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ORIGINAL CONTRIBUTIONS

Cancer Incidence near Radio and Television Transmitters in Great Britain

I. Sutton Coldfield Transmitter

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A small area study of cancer incidence in 1974–1986 was carried out to investigate an unconfirmed report of a "cluster" of leukemias and lymphomas near the Sutton Coldfield television (TV) and frequency modulation (FM) radio transmitter in the West Midlands, England. The study used a national database of postcoded cancer registrations, and population and socioeconomic data from the 1981 census. Selected cancers were hematopoietic and lymphatic, brain, skin, eye, male breast, female breast, lung, colorectal, stomach, prostate, and bladder. Expected numbers of cancers in small areas were calculated by indirect standardization, with stratification for a small area socioeconomic index. The study area was defined as a 10 km radius circle around the transmitter, within which 10 bands of increasing distance from the transmitter were defined as a basis for testing for a decline in risk with distance, and an inner area was arbitrarily defined for descriptive purposes as a 2 km radius circle. The risk of adult leukemia within 2 km was 1.83 (95% confidence interval 1.22–2.74), and there was a significant decline in risk with distance from the transmitter ($p = 0.001$). These findings appeared to be consistent over the periods 1974–1980 and 1981–1986, and were probably largely independent of the initially reported cluster, which appeared to concern mainly a later period. In the context of variability of leukemia risk across census wards in the West Midlands as a whole, the Sutton Coldfield findings were unusual. A significant decline in risk with distance was also found for skin cancer, possibly related to residual socioeconomic confounding, and for bladder cancer. Study of other radio and TV transmitters in Great Britain is required to put the present results in wider context. No causal implications can be made from a single cluster investigation of this kind. *Am J Epidemiol* 1997;145:1–9.

electromagnetic fields; leukemia; neoplasms; radio waves

There has been considerable public and scientific debate concerning the possible adverse health effects associated with environmental exposure to extremely low frequency (0–300 Hz) non-ionizing radiation, as emitted by power cables and electric substations (1–5). Exposure to extremely low frequency radiation has most commonly been associated with leukemia, particularly acute myeloid and childhood leukemia, and also brain cancer, male breast cancer, and skin and eye melanoma (1, 3, 6–12), although there is currently no agreement as to causality (2–5).

Far less attention has been paid to environmental

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Abbreviations: CI, confidence interval; erp, effective radiated power; FM, frequency modulation; ICD, *International Classification of Diseases*; O/E ratio, observed/expected ratio; TV, television.

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exposure to radiation in the radiofrequency range (100 kHz to 300 GHz), including television (TV) and frequency modulation (FM) broadcast frequencies (30 MHz to 1 GHz), at field strengths below those required to produce thermal effects. The few epidemiologic studies that have reported on cancer incidence in relation to radiofrequency radiation (mainly from occupational exposure including microwave and radar) have generally presented negative or inconsistent results, or were subject to possible confounding from other exposures (2, 13–22). A study of residential exposure in Hawaii examined cancer incidence for census tracts with broadcasting antennae (22). A significantly increased relative risk of all cancers was found (standard incidence ratio (SIR) = 1.36 based on 905 cases, $p < 0.01$), and there was a nonsignificant excess of leukemias (SIR = 1.56 based on 23 cases, $p > 0.01$). However, there was only limited control for possible confounding.

Nevertheless, concerns have been expressed about the possible health effects of living near high power radio transmitters. Following a claim (see Appendix) of an excess of cases of leukemia and lymphoma near the Sutton Coldfield radio and television transmitter in the West Midlands, England, the Small Area Health Statistics Unit in the United Kingdom (23) was asked to investigate the incidence of selected cancers in the vicinity. The results of those analyses are reported here.

MATERIALS AND METHODS

The Sutton Coldfield transmitter is sited at the northern edge of the city of Birmingham. It first came into service in 1949 for television. High power transmission at 1 megawatt effective radiated power (erp) per frequency began with one frequency in 1964, rose to 3 frequencies in 1969, and then 4 frequencies in 1982. Three frequencies of very high frequency (VHF) radio began in 1957, at 250 kW erp per frequency. The mast is 240 m high. There are no big hills (above the height of the transmitter) in the study area. Nearby industrial processes registered with Her Majesty's Inspectorate of Pollution include a mineral works 3 km east, a copper works 6.5 km west, and a lead works 7 km west (Department of the Environment, personal communication, 1993).

Cancer incidence data postcoded to address at diagnosis were examined from 1974 to 1986. Population statistics were from the 1981 census enumeration districts and wards. The study area was defined by a circle of 10 km radius centered on the transmitter, grid reference SK 113003 (figure 1). The population within 10 km was around 408,000. Within the study area, ten bands of outer radius 0.5, 1, 2, 3, 4.9, 6.3, 7.4, 8.3, 9.2, and 10 km were defined (giving equal areas beyond 3 km). Populations and cases were located in the study area via the postcode of residence (which refers to an average of 14 households in Great Britain) according to methods described elsewhere (23). The completeness of postcoding of cancer registrations is high both nationally (96.6 percent) and in the West Midlands region (98.7 percent).

The following cancers at ages 15 years and over were considered as a priori groupings according to the 8th and 9th revisions of the *International Classification of Diseases* (ICD):

1) all cancers, excluding non-melanoma skin cancer (ICD-8/9 code 173);
2) cancers of the type stated in the initial cluster report, i.e., hematopoietic and lymphatic cancers: all leukemias (ICD-8/9 code 204–207 + ICD-9 code 208); multiple myeloma (ICD-8/9 code 203 + ICD-9 code 238.6), non-Hodgkin's lymphoma (ICD-8/9 code 200 + ICD-8 code 202 + ICD-9 codes 202.0, 201.1, 202.8); all hematopoietic and lymphatic (all leukemias, multiple myeloma, non-Hodgkin's lymphoma and ICD-8/9 code 201); all leukemias and non-Hodgkin's lymphoma combined; all leukemias; acute leukemia, i.e., acute myeloid leukemia (205.0) and acute lymphatic leukemia (204.0) separately, and combined with ICD-8/9 code 206.0 + ICD-9 codes 204.2, 205.2, 206.2, 208.0, 208.2 + ICD-8 code 207.0; chronic myeloid leukemia (205.1); chronic lymphatic leukemia (204.1);
3) cancers possibly associated with non-ionizing radiation (1, 3, 6–12), i.e., malignant brain and nervous system cancers (ICD-8/9 codes 191, 192); brain and nervous system cancers of malignant, benign, and uncertain behavior (ICD-8/9 codes 191, 192 + ICD-8/9 code 225 + ICD-9 codes 237.5, 237.6, 237.9); skin melanoma (ICD-8/9 code 172); eye (mainly melanoma) (ICD-8/9 code 190); male breast (ICD-8 codes 174.0–2, ICD-9 code 175);
4) common cancers (examined separately), i.e., lung (162), colon (ICD-8 codes 153.0–3, 153.7–8, ICD-9 code 153), rectal (154), colorectal (colon + rectal), stomach (ICD-8/9 code 151), bladder (ICD-8/9 code 188), prostate (ICD-8/9 code 185), female breast (ICD-8 codes 174.0–2, ICD-9 code 174).

Childhood cancer (0–14 years) was restricted to all cancers and all leukemias.

To allow for possible socioeconomic confounding, a deprivation score, shown elsewhere to be a powerful predictor of cancer rates (24), was calculated for each census enumeration district in Great Britain using 1981 census data on unemployment, overcrowding, and social class of head of household. The scores were grouped into quintiles, with a small sixth category for unclassifiable enumeration districts, mostly with institutional populations. According to this deprivation score, the areas closer to the transmitter were more affluent than those further away, i.e., at 1–2 km, 67 percent of the population was in the two most affluent

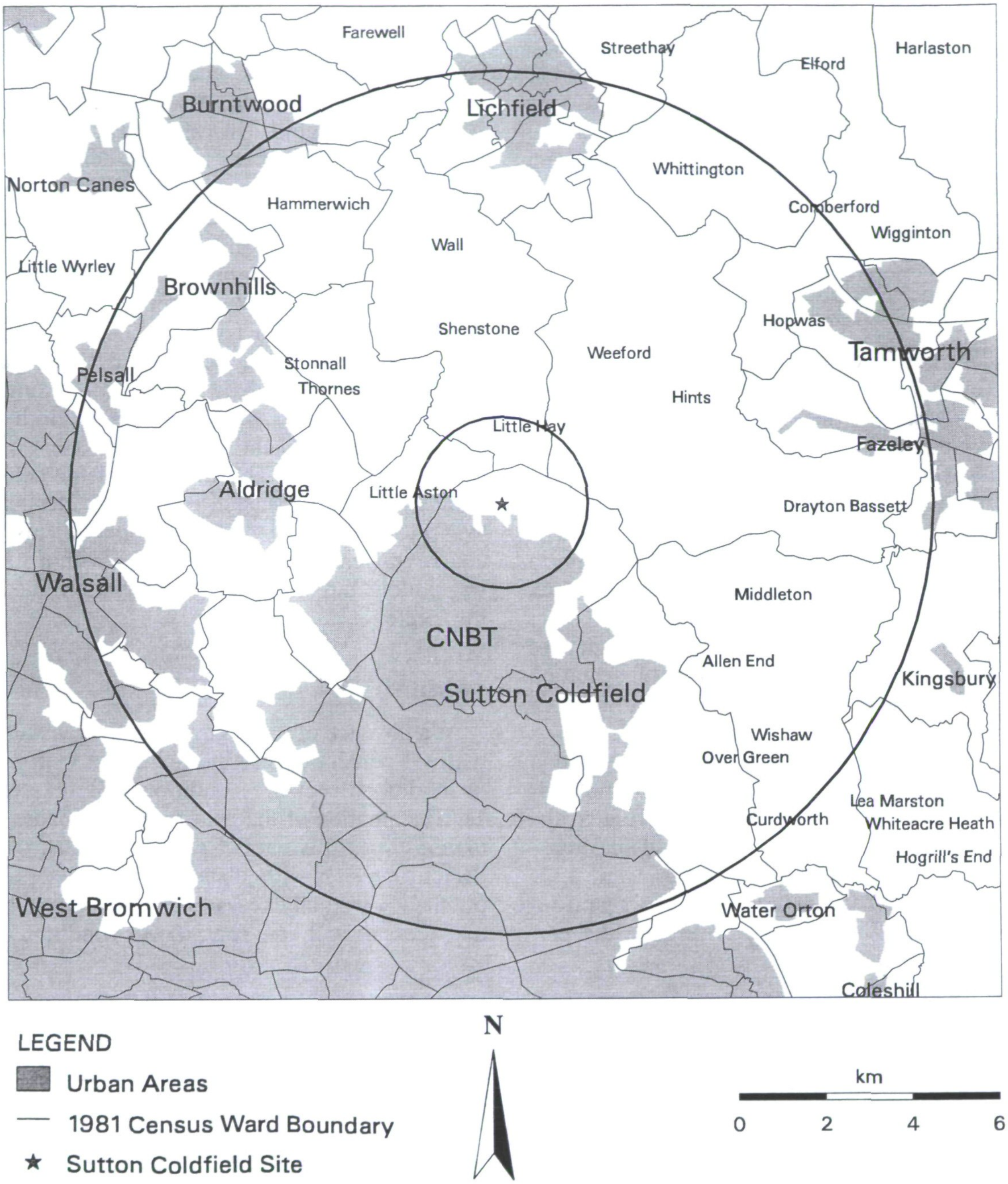

FIGURE 1. Map of 2 and 10 km circles surrounding Sutton Coldfield television and FM radio transmitter, showing position of census ward "CNBT." (Map data copyright Automobile Association.)

quintiles, compared with 28 percent at 9.2–10 km. For many cancers (e.g., lung), lower incidence rates would be expected in the more affluent areas; for some other cancers (e.g., leukemia), there is essentially no relation between incidence and deprivation thus measured, whereas for others (e.g., skin melanoma), higher disease rates are found in the more affluent areas (24).

Statistical analysis was based on the comparison of observed and expected numbers of cancer cases; the expected numbers were calculated from national incidence rates stratified by 5-year age group, sex, year, and deprivation quintile, and regionally adjusted, as described in detail elsewhere (25). Compared with national rates, the West Midlands region had standardized incidence ratios of 0.95 for all cancers and 0.80 for leukemias (0.65 for chronic lymphatic leukemia).

For descriptive purposes, observed and expected values, observed/expected (O/E) ratios, and their 95 percent confidence intervals (calculated assuming a Poisson distribution) are reported for the entire study area (0–10 km) and for an area close to the source, arbitrarily chosen to be 0–2 km. Formal tests of significance were based on those proposed by Stone (26) for isotonic decline in risk with distance from the source. These tests give due weight to the smaller populations near the site, and do not prespecify the shape of the decline, or boundaries between "exposed" and "unexposed" populations. Both an unconditional and a conditional test were performed (25, 27, 28). For the unconditional test, the null hypothesis is that the relative risk is one in each of the bands. An isotonic alternative includes any pattern of non-increasing risk over the study area. The data were further explored by use of the conditional test that corrects for the overall level of risk over the 10 km study area, thereby specifying a null hypothesis where all relative risks are equal to a constant, not necessarily one (25, 27). Significance levels were obtained by Monte Carlo methods based on 999 simulations and the nominal statistical significance level taken to be $p = 0.05$. Stone's tests were in all cases performed on the data in the ten predefined distance bands. For presentation purposes only, we give some data collapsed into four distance bands.

A geographic analysis to investigate the background variability of leukemia incidence in the West Midlands region was also done, in order to place in context the size of any excess found in the vicinity of the transmitter. This analysis was done at census ward level relating to around 10,000 people on average and included supplementary postcoding to reduce the percentage of unpostcoded cases of leukemias from 2.5 percent to 0.3 percent. Observed and expected numbers per ward were calculated as for the main analysis. Departure from Poisson variability was tested by the Pothoff-Whittinghill test (29) and a 5th to 95th percentile range in O/E ratios was calculated using a likelihood method that removes the random component of variability (30). O/E ratios were "smoothed" using an empirical Bayesian method (31). This method produces a set of smoothed estimates on the basis of a compromise between the observed relative risks and the overall regional mean, with the amount of "shrinkage to the mean" being determined by the population size of each ward, thereby removing variability in O/E ratios due to small population sizes. Both raw and smoothed values of the O/E ratio for each of the 832 wards were ranked, and the rank of the census ward containing the transmitter (ward designated as "CNBT" in figure 1) was determined. This ward included 90 percent of the population within 2 km of the transmitter, but with half its population outside the 2 km circle.

RESULTS

At a distance of 0–10 km from the transmitter, there was a 3 percent excess in all cancers with significant unconditional but not conditional Stone's test (table 1). Examination of the data for all ten bands (table 2) demonstrates this overall excess but lack of trend of decreasing risk with distance. Non-Hodgkin's lymphoma showed an excess from 0–10 km (table 1) but no excess at 0–2 km. The Stone's conditional test and

TABLE 1. Selected cancers near the Sutton Coldfield transmitter, West Midlands, England: observed and expected numbers of cases, observed/expected (O/E) ratios, and 95% confidence intervals (CI), by distance of residence from transmitter, in persons aged ≥15 years, 1974–1986

Type of cancer	Distance from transmitter (km)								Stone's p value*	
	0–2				0–10					
	Observed	Expected	O/E ratio	95% CI	Observed	Expected	O/E ratio	95% CI	U	C
All cancers†	703	647.49	1.09	1.01–1.17	17,409	16,861.22	1.03	1.02–1.05	0.001	0.462
Hematopoietic and lymphatic	45	37.08	1.21	0.91–1.62	935	895.83	1.04	0.98–1.11	0.153	
All leukemias and non-Hodgkin's lymphomas	31	24.76	1.25	0.88–1.78	661	592.84	1.11	1.03–1.20	0.018	0.161
All leukemias	23	12.59	1.83	1.22–2.74	304	302.34	1.01	0.90–1.13	0.001	0.001
All acute	10	5.38	1.86	0.89–3.42	116	131.75	0.88	0.73–1.06	0.003	0.004
Acute myeloid	4	3.94	1.02	0.28–2.60	81	95.60	0.85	0.68–1.05	0.024	0.045
Acute lymphatic	3	0.84	3.57	0.74–10.43	21	20.62	1.02	0.67–1.56	0.201	
Chronic myeloid	2	1.63	1.23	0.15–4.43	42	39.95	1.05	0.78–1.42	0.257	
Chronic lymphatic	8	3.12	2.56	1.11–5.05	96	72.56	1.32	1.08–1.62	0.002	0.007
Non-Hodgkin's lymphomas	8	12.17	0.66	0.28–1.30	357	290.50	1.23	1.11–1.36	0.005	0.958
Multiple myeloma	10	6.51	1.54	0.74–2.83	174	154.52	1.13	0.97–1.31	0.156	

* *p* values given by Stone's unconditional (U) and conditional (C) tests.

† All cancers excluding non-melanoma skin cancer.

TABLE 2. All cancers, all leukemias, and non-Hodgkin's lymphomas near the Sutton Coldfield transmitter, West Midlands, England: observed and expected numbers of cases, observed/expected (O/E) ratios, and cumulative O/E ratios, by distance of residence from transmitter, in persons aged ≥15 years, 1974–1986

Distance from transmitter (km)	All cancers*				All leukemias				Non-Hodgkin's lymphomas			
	Observed	Expected	O/E ratio	Cumulative O/E ratio	Observed	Expected	O/E ratio	Cumulative O/E ratio	Observed	Expected	O/E ratio	Cumulative O/E ratio
0–0.5	2	5.61	0.36	0.36	1	0.11	9.09	9.09	0	0.11	0.00	0.00
0.5–1.0	96	137.19	0.70	0.69	5	2.72	1.84	2.12	3	2.60	1.15	1.11
1.0–2.0	605	504.59	1.20	1.09	17	9.76	1.74	1.83	5	9.46	0.53	0.66
2.0–3.0	282	279.01	1.01	1.08	9	5.56	1.62	1.76	9	5.76	1.56	0.95
3.0–4.9	1,002	1,050.86	0.95	1.00	25	20.22	1.24	1.49	20	20.25	0.99	0.97
4.9–6.3	2,414	2,301.25	1.05	1.03	54	41.96	1.29	1.38	45	40.60	1.11	1.04
6.3–7.4	2,734	2,650.62	1.03	1.03	48	46.54	1.03	1.25	57	43.95	1.30	1.13
7.4–8.3	2,827	2,798.65	1.01	1.02	51	49.22	1.04	1.19	52	47.19	1.10	1.12
8.3–9.2	3,383	3,213.75	1.05	1.03	40	57.35	0.70	1.07	80	54.56	1.47	1.21
9.2–10	4,084	3,919.59	1.04	1.03	54	68.90	0.78	1.01	86	66.02	1.30	1.23

* All cancers excluding non-melanoma skin cancer.

examination of the data over the ten bands (table 2) do not indicate a decline in risk with distance. Excesses within 2 or 10 km of the transmitter for hematopoietic and lymphatic cancers and multiple myeloma, were not statistically significant (table 1), nor was there evidence of a significant decline in risk with distance.

For adult leukemias from 0–2 km, the O/E ratio was 1.83 (95 percent confidence interval (CI) 1.22–2.74), based on 23 cases (table 1). The Stone's tests indicated a significant ($p = 0.001$) decline in risk with distance; data for all ten bands (table 2) were consistent with a decline in risk extending over the entire 10 km. Risk fell below 1.0 in the outer bands so that there was no overall excess over the 10 km area (O/E ratio = 1.01, 95 percent CI 0.90–1.13) (table 1). A pattern of decline with significant Stone's conditional tests was also found at ages 15–64 and ≥65 years, and for each sex separately (table 3). Acute leukemias, acute myeloid leukemia, and chronic lymphatic leukemia showed significant declines in risk with distance, as indicated by Stone's tests (table 1) and inspection of the data (table 4).

The leukemia excess at 0–2 km was apparent in both the earlier (1974–1980) and later (1981–1986) periods; there were 11 leukemia cases in the first period and 12 leukemia cases in the second period, and O/E ratios of 1.80 and 1.85, respectively. Stone's tests were significant in both periods. Twenty-one of the 23 cases within 2 km are known to have died, as verified by death certificates, and all but one had died by 1988. The stated occupations at diagnosis of the 23 adult leukemia cases were as follows: of 10 females, 4 housewives, 1 clerk/cashier, and 5 unstated; of 13 males, 2 clerk/cashiers, 3 managers, 1 printer, 1 gardener, 1 teacher, 1 farmer, 1 driver/foreman of roads goods vehicles, 1 inadequately described, and 2 unstated.

Among children, there were 97 cancers within 0–10 km of the transmitter (106.1 expected), including 34 leukemia cases (29.7 expected), of which 2 cases were at 0–2 km (1.1 expected); Stone's tests were not significant (leukemia conditional test $p = 0.173$).

Among other adult cancers, there was a significant decline in risk for skin melanoma and for bladder

TABLE 3. Leukemia near the Sutton Coldfield transmitter, West Midlands, England, by age and sex: observed and expected numbers of cases, observed/expected (O/E) ratios, and 95% confidence intervals (CI), by distance of residence from transmitter, in persons aged ≥15 years, 1974–1986

Sex and age (years)	Distance from transmitter (km): 0–2				Distance from transmitter (km): 0–10				Stone's p value*	
	Observed	Expected	O/E ratio	95% CI	Observed	Expected	O/E ratio	95% CI	U	C
Both sexes										
15–64	10	4.75	2.11	1.01–3.87	132	121.71	1.08	0.91–1.29	0.003	0.001
≥65	13	7.84	1.66	0.97–2.84	172	180.63	0.95	0.82–1.11	0.009	0.008
Males										
≥15	13	6.72	1.93	1.13–3.31	162	164.72	0.98	0.84–1.15	0.002	0.000
Females										
≥15	10	5.86	1.71	0.82–3.14	142	137.60	1.03	0.88–1.22	0.014	0.006

* p values given by Stone's unconditional (U) and conditional (C) tests.

TABLE 4. Acute leukemias and acute myeloid, acute lymphatic, chronic myeloid, and chronic lymphatic leukemias near the Sutton Coldfield transmitter, West Midlands, England: observed numbers of cases and observed/expected (O/E) ratios, by distance of residence from transmitter, in persons aged ≥15 years, 1974–1986

Leukemia subtype	Distance from transmitter (km)							
	0–2		2–4.9		4.9–7.4		7.4–10	
	Observed	O/E ratio	Observed	O/E ratio	Observed	O/E ratio	Observed	O/E ratio
Acute leukemias	10	1.86	11	0.95	38	0.99	57	0.75
Acute myeloid	4	1.02	8	0.97	28	1.00	41	0.74
Acute lymphatic	3	3.57	3	1.52	5	0.83	10	0.85
Chronic myeloid	2	1.23	3	0.87	19	1.62	18	0.78
Chronic lymphatic	8	2.56	14	2.31	27	1.27	47	1.12

cancer (table 5), although point estimates of O/E ratios were not in excess within 1 km for these cancers (table 6); none of the other Stone's tests were significant.

The ward level geographic analysis of adult leukemia in the West Midlands region showed significant extra-Poisson variability (Pothoff-Whittinghill $z = 2.67$, $p = 0.004$). The 5th to 95th percentile range of O/E ratios was estimated as 0.70 to 1.35 after removing random fluctuation. Census ward "CNBT," containing 90 percent of the population within 2 km of the transmitter, had a raw O/E ratio of 1.55, which ranked 154 out of 832 wards. After smoothing, the ratio was 1.25, ranking second. The highest ranking ward for smoothed values had 26 observed cases and a raw O/E ratio of 1.74, which after smoothing was reduced to 1.26. This analysis therefore indicates that the excess in the 0–2 km circle around Sutton Coldfield, with 23 cases observed and 12.6 expected, was unusual, even in the presence of significant geographic variation in leukemia incidence in the West Midlands region. However, the magnitude of excess was not much greater than that found elsewhere in the region.

DISCUSSION

The main finding was the confirmation of a reported excess of leukemias near the Sutton Coldfield radio and television transmitter, and a decline in risk with distance from the site. Because all but one of the leukemia cases included in our study had died by 1988, this would seem to be independent of the seven apparently current cases reported in the media in 1992, although unfortunately further details of those cases were not made available to us or to the health authorities. Our findings appear to be consistent over two independent time periods (1974–1980 and 1981–

TABLE 5. Other cancers near the Sutton Coldfield transmitter, West Midlands, England: observed and expected numbers of cases, observed/expected (O/E) ratios, and 95% confidence intervals (CI), by distance of residence from transmitter, in persons aged ≥15 years, 1974–1986

Type of cancer	Distance from transmitter (km)								Stone's *p* value*	
	0–2				0–10					
	Observed	Expected	O/E ratio	95% CI	Observed	Expected	O/E ratio	95% CI	U	C
Cancers possibly associated with non-ionizing radiation										
Brain										
Malignant and benign	17	13.20	1.29	0.80–2.06	332	317.74	1.04	0.94–1.16	0.612	
Malignant	12	9.18	1.31	0.75–2.29	218	223.27	0.98	0.86–1.11	0.717	
Skin melanoma	13	9.10	1.43	0.83–2.44	189	196.53	0.96	0.83–1.11	0.027	0.018
Eye melanoma	0	0.71	0	0–4.22	20	17.19	1.16	0.75–1.80	0.849	
Male breast	1	0.61	1.64	0.04–9.13	15	15.08	0.99	0.60–1.64	0.889	
Common cancers										
Female breast	107	98.67	1.08	0.90–1.31	2,412	2,288.30	1.05	1.01–1.10	0.131	
Lung	113	112.31	1.01	0.84–1.21	3,466	3,418.60	1.01	0.98–1.05	0.875	
Colorectal	112	99.48	1.13	0.94–1.35	2,529	2,454.93	1.03	0.99–1.07	0.330	
Stomach	33	43.75	0.75	0.54–1.06	1,326	1,248.40	1.06	1.01–1.12	0.246	
Prostate	37	32.81	1.13	0.82–1.55	785	760.45	1.03	0.96–1.11	0.466	
Bladder	43	28.37	1.52	1.13–2.04	788	728.96	1.08	1.01–1.16	0.008	0.040

* *p* values given by Stone's unconditional (U) and conditional (C) tests.

TABLE 6. **Skin melanoma and bladder cancers in the vicinity of the Sutton Coldfield transmitter, West Midlands, England: observed and expected numbers of cases, observed/expected (O/E) ratios, and cumulative O/E ratios, by distance of residence from transmitter, in persons aged ≥15 years, 1974–1986**

Distance from transmitter (km)	Skin melanoma				Bladder cancer			
	Observed	Expected	O/E ratio	Cumulative O/E ratio	Observed	Expected	O/E ratio	Cumulative O/E ratio
0–0.5	0	0.09	0.00	0.00	0	0.24	0.00	0.00
0.5–1.0	2	2.02	0.99	0.95	4	5.96	0.67	0.65
1.0–2.0	11	6.99	1.57	1.43	39	22.17	1.76	1.52
2.0–3.0	12	5.03	2.39	1.77	11	11.94	0.92	1.34
3.0–4.9	16	16.16	0.99	1.35	43	45.27	0.95	1.13
4.9–6.3	26	28.77	0.90	1.13	119	100.31	1.19	1.16
6.3–7.4	28	27.93	1.00	1.09	131	114.85	1.14	1.15
7.4–8.3	32	30.90	1.04	1.08	117	120.64	0.97	1.10
8.3–9.2	28	35.66	0.79	1.01	169	140.13	1.21	1.13
9.2–10	34	43.08	0.79	0.96	155	167.45	0.93	1.08

1986). Within the context of some unexplained variability in leukemia incidence across census wards in the West Midlands region, the excess near Sutton Coldfield can be considered unusual.

Possible methodological artefacts to explain the leukemia findings were explored. First, the lower registration of cancers, and particularly leukemias, in West Midlands relative to the country as a whole, is unexplained, but there was no suggestion that the level of registration varied systematically within the region; nor would it seem likely that any such registration artefact could produce local trends in risk of the order seen around Sutton Coldfield. Second, there are known problems of leukemia diagnosis and registration, particularly at older ages, but we found similar results in the younger and older age groups. Third, the study spanned 1974–1986, but relied on population data from the 1981 census, i.e., around the midpoint of the study period. Estimates were made of the extent to which population change over the period (including ageing of the population) may have led to bias in the calculation of the expected numbers of cancers. Based on data from the 1971 and 1991 censuses, there appeared to be a tendency for overestimation of the O/E ratios close to the site (within 2 km), but the bias, estimated at less than 5 percent, was not sufficient to explain the excesses of leukemia observed.

Secondary findings of the study were declines in skin melanoma and bladder cancer with distance from the transmitter site. Because skin melanoma is strongly inversely related to level of deprivation (24), and because this transmitter is located in a relatively affluent area, control for socioeconomic confounding, as expected, reduced the size of the excess—by 11 percent within 2 km. However, it is possible that further socioeconomic confounding could explain at least part of the residual excess of skin melanoma near the site. Bladder cancer was examined along with other causes to explore the small general excess in all cancers, and there was no a priori hypothesis linking it to the exposure under consideration. The results should be viewed in the context of the large number of statistical tests performed and hence may be chance findings.

Field strength measurements have been made in the vicinity of the transmitter (British Broadcasting Corporation, internal report, 1994). In general, both measured and predicted field strength values tended to show a decline in average field strength or power density with distance from the transmitter, although there are undulations in predicted field strength up to distances of about 6 km from the transmitter resulting from the vertical radiation pattern. The maximum total power density equivalent summed across frequencies at any one measurement point (at 2.5 m above ground) was 0.013 W/m^2 for TV, and 0.057 W/m^2 for FM. However, there was considerable variability between different measurement points at any one distance from the transmitter, as would be expected from the impact of reflections from the ground and buildings, and this variability was as great as that related to distance. Power density on average declines by a factor of at least 5 to 10 over 10 km. Field strength varies as the square root of power density, thus declining less steeply, and it is not clear which exposure measure would be biologically more relevant for athermal effects. These measurements cannot of course be converted to personal dose to residents, which depends on numerous factors, including building type, the amount of time spent inside the home as well as away from home, and the number of years spent at the residence. It can nevertheless be assumed that, on average, residents in higher exposure areas receive higher doses unless this is obscured by the combination of patterns of population density and of variable field strengths at any one distance from the transmitter. The exposures near Sutton Coldfield appear to be much lower than those in other epidemiologic studies where the health effects of radiofrequency exposure have been examined (2, 13, 14, 22). They are well within current guidelines based on the thermal effects of radiofrequency exposure (15, 32).

In conclusion, the results of this study confirm that there was an excess of adult leukemia within the vicinity of the Sutton Coldfield TV/FM transmitter in the period 1974–1986, accompanied by a decline in risk with distance from the transmitter. Further monitoring of cancer statistics in the area appears warranted. No causal implications regarding radio and TV transmitters can be drawn from this finding, based as it is on a single "cluster" investigation. Results of a study of cancer incidence around all other high power radio and TV transmitters in Great Britain are given in the accompanying paper (33) in order to put the present results in wider context.

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APPENDIX

On March 30, 1992, the *Guardian* newspaper (34) reported that Dr. Mark Payne of Solihull, Birmingham, had collected data on cancer cases from a north Birmingham general practitioner with 2,600 patients. According to the report, seven existing cases of leukemia and lymphoma, five men and two women aged 18–66 years, were identified, living 400 to 1,500 m from the Sutton Coldfield transmitter. All but one of the cases had lived in the region for 14–25 years; the remaining case had lived there for only 2 years. As a rough guide, in a population with the same age structure as England and Wales, one could expect 2.5 cases per 10,000 persons per year to be newly diagnosed with leukemia or lymphoma. Dr. Payne explained later (Dr. M. Payne, Alternative Medicine Centre, Solihull, Birmingham, personal communication, 1993) that his attention had been drawn to the area because of his concerns that non-ionizing radiation is harmful to health, although it is not clear how the particular general practice was chosen for study (the practice population forms approximately 16 percent of the population within 2 km of the transmitter). Details of the study have not subsequently been published outside the popular press.