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Cancer Incidence near Radio and Television Transmitters in Great Britain

II. All High Power Transmitters

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A small area study of cancer incidence, 1974–1986, near 20 high power television (TV) and frequency modulation (FM) radio transmitters in Great Britain was carried out to place in context the findings of an earlier study around the Sutton Coldfield transmitter. The national database of postcoded cancer registrations was used with population and socioeconomic data from the 1981 census. Cancers examined were adult leukemias, skin melanoma, and bladder cancer, following the findings in the earlier study of significant declines in risk of these cancers with distance from the Sutton Coldfield transmitter. Childhood leukemia and brain cancer were also examined. Statistical analysis was performed for all transmitters combined, four overlapping groups of transmitters defined by their transmission characteristics, and for all transmitters separately. There were 3,305 adult leukemia cases from 0–10 km (observed/expected (O/E) ratio = 1.03, 95% confidence interval (CI) 1.00–1.07). A decline in risk of adult leukemia was found for all transmitters combined ($p = 0.05$), two of the transmitter groups, and three of the single transmitters; for all transmitters combined, observed excess risk was no more than 15% at any distance up to 10 km, and there was no observed excess within 2 km of transmitters (O/E ratio = 0.97, 95% CI 0.78–1.21). For childhood leukemia and brain cancer, and adult skin melanoma and bladder cancer, results were not indicative of a decline in risk with distance from transmitters. The magnitude and pattern of risk found in the Sutton Coldfield study did not appear to be replicated. The authors conclude that the results at most give no more than very weak support to the Sutton Coldfield findings. *Am J Epidemiol* 1997;145:10–17.

electromagnetic fields; leukemia; neoplasms; radio waves

This study of the incidence of leukemia and other selected cancers near high power frequency modulation (FM) radio and television (TV) transmitters in Great Britain follows an earlier study of the incidence of hematopoietic and selected cancers near the Sutton Coldfield transmitter (1), in order to provide an independent test of hypotheses arising from the findings of that study.

The Sutton Coldfield study, covering the period 1974–1986, found a decline in the ratio of observed to expected cases of adult leukemia with distance from the transmitter over a 10 km radius, with a risk within 2 km of the transmitter of 1.83 (95 percent confidence interval (CI) 1.22–2.74) relative to the West Midlands regional average. Within the range of variability of leukemia incidence across census wards in the West Midlands region, the Sutton Coldfield excess was unusual. Of a number of cancers other than leukemia studied in the Sutton Coldfield area, only skin melanoma and bladder cancer showed a decline in the ratio of observed to expected cases with distance from the transmitter.

We report here findings for adult leukemias, skin melanoma, and bladder cancer near the other 20 high power radio and TV transmitters in Great Britain. Eight of these transmit FM radio frequencies and three transmit TV frequencies at power equivalent to Sutton Coldfield (figure 1), but none transmit at exactly the same combination of frequencies and power as Sutton Coldfield. Childhood leukemias and brain cancers are also included in this

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Abbreviations: BBC, British Broadcasting Corporation; CI, confidence interval; erp, effective radiated power; FM, frequency modulation; O/E ratio, observed/expected ratio; TV, television.

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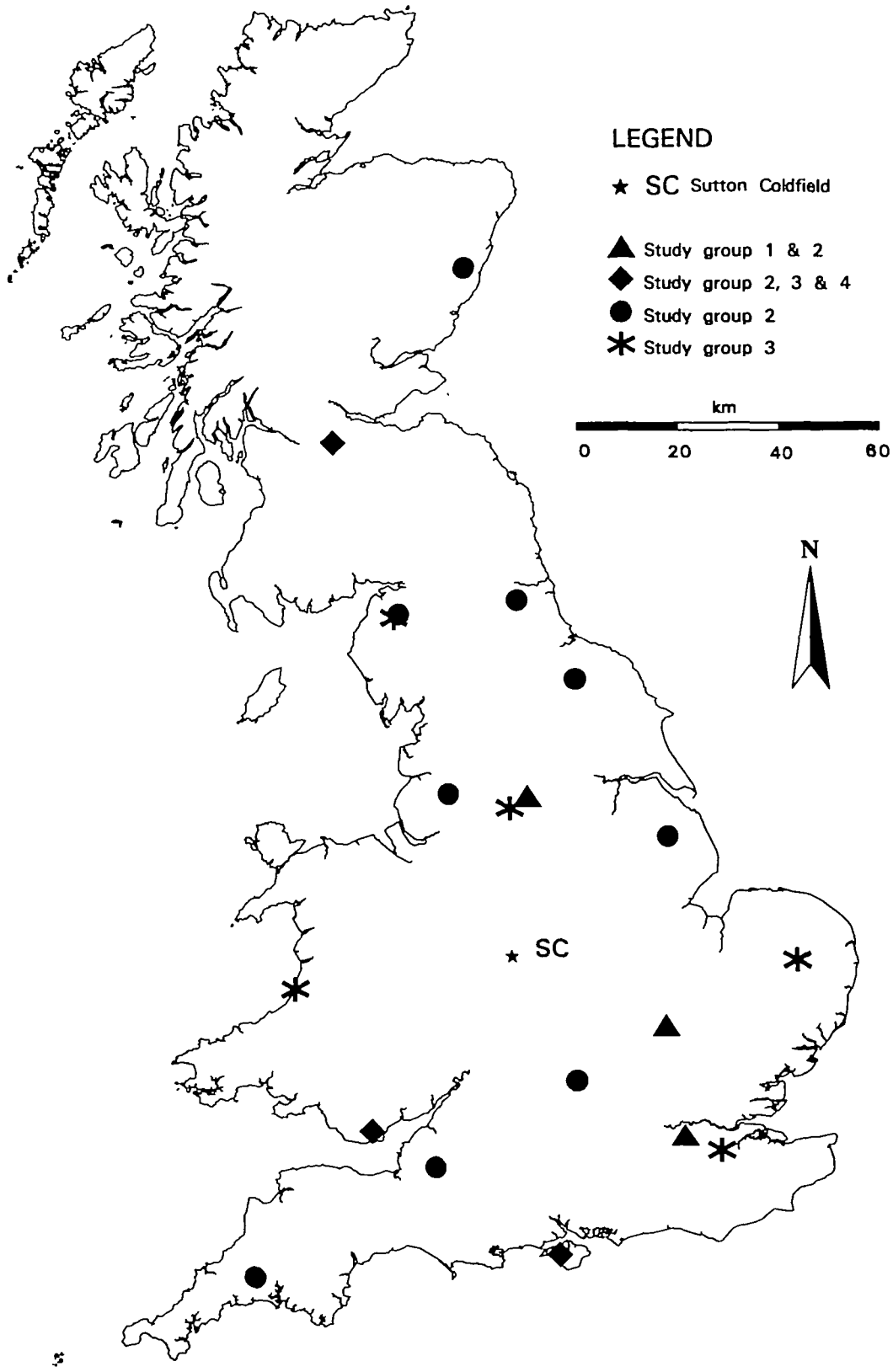

FIGURE 1. Map showing 21 television and FM radio high power transmitters (including Sutton Coldfield) in Great Britain. Definitions of transmitter groups: Group 1, highest power TV transmitters of 870–1,000 kW erp; Group 2, all TV transmitters of 500–1,000 kW erp; Group 3, all FM transmitters of 250 kW erp; Group 4, all transmitters with a combination of TV (≥500 kW erp) and FM (250 kW erp) transmission.

study in view of the a priori interest of these cancers in relation to electromagnetic field exposure.

MATERIALS AND METHODS

The study gives an independent test of the association found in the Sutton Coldfield study between residence near a high power radio transmitter and risk of adult leukemia, skin melanoma, and bladder cancer. The analysis was therefore done excluding the Sutton Coldfield transmitter itself. For childhood leukemia and brain cancer, which were not significantly in excess near the Sutton Coldfield transmitter, we took advantage of the larger sample size available to investigate more generally whether residence near a transmitter is associated with increased risk. Therefore, those data are analyzed with the inclusion of Sutton Coldfield.

A list of all radio and TV transmitters with transmission power of at least 500 kW effective radiated power (erp) for television and 250 kW erp for FM was supplied by the British Broadcasting Corporation (BBC), including both BBC and non-BBC transmitters (figure 1). No other transmitter resembles Sutton Coldfield exactly in its combination of both high power TV and FM transmission. In addition to the main analysis of all transmitters combined, analysis was carried out for each transmitter separately and for four groups of transmitters: Group 1, highest power TV transmitters of 870–1,000 kW erp; Group 2, all TV transmitters of 500–1,000 kW erp; Group 3, all FM transmitters of 250 kW erp; Group 4, all transmitters with a combination of TV (≥500 kW erp) and FM (250 kW erp) transmission.

These groups were not mutually exclusive, because one transmitter could be in more than one group. The groups were therefore not designed to give independent tests of the hypotheses, but were chosen to allow for the possibility of a strong dose-response effect or threshold (in view of the fact that electromagnetic fields are considered to be non-genotoxic so that a threshold model is more likely to be appropriate (2–4)), and to allow for differences between FM and TV frequencies, alone or in combination. Human absorption of FM radiation is higher than that of TV radiation, but this is thought to be relevant only to thermal effects (2).

Most transmitters started with ultra high frequency (UHF) TV transmission in 1965 with one frequency, adding two further frequencies in 1969, and one more in 1982. All transmitters had three frequencies by 1971. Three FM channels began in 1955–1958 (except at Black Hill and Blaenplwyf, where one of these was added in 1988–1989), and one further frequency was added between 1988 and 1990.

The study areas were defined by circles of radius 10 km from each transmitter. The total study population was around 3.39 million persons. Two pairs of transmitters were closer than 20 km to each other—Emley Moor and Holme Moss, which were 15.4 km apart, and Sandale and Calbeck, which were 4.3 km apart. Their populations were assigned to the nearest transmitter.

Cancer registration data were used, with the data postcoded to address at diagnosis for 1974–1986 for England, 1974–1984 for Wales, and 1975–1986 for Scotland. The selected cancers studied were all leukemias, all acute leukemias, acute lymphocytic leukemia, acute myelocytic leukemia, chronic lymphocytic leukemia, chronic myelocytic leukemia, skin melanoma, and bladder cancer, and in children, all leukemias, brain cancers (malignant), and brain cancers (malignant and benign). *International Classification of Diseases* codes for these cancers and a description of methods are given in the accompanying paper (1). Among adults, special attention was paid to the 15–64 years age group on the basis that leukemia diagnosis and its registration are more reliable in this age group. Analysis for the four transmitter groups was restricted to all leukemias.

In brief, arbitrary circles 0.5, 1.0, 2.0, 3.0, 4.9, 6.3, 7.4, 8.3, 9.2, and 10 km from each transmitter were defined. Observed cases were allocated according to the grid reference of the postcode of residence at diagnosis. Expected cases were based on national rates (Great Britain), stratified by year, age (5-year age groups), sex, and socioeconomic deprivation quintile, and adjusted for region. Population data were from the 1981 small area census statistics.

Statistical methods, based on descriptive statistics for 0–2 and 0–10 km circles (chosen a priori), and Stone's tests (5, 6) (unconditional and conditional) for decline in risk with distance from the transmitter, have been described in the accompanying paper (1). The main test of hypothesis was for all transmitters combined. Methods of pooling results from individual point sources to give overall (studywide) p values are given elsewhere (7, 8). When combining the data from multiple point sources, the Stone's conditional method takes into account the possibility that transmitters may vary in the overall level of risk over the surrounding 10 km, as well as in the pattern of decline of risk. While Stone's method gives a significance test of decline in disease risk with distance, it does not give an estimate of the magnitude of any excess (8), therefore inspection of the ten-band data is important for its interpretation. For presentation purposes only, we have given some data collapsed into four distance bands, although

significance tests were based on all ten bands, chosen a priori.

RESULTS

Results are given here for both sexes combined for persons aged 15 years and over and for children aged 0–14 years. (The age-, sex-, and transmitter-specific results, as well as results for leukemia subgroups, are available on request from the first author.)

Over all 20 transmitters (excluding Sutton Coldfield), there were 3,305 adult leukemia cases from 0–10 km (observed/expected (O/E) ratio = 1.03, 95 percent CI 1.00–1.07) and 79 cases from 0–2 km (O/E ratio = 0.97, 0.78–1.21) (table 1). Although there was no excess within 2 km, Stone's tests indicated a decline in O/E ratio with distance from transmitter of borderline significance ($p = 0.001$ unconditional, $p = 0.052$ conditional, table 1). Table 2 also shows that point estimates of O/E ratios in individual bands never exceeded 1.15 (2–3 km) for all transmitters combined. Although it is not possible to use Stone's test to compare subgroups directly, the significance of the decline for the 15–64 years age group ($p = 0.028$ unconditional, $p = 0.001$ conditional, data not shown) indicates that it is not restricted to older ages.

The Stone's tests were significant for Groups 3 and 4 (table 3), but the conditional test did not reach statistical significance for Groups 1 and 2. O/E ratios by band are given in table 2 for the four transmitter groups. Groups 3 and 4 had very few expected cases within 2 km.

Results for individual transmitters (table 3) showed significant ($p < 0.05$) declines in risk with distance for Crystal Palace, Rowridge, and Wenvoe (tables 2 and 3). Around both the Rowridge and Wenvoe transmitters, the O/E ratio in the outermost bands fell well below 1.00 (table 2). There was excess leukemia risk at 0–10 km for Sandy Heath (O/E ratio = 1.38, 95 percent CI 1.05–1.81) and Winter Hill (O/E ratio = 1.16, 95 percent CI 1.04–1.29) but no significant declines in risk (table 3), and a deficit at 0–10 km for Black Hill (O/E ratio = 0.80, 95 percent CI 0.67–0.97) (table 3).

None of the leukemia subtypes on their own showed a significant decline with distance for all transmitters combined (table 1). Inspection of the data (table 4) indicates that the small excess from 2–4.9 km in all leukemias is mainly associated with acute, acute myeloid, and chronic lymphatic leukemias.

For skin melanoma (table 1), there was an overall deficit of cases from 0–10 km (O/E ratio = 0.90, 95 percent CI 0.85–0.94), reflected in a significant unconditional Stone's test. Results of the conditional Stone's test (table 1) were not indicative of decline in risk with distance, and examination of data by distance (table 4) shows only a small nonsignificant excess within 2 km followed by a steady deficit at further distances. For bladder cancer, although there was an excess risk from 0–10 km (O/E ratio = 1.09, 95 percent CI 1.06–1.11) reflected in a significant unconditional Stone's test, the conditional Stone's test did not indicate decline in risk with distance, and this was supported by examination of data over the ten bands (table 4), indicating a constant excess with distance.

For childhood leukemia and brain cancer around all 21 transmitters combined (including Sutton Coldfield), numbers were small and confidence intervals within 2 km wide (table 5), and there were no significant declines in risk with distance.

DISCUSSION

In the earlier study of the Sutton Coldfield transmitter (1), the main finding was a decline in risk of adult leukemia with distance from the transmitter, accom-

TABLE 1. Cancer incidence near 20 high power radio and TV transmitters in Great Britain (excluding Sutton Coldfield): observed and expected numbers of cases, observed/expected (O/E) ratios, and 95% confidence intervals (CI), for all transmitters combined, 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 leukemias	79	81.58	0.97	0.78–1.21	3,305	3,194.25	1.03	1.00–1.07	0.001	0.052
All acute	34	36.21	0.94	0.67–1.31	1,422	1,347.90	1.05	1.00–1.11	0.124	
Acute myeloid	20	26.06	0.77	0.50–1.19	1,022	964.48	1.06	1.00–1.13	0.152	
Acute lymphatic	5	5.54	0.90	0.39–2.11	204	202.63	1.00	0.88–1.15	0.500	
Chronic myeloid	7	11.19	0.63	0.30–1.29	449	448.67	1.00	0.91–1.10	0.315	
Chronic lymphatic	28	23.23	1.20	0.83–1.74	969	953.98	1.02	0.95–1.08	0.055	0.674
Skin melanoma	51	46.08	1.11	0.84–1.46	1,540	1,719.36	0.90	0.85–0.94	0.001	0.725
Bladder cancer	209	193.66	1.08	0.94–1.24	8,307	7,655.32	1.09	1.06–1.11	0.001	0.864

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

TABLE 2. Cancer incidence near 20 high power radio and TV transmitters in Great Britain—all leukemias: observed (O) and expected (E) numbers of cases, O/E ratios, and cumulative O/E ratios, for all transmitters combined, for transmitter groups, and selected individual transmitters, by distance of residence from transmitter, in persons aged ≥15 years, 1974–1986

Distance from transmitter (km)	O	E	O/E ratio	Cumulative O/E ratio	O	E	O/E ratio	Cumulative O/E ratio	O	E	O/E ratio	Cumulative O/E ratio	O	E	O/E ratio	Cumulative O/E ratio
	All transmitters				*Group 1**				*Group 2**				*Group 3**			
0–0.5	2	2.3	0.87	0.87	2	1.9	1.08	1.08	2	2.2	0.91	0.91	0	0.2	0.0	0.00
0.5–1.0	12	13.8	0.87	0.87	11	12.0	0.92	0.94	12	13.4	0.90	0.90	0	0.6	0.0	0.00
1.0–2.0	65	65.5	0.99	0.97	53	52.6	1.01	0.99	63	63.2	1.00	0.98	6	5.8	1.03	0.90
2.0–3.0	155	135.3	1.15	1.08	125	97.1	1.29	1.17	155	132.0	1.17	1.10	11	13.9	0.79	0.82
3.0–4.9	539	494.1	1.09	1.09	377	342.7	1.10	1.12	516	476.1	1.08	1.09	78	61.0	1.28	1.16
4.9–6.3	623	589.7	1.06	1.07	376	341.0	1.10	1.11	607	562.6	1.08	1.08	103	123.3	0.84	0.97
6.3–7.4	547	518.0	1.05	1.07	315	297.1	1.06	1.10	503	484.8	1.04	1.07	134	120.7	1.11	1.02
7.4–8.3	434	453.4	0.96	1.05	220	245.0	0.90	1.06	414	429.2	0.96	1.05	83	100.0	0.83	0.98
8.3–9.2	497	493.5	1.01	1.04	304	296.8	1.02	1.06	465	458.1	1.02	1.04	83	97.5	0.85	0.95
9.2–10	431	427.9	1.01	1.03	259	254.1	1.02	1.05	393	398.7	0.99	1.04	80	96.0	0.83	0.93
	Crystal Palace				*Wenvoe*				*Rowridge*				*Group 4**			
0–0.5	1	1.6	0.62	0.62	0	0.1	0.00	0.00	0	0.02	0.00	0.00	0	0.1	0.00	0.00
0.5–1.0	11	11.7	0.94	0.90	0	0.2	0.00	0.00	0	0.02	0.00	0.00	0	0.2	0.00	0.00
1.0–2.0	50	48.5	1.03	1.00	4	2.9	1.38	1.25	0	0.1	0.00	0.00	4	3.6	1.12	1.02
2.0–3.0	116	87.4	1.33	1.19	9	9.2	0.98	1.05	1	0.5	2.08	1.54	11	10.7	1.03	1.03
3.0–4.9	343	310.4	1.10	1.13	35	27.0	1.30	1.22	12	7.9	1.52	1.52	55	42.9	1.28	1.22
4.9–6.3	346	311.2	1.11	1.12	61	54.6	1.12	1.16	17	15.6	1.09	1.24	87	96.2	0.90	1.02
6.3–7.4	273	259.2	1.05	1.11	58	51.7	1.12	1.15	3	7.2	0.42	1.05	90	86.4	1.04	1.03
7.4–8.3	184	207.1	0.89	1.07	49	48.5	1.01	1.11	1	2.8	0.35	1.00	63	75.9	0.83	0.98
8.3–9.2	244	250.4	0.97	1.05	20	36.4	0.55	1.02	2	3.4	0.58	0.96	51	62.1	0.82	0.95
9.2–10	190	185.1	1.03	1.05	16	30.3	0.53	0.97	6	10.9	0.55	0.87	42	66.8	0.63	0.91

* Group 1, highest power TV transmitters of 870–1,000 kW erp; Group 2, all TV transmitters of 500–1,000 kW erp; Group 3, all FM transmitters of 250 kW erp; Group 4, all transmitters with a combination of TV (≥500 kW erp) and FM (250 kW erp) transmission.

TABLE 3. Cancer incidence near 20 high power radio and TV transmitters in Great Britain—all leukemias: observed and expected numbers of cases, observed/expected (O/E) ratios, and 95% confidence intervals (CI), for individual transmitters and transmitter groups, by distance of residence from transmitter, in persons aged ≥15 years, 1974–1986

Site (transmitter group†)	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
Crystal Palace (1, 2)	62	61.78	1.00	0.78–1.29	1,758	1,672.59	1.05	1.00–1.10	0.009	0.025
Emley Moor (1, 2)	2	1.94	1.03	0.13–3.72	232	229.89	1.01	0.89–1.15	0.941	
Sandy Heath (1, 2)	2	2.70	0.74	0.09–2.68	52	37.64	1.38	1.05–1.81	0.069	0.235
Black Hill (2, 3, 4)	0	0.53	0.00	0.00–5.65	109	135.69	0.80	0.67–0.97	0.163	
Rowridge (2, 3, 4)	0	0.17	0.00	0.00–17.62	42	48.46	0.87	0.64–1.17	0.023	0.018
Wenvoe (2, 3, 4)	4	3.21	1.25	0.34–3.19	252	260.85	0.97	0.85–1.09	0.001	0.001
Belmont (2)	0	0.46	0.00	0.00–6.51	7	6.25	1.12	0.45–2.31	0.352	
Bilsdale (2)	0	0.03	0.00	0.00–99.86	3	3.53	0.85	0.18–2.48	0.867	
Calbeck (2)	0	0.06	0.00	0.00–49.93	7	8.63	0.81	0.33–1.67	0.848	
Caradon Hill (2)	1	1.51	0.66	0.02–3.69	25	27.23	0.92	0.62–1.36	0.737	
Durris (2)	0	0.00	–	–	10	7.46	1.34	0.64–2.47	0.755	
Mendip (2)	1	0.50	2.00	0.05–11.14	45	38.89	1.16	0.86–1.55	0.440	
Oxford (2)	1	0.58	1.72	0.04–9.61	160	149.04	1.07	0.92–1.25	0.453	
Pontop Pike (2)	4	5.28	0.76	0.21–1.94	101	112.37	0.90	0.74–1.09	0.734	
Winter Hill (2)	0	0.06	0.00	0.00–49.93	327	281.56	1.16	1.04–1.29	0.100	0.753
Blaenplwyf (3)	0	0.15	0.00	0.00–19.97	14	14.77	0.95	0.56–1.59	0.241	
Holme Moss (3)	0	0.03	0.00	0.00–99.86	39	36.63	1.06	0.78–1.46	0.745	
Sandale (3)	0	0.10	0.00	0.00–29.96	1	2.88	0.35	0.01–1.93	0.526	
Tacolneston (3)	0	1.12	0.00	0.00–2.67	45	43.15	1.04	0.78–1.40	0.966	
Wrotham (3)	2	1.37	1.46	0.18–5.27	76	76.74	0.99	0.79–1.24	0.395	
Group										
1	66	66.42	0.99	0.78–1.26	2,042	1,940.12	1.05	1.01–1.10	0.019	0.182
2	77	78.81	0.98	0.78–1.23	3,130	3,020.1	1.04	1.00–1.07	0.053	0.066
3	6	6.68	0.90	0.33–1.96	578	619.17	0.93	0.86–1.01	0.018	0.006
4	4	3.91	1.02	0.28–2.62	403	445.00	0.91	0.82–1.00	0.001	0.002

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

† Group 1, highest power TV transmitters of 870–1,000 kW erp; Group 2, all TV transmitters of 500–1,000 kW erp; Group 3, all FM transmitters of 250 kW erp; Group 4, all transmitters with a combination of TV (≥500 kW erp) and FM (250 kW erp) transmission.

panied by an excess risk of 1.83 (95 percent CI 1.22–2.74) within 2 km. The excess leukemia risk was apparent beyond 2 km from the transmitter, with a gradual decline in risk that extended over the entire 10 km of the study area. In the present study, we sought an independent test of the hypothesis of increased leukemia risk seen near high power transmitters using data from the 20 such transmitters in Great Britain other than Sutton Coldfield. When we combined results for all 20 transmitters together, there was a significant decline in risk of leukemia with distance from transmitters, although the excess was observed only beyond 2 km and was small in comparison with that observed within 2 km of Sutton Coldfield. No clear interpretation of differences between leukemia subtypes was possible. The findings for adult leukemia were not apparent for childhood leukemia (albeit based on few cases); nor was there indication overall of a declining pattern of risk with distance for skin melanoma or bladder cancer.

The Crystal Palace transmitter contributed a large proportion of the population of this study, particularly in regard to the population closest to transmitters. A significant decline in leukemia risk with distance was demonstrated for this transmitter alone, although as in the analysis for all transmitters combined, the excess risks involved were small. There was no observed excess within 2 km, although the power of the study was not great enough to rule out a small excess or deficit in risk within this radius. Measurements taken by the BBC (British Broadcasting Corporation internal report, 1994) within a 2 km radius of Crystal Palace have confirmed that field strengths for TV frequencies are at least as great as those measured within the same radius of Sutton Coldfield. There is no high power FM transmission at Crystal Palace. The statistical power of the analysis for other single transmitters was lower, but significant declines with distance were also found for Rowridge and Wenvoe, although for those transmitters there was very little population within 5 km and the declines with distance were associated with an unexplained deficit of cases at distance from the transmitters.

Sutton Coldfield transmits both TV and FM frequencies. The analysis by transmitter group was de-

TABLE 4. Cancer incidence near 20 high power radio and TV transmitters in Great Britain (excluding Sutton Coldfield)—leukemia subtypes, skin melanoma, and bladder cancer: observed numbers of cases and observed/expected (O/E) ratios, for all transmitters combined, by distance of residence from transmitter, in persons aged ≥15 years, 1974–1986

Type of cancer	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
Leukemia								
Acute	34	0.94	302	1.12	494	1.06	585	1.03
Acute myeloid	20	0.77	227	1.17	347	1.04	424	1.04
Acute lymphatic	5	0.90	42	1.04	66	0.95	89	1.04
Chronic myeloid	7	0.63	82	0.96	177	1.16	179	0.92
Chronic lymphatic	27	1.20	208	1.13	323	0.99	401	0.97
Skin melanoma	51	1.11	297	0.86	508	0.86	673	0.94
Bladder cancer	204	1.08	1,620	1.08	2,815	1.06	3,603	1.10

TABLE 5. Childhood cancer incidence near 21 high power radio and TV transmitters in Great Britain (including Sutton Coldfield)—leukemias and brain cancers in persons aged 0–14 years: observed and expected numbers of cases, observed/expected (O/E) ratios, and 95% confidence intervals (CI), for all 21 transmitters combined, by distance of residence from transmitter, 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 leukemias	10	8.94	1.12	0.61–2.06	317	326.82	0.97	0.87–1.08	0.266	
Brain										
Malignant and benign	4	6.48	0.62	0.17–1.59	244	230.70	1.06	0.93–1.20	0.465	
Malignant only	3	5.99	0.50	0.10–1.46	220	213.41	1.03	0.90–1.18	0.513	

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

signed to examine for any effects, if present, restricted to either the highest power TV transmission (within the high power range studied) or to either TV or FM or their combination. Significant declines in leukemia risk with distance were found for Groups 3 and 4, which transmit FM frequencies, although these groups had very little population within 2 km. The results did not reach statistical significance for TV transmitters as a whole, despite the greater population of study in Groups 1 and 2 (which include Crystal Palace). No clear interpretation seems possible as to whether the overall decline in risk with distance is associated specifically with TV or FM transmission, or a combination of the two.

The analyses presented here used population figures from the 1981 census, i.e., around the midpoint of the period. Using data from the 1971 and 1991 censuses to estimate the effects of population change, it was concluded that O/E ratios may have been overestimated by around 1.6 percent within 10 km of all 20 transmitters combined, and 4 percent for Crystal Palace. However, there is no evidence to suggest that such population artefacts occurred differentially with distance so as to generate spurious trends. No information was available concerning relative mobility of populations near different transmitters. Such mobility, i.e., migration of people away from transmitters between exposure and diagnosis, and migration toward transmitters of unexposed people, would tend to bias estimations of O/E ratios toward the null.

The Small Area Health Statistics Unit was established to examine the available routinely collected health statistics near industrial point sources. The limitations of routine cancer registry data for small area analyses have been discussed elsewhere (9), and include geographic variability in diagnostic practice as well as completeness and accuracy of data collection. Although apparent excesses and deficits may occur due to these limitations, it is less likely that a spurious pattern of decline around multiple point locations would be generated.

In conclusion, while there is evidence of a decline in leukemia risk with distance from transmitters, the pattern and magnitude of risk associated with residence near the Sutton Coldfield transmitter do not appear to be replicated around other transmitters. The only other

epidemiologic study of radio transmission and cancer that we know of*, in Honolulu (10), found a relative risk of leukemia of 1.56 (99 percent CI 0.86–2.63) in census tracts with broadcasting antennae, within the context of an overall raised cancer risk in these census tracts (relative risk = 1.36, 99 percent CI 1.25–1.48). Interpretation of that study was complicated both by the ecologic nature of the design and the problem of potential confounding. We are aware of no other epidemiologic (2, 11) evidence to suggest an increased risk of leukemia from non-ionizing radiation in the radiofrequency range. The existence of biologically significant athermal effects of radiofrequency radiation in animal and in vitro experiments is a subject of research and controversy, and evidence at present is not sufficient to support a leukemogenic effect (4, 12), especially at the low field strengths to which people who reside near radio transmitters are exposed. We can consider three options. First, the apparent decline in risk may be a chance finding although statistically significant at the conventional 5 percent level. Second, there may be a shallow decline in risk with distance from the transmitters, but this does not necessarily imply any causal link with radiofrequency transmission and may reflect the geographic distribution of other unmeasured sociodemographic or environmental factors. Third, if there were a true association with radio transmission, the lack of replication of the pattern and magnitude of excesses near Sutton Coldfield may indicate that a simple radial decline exposure model is not sufficient (1). The results, at most, give no more than very weak support to the Sutton Coldfield findings.

ADDENDUM

* We have subsequently become aware of a paper about to be published in which the authors found an excess of childhood leukemia near TV towers in Sydney, Australia (13).

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