their area contained within a 5 km circle around this establishment, and in the two West Berkshire wards within 10 km no cases of leukaemia were observed at age 0-14 and 0.39 were expected.

Discussion

These data confirm our preliminary finding of an increased incidence of leukaemia in children aged 0-4 in the West Berkshire District Health Authority.² In the adjacent district health authority of Basingstoke and North Hampshire, registrations of leukaemia at age 0-4 were also increased, but not significantly so. When the data for the two authorities were combined there was a significant increase in registrations of leukaemia in the 0-14 age group (89 registrations observed, 69.3 expected), which was almost entirely due to the excess registrations in the 0-4 age group (53 registrations observed, 34.0 expected). The incidence of childhood leukaemia in the surrounding regional health authorities, after the two district health authorities under investigation had been excluded, was virtually identical with national figures (incidence ratio=1.0) suggesting that the increased incidence is specific for the two district health authorities of interest and not characteristic of the region as a whole.

The classification of electoral wards according to whether all or at least half of their area lay within a circle of radius 10 km around the three nuclear establishments in the vicinity indicated that at ages 0-4 and 0-14 the number of children registered with leukaemia was significantly greater than that expected, based on the rates in England and Wales. The 42% excess at age 0-14 (41 cases observed, 28.6 expected, $p<0.05$) was entirely due to the 101% excess at ages 0-4 (29 cases observed, 14.4 expected, $p<0.001$). Although fairly few people live within a 5 km radius of the establishments, a significant excess of leukaemia was also found in the 0-4 age group (nine cases observed, 3.85 expected, $p<0.05$). This area corresponds roughly with that investigated by the Yorkshire Television researchers, who, although examining data for a different period, reported a significantly increased incidence of leukaemia and lymphoma in 0-25 year olds.³ In areas further than 10 km from the establishments the number of cases observed was slightly greater than that expected, but the excess was not significant (48 observed, 40.8 expected at age 0-14). The 10 km boundary was selected for analysis before the registration data were examined. If a 5 km or 15 km boundary had been selected instead the incidence ratios at ages 0-4 and 0-14 would all have been greater than one and significant at the 5% level, except at 5 km for the 0-14 year olds.

Although the incidence ratios within the 10 km circle were significantly greater than those expected on the basis of rates in England and Wales (table IV), the incidence rates in children living within the 10 km boundary were not significantly different from those in children living outside the 10 km boundary. The statistical power of comparisons of leukaemia rates in two small areas is, however, low: data would have had to be collected for more than 40 years before the almost twofold difference in incidence noted here at age 0-4 between those inside and outside the 10 km boundary would have been significant at the 5% level. That the pattern of childhood leukaemia in the two district health authorities is consistent with a random distribution partly reflects the low statistical power of such methods when applied to small populations. It is also consistent with the findings from systematic analyses of the geographical distribution of childhood leukaemia, which have indicated that there is no strong evidence why this malignancy should cluster in space.¹⁶ That the overall pattern of leukaemia was compatible with a random distribution might be thought to conflict with the observed excess incidence around the nuclear establishments, but the methods used to assess variation in the spatial incidence of disease were non-specific and not necessarily sensitive for the detection of a raised incidence of disease around a defined point source.

The calculation of the expected numbers of cases of leukaemia necessitated certain assumptions, but none of these is likely to result in major errors in the estimates. Leukaemia registration rates for

England and Wales were not available for the years 1983-5 and were assumed to be the average for the years 1972-82. As there was no significant increasing or decreasing trend in national childhood leukaemia registration rates during that period, this assumption seems reasonable. Moreover, even when data for 1983-5 were excluded there were still significantly more registrations of childhood leukaemia than expected in the West Berkshire and Basingstoke and North Hampshire District Health Authorities (table II). There were also significantly more leukaemia registrations than expected in children living within 10 km of the establishments for the years 1972-82 alone (25 observed, 11.6 expected at ages 0-4, $p<0.001$; 34 observed, 23.2 expected at 0-14, $p<0.05$). The use of national rather than local rates to calculate expected registrations is unlikely to have biased the findings as the registration rates in the surrounding Oxford and Wessex regional health authorities were almost identical with national rates (table II). Four children (5%) were not registered, which is comparable with reported figures on the completeness of cancer registration elsewhere in England and Wales.⁸ These four were excluded to permit valid comparisons with national rates. Their inclusion would not have altered the conclusions. Two of the children were aged less than 5; one lived outside the 10 km circle and the other lived within 10 km of both the Atomic Weapons Research Establishment at Aldermaston and the Royal Ordnance Factory at Burghfield. The two other children were aged 6 and 8 years, respectively, and both lived outside the 10 km circle.

Could the finding of the increased incidence of leukaemia in 0-4 year olds living within 10 km of the nuclear establishments be explained by other factors? The characteristics of the children with leukaemia—the type of leukaemia, the sex of the children, and the percentage with Down's syndrome—are similar to those described elsewhere,¹⁷⁻¹⁹ and there were no obvious differences in the characteristics of those who lived close to or far from the nuclear establishments in the vicinity. All diagnoses were confirmed histologically. The whole of the Oxford and Wessex Regional Health Authorities, including the West Berkshire and Basingstoke and North Hampshire District Health Authorities, are areas of fairly high social class compared with the rest of England and Wales, and it has been suggested that the incidence of leukaemia is increased in children whose parents are in the upper social classes. If such a gradient exists, however, it is weak,^{19,20} and social class differences are unlikely to account for the almost twofold increase in risk noted for the 0-4 year olds living within 10 km of the establishments. There have also been suggestions that the incidence of childhood leukaemia may be greater in urban than rural areas.^{18,19} It is unlikely that our findings could be explained by such variation in incidence of disease. The incidence ratios among 0-4 year olds were significantly increased within both the 5 km and the 10 km circles, yet the 5 km circles included predominantly rural areas, whereas the 10 km circles included the urban centre, Reading. Infection, birth order, and certain parental occupations have also been linked with childhood leukaemia,^{18,20} but it is impossible to assess their roles or that of other environmental influences here. To investigate these findings further, and in particular to study the possible contribution of other factors, a case-control study of childhood cancer in the area is planned.

Could the excess registration of leukaemia in the electoral wards lying within 10 km of the nuclear establishments be due to chance? The probability of the excess in the 0-4 age group occurring by chance is less than 0.001 and in the 0-14 year olds 0.05, based on a stringent two sided statistical test. Moreover, this investigation is now one of a series examining the incidence of childhood leukaemia around nuclear establishments.¹⁻⁶ Table VII summarises the findings from the published reports. Although the years included and the age groups studied differed, the incidence ratio for leukaemia was greater than 1.0 for each establishment but not always significant at the 5% level. When all the data are added together a total of 96 cases of leukaemia are observed, compared with the expected total of 65 ($p<0.001$). As the suspicion of an increased occurrence of childhood leukaemia in a village near the Sellafield plant prompted many of the other investigations, the Sellafield data should be viewed as generating, rather than testing, the hypothesis that the

TABLE VII—Summary of the reported findings on the incidence of childhood leukaemia in the vicinity of nuclear establishments in the United Kingdom

Nuclear establishment	Approximate date when operations began	Area included in the analysis	Childhood leukaemia incidence				
			Time period	Age group (years)	Observed No of cases	Expected No of cases	Incidence ratio (95% confidence interval)*
Sellafield ¹	1947	Copeland district	1961-80	0-14	19	10.5	1.8 (1.1 to 2.8)
Dounreay ^{4,5}	1954	Enumeration districts whose centres fell within a 12.5 km radius of the establishment	1968-84	0-24	5	1.6	3.2 (1.0 to 7.3)
Holy Loch ⁶	1961	Postcode sectors immediately adjacent to the installations	1964-85	0-14	4	2.1	1.9 (0.5 to 4.9)
Faslane ⁶	1963		1964-85	0-14	5	4.2	1.2 (0.4 to 2.8)
Chapel Cross ⁶	1962		1964-85	0-14	3	2.3	1.3 (0.3 to 3.8)
Hunterston ⁶	1963		1964-85	0-14	19	15.7	1.2 (0.7 to 1.9)
Atomic Weapons Research Establishment, Aldermaston, Royal Ordnance Factory, Burghfield, and a small part of United Kingdom Atomic Energy Authority's establishment, Harwell	1952, 1962, and 1946, respectively	Electoral wards lying within (or with at least half their area within) a 10 km circle around the establishments	1972-85	0-14	41	28.6	1.4 (1.0 to 2.0)

*Incidence ratio (95% confidence interval) for all nuclear establishments=1.5 (1.2 to 1.8) and for all establishments excluding Sellafield=1.4 (1.1 to 1.8). For Hunterston inner and outer postcode sectors are included.

incidence of childhood cancers is increased around nuclear establishments. If the Sellafield data are excluded from the totals 77 cases of leukaemia are observed and 54.5 expected. The probability of such an excess occurring by chance is less than 0.01. Our data dominate the figures, as, unlike many nuclear establishments, those we studied are situated near areas of fairly high population density. Almost all the excesses described here were attributable to children aged 0-4. Other analyses of childhood leukaemia near nuclear establishments have not presented data for 0-4 year olds separately. The difficulty in accounting for the observed excesses of childhood leukaemia in terms of known emissions from nuclear establishments is a complex issue, which has been discussed in detail only for the Sellafield data.¹

The data reported so far do not cover all nuclear establishments in the country, and our data include only a small part of the area around the United Kingdom Atomic Energy Authority's establishment at Harwell. There were no cases at all in the two West Berkshire electoral wards with at least half of their area included in the 10 km circle around Harwell, and only 0.38 cases were expected at ages 0-14. Other research groups are studying the incidence of childhood leukaemia around Harwell, and it is hoped that their findings will be available soon. The data described here are essentially confined to the area around the Atomic Weapons Research Establishment, Aldermaston, and the Royal Ordnance Factory, Burghfield, and all the excess registrations of childhood leukaemia described occurred there. The incidence ratios were similar around each of the two establishments, although significant only around the Royal Ordnance Factory, which lies near areas of high population density. The reports so far may have selected establishments that happen to be located near areas with an increased rate of childhood leukaemia. The analyses for Dounreay were prompted by the impending local inquiry,^{4,5} as were those relating to Holy Loch, Faslane, Chapel Cross, and Hunterston, which were reported as showing no evidence of an increase in childhood leukaemia.⁶ Staff at the Royal Berkshire and Basingstoke District Hospitals have had a longstanding clinical impression, dating from the 1970s, that more children were attending their hospitals with leukaemia than might be expected but did not suggest that the excess incidence was confined to an area within a 10 km radius of the local nuclear establishments.

Despite the significance of our findings the actual risk of leukaemia to children living in the West Berkshire and Basingstoke and North Hampshire District Health Authorities and within a 10 km radius of the nuclear establishments is not great. About 60 000 children aged 0-14 were living at any one time within a 10 km radius of the nuclear establishments. About two of these children would normally be expected to develop leukaemia each

year, but three have been registered, representing one extra case of leukaemia among these 60 000 each year.

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