THE INCIDENCE OF BRAIN AND CENTRAL NERVOUS SYSTEM TUMORS IN RESIDENTS IN THE VICINITY OF THE LOOKOUT MOUNTAIN ANTENNA FARM IN GOLDEN, COLORADO

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I. INTRODUCTION

This study is a follow-up to an investigation of cancer incidence in the Lookout Mountain area that was conducted by the Colorado Department of Public Health and Environment (CDPHE) in June 1998. The current study examines the incidence of brain and central nervous system (CNS) tumors in Census Tract 98.10 subunits called block groups (see Figure 1). In June 1998, the State Health Department completed an epidemiologic study that was initiated in response to concerns about the health status of people living in Jefferson County, Colorado adjacent to the Lookout Mountain antenna farm.[1] Prior to the initiation of the study, a scientific advisory panel consisting of researchers and epidemiologists from the Jefferson County Health and Environment Department, the Department of Environmental Health at Colorado State University, and the Colorado Department of Public Health and Environment was convened to develop a study protocol and provide peer review of the study results. The protocol was described in a document entitled *Protocol for a Study of Cancer Incidence in Residents Adjacent to the Lookout Mountain Antenna Farm*, May 28, 1998.[2]

Previously published epidemiologic studies have suggested an association between electromagnetic radiation (EMR) and increased rates of brain tumors, particularly in persons working in certain occupations.[4-8,21,23,25] Research results have been less conclusive for EMR exposure in residential settings, in part due to limitations of the designs of the research studies.[9] Nonetheless, the published scientific literature does not exclude an association between radiofrequency exposure and an increased risk of cancer.

The objective of the June 1998 study was to examine the incidence of a number of different types of cancer in census tract 98.10, which includes communities near the Lookout Mountain antenna farm, and to compare the incidence to that of metro Denver. Cancer incidence data were available for the Denver metropolitan area from the CDPHE Colorado Central Cancer Registry (CCCR), a population-based registry of cancer diagnoses for the entire state of Colorado. Overall, the number of cancers diagnosed in census tract 98.10 was not higher statistically than would be expected for the ages and numbers of men and women living there. An addendum to the June 1998 report was released in July 1998[3]. The addendum differed from the initial report in the comparison population, which was restricted to 30 census tracts in metro

Denver with a median household income similar to census tract 98.10. The new calculations presented in the addendum did not change the conclusions of the original study.

The present epidemiologic study was prepared in response to citizen concerns about reported brain tumors in residents in the Lookout Mountain area. When the June 1998 report was released, analyses of areas smaller than the entire census tract had not been done. In September 1998, a citizens group provided CDPHE with maps of radiofrequency measurements taken on Lookout Mountain and maps indicating the residence location of persons with suspected brain cancers. The maps indicated possible spatial clustering of persons with brain cancer in areas where the radiofrequency measurements were higher relative to other parts of Lookout Mountain. It was recommended in the June 1998 report that if additional radiofrequency exposure data become available, the CDPHE scientific advisory panel should convene "to determine if a relationship between exposure distribution and existing block groups can be identified, and...guide the design of any further studies." The panel met on October 7, 1998 and decided to initiate the present study.

II. METHODS

The June 1998 study considered all of census tract 98.10 as one geographical unit for statistical purposes, using 1985-95 Cancer Registry data and 1990 census data. The current study of brain and CNS tumors examines incidence in the seven block groups of census tract 98.10 from 1979 (the first year of complete metro Denver data from the Cancer Registry) through 1997 (the most recent year for which there is complete data). Calculations were performed separately for 1979-84 and 1985-97 because of changes in population between 1980 and 1990 and changes in the geographic boundaries for some of the block groups between the 1980 and 1990 U.S. censuses.

A. Definition of study areas and time periods selected for study

The area of study adjacent to the Lookout Mountain antenna farm was defined by census tract 98.10. The boundaries of this census tract are Clear Creek, U.S. Highway 6, I-70, the Dakota Hogback, Bear Creek, State Highway 74, Cold Springs Gulch, I-70 and Beaver Brook. The total population of census tract 98.10 was 8,897 in 1990 and 5,971 in 1980, and estimated as 11,001 in 1997.

Block group boundary definitions from the 1990 census were used. These are presented schematically in Figure 1 and are described below.

- Block group 1, generally located in the northwest portion of the census tract, is bounded by Lookout Mtn. Rd., I-70, Beaver Brook and Clear Creek. 1990 population =1,500.

- Block group 2 is a small area located mostly west of the corner of Highway 6 and Lookout Mtn. Rd. 1990 population = 488.

- Block group 3 is generally bounded by Lookout Mtn. Rd., Highway 6, Heritage Rd. and I-70. 1990 population = 1,803.

- Block group 4 is an "island" , i.e., completely contained, within block group 5; therefore analyses for block group 4 were combined with block group 5. Block groups 4 and 5 make up a triangle shaped area bounded by Highway 6, I-70 and Heritage Rd. 1990 population for block group 4 = 470 and for block group 5 = 1,604.

- Block group 6 in the southeast portion of the census tract is bounded by I-70, the Dakota Hogback, Bear Creek, and Grapevine Rd. 1990 population = 232.

- Block group 7 in the southwest portion of the census tract is bounded by Bear Creek, State Highway 74, Cold Springs Gulch, I-70 and Grapevine Rd. 1990 population = 2,800.

Boundaries for the entire census tract and for block groups 1, 4/5, 6 and 7 were the same in the 1980 and 1990 censuses, so analyses for these areas were performed for the entire time period from 1979 to 1997. Block groups 2 and 3 were separate in the 1990 census, but, in 1980, the area covered by these two block groups was one block group for census purposes with no sub-block group boundaries matching the 1990 block group boundaries. Therefore, analyses for these two block groups were restricted to the 1985-97 time period.

B. Tumors selected for study

In the June 1998 study, the ratio of observed to expected number of cases of brain and CNS cancer during 1985-1995 was 1.26 for males, 1.89 for females, and 1.51 for both sexes combined. Although these risk ratios are not statistically higher than expected, they are the only consistently elevated risk ratios for any of the seven cancer categories (brain & CNS, leukemias, non-Hodgkins lymphoma, female breast, male breast, eye melanoma, and all cancers combined) that were investigated. Further analysis of brain and CNS tumor incidence is appropriate due to evidence in the scientific literature which indicates this is a plausible outcome associated with electromagnetic radiation. The present study was restricted to brain and CNS tumors. Both malignant and non-malignant brain tumors were included to be consistent with previously published epidemiologic studies. Childhood leukemia, which is most consistently associated in the epidemiological literature with residential exposure to radiofrequency exposure, was not included in this study because only two cases from census tract 98.10 were reported to the CCCR for the 1979-1997 time period and these cases occurred in different block groups.

Primary brain and CNS tumors are categorized in the CCCR according to the International Classification of Diseases for Oncology (ICD-O) anatomic site and histology

codes. Tumors metastatic to the brain or CNS from a distant primary site are not included. Likewise, tumors originating in other structures of the face, head, and neck are not included. The ICD-O codes include a classification for tumor behavior, i.e., benign, in-situ, malignant or uncertain.

C. Calculation of observed/expected ratios of cases of brain/CNS tumor and tests of statistical significance

The expected number of brain and CNS tumors was calculated by multiplying the comparison area's age- and gender-specific incidence rates by the age- and gender-specific population estimates for census tract 98.10 and its seven block groups. Risk ratios termed Observed/Expected, or O/E, ratios were calculated by dividing the number of diagnosed tumors by the expected number of tumors for the geographic area for a particular block group for a particular time period. The ratio of the observed number of tumor cases to the expected number may be considered a standardized incidence ratio (SIR).

We performed two types of analyses: (1) an O/E ratio for all brain and CNS tumors (combining benign and malignant) and (2) an O/E ratio for malignant tumors alone. To be consistent with previously published studies, we did not calculate O/E ratios for benign only brain and CNS tumors. In this study, the O/E ratios are reported with 95% confidence intervals. Observed/Expected ratios that have a 95% confidence interval that includes the value of 1 are not considered statistically high or low. For example, an O/E ratio of 1.50 with a 95% confidence interval of 0.2 to 3.6 includes the value 1 in the confidence interval, i.e., 1 is within the interval from 0.2 to 3.6. Therefore, the O/E ratio is considered to be within expected statistical variation and not a "statistically significant" outcome.

The statistical significance of the O/E ratio or SIR was tested by treating the observed number as a Poisson variate in respect to its expected frequency.[11] A two-tailed test was used to test the null hypothesis that there was no difference between observed and expected numbers of cancer cases. The probability level of 0.05 was used as a cutoff with the one tailed bound at the 0.025 level. We did not perform statistical testing on O/E ratios with less than three observed cases due to the high statistical variability that is inherent with such frequencies.

D. Adjusting for income

For the 1985-97 time period, the analysis used the same observed/expected analysis methodology as in the June 1998 report, except the comparison census tracts were identified using the methodology of the July 1998 report addendum that attempted to control for household income, as described below. There was variation in the median household income among the seven block groups of census tract 98.10. However, because the number of metro Denver comparison census tracts (and corresponding population size) would be small for several of the seven block group income categories, we selected comparison census tracts using the median

household income for the entire 98.10 census tract and used the same tracts for comparisons with all seven block groups.

Thirty census tracts with a 1990 median household income between $43,875 and $53,875 (within plus or minus $5000 of the 1990 median household income of $48,875 in census tract 98.10) were selected from Adams, Arapahoe, Douglas, Denver and Jefferson counties to use as the standard to calculate the expected number of brain and CNS tumors. Median household incomes were obtained from a December 1993, Denver Regional Council of Government's publication, *The New Audience: a demographic report about older adults in the region: Census Tracts by County.*

For the 1979-84 time period, 35 census tracts with a 1980 median household income between $22,286 and $25,286 (within plus or minus $1500 of the median household income of $23,786 in census tract 98.10) were selected from the same five counties to use as the standard. Median household incomes were obtained from the report, *1980 Census of Population and Housing, Census Tracts, Denver-Boulder, Colorado Standard Metropolitan Statistical Areas, PHC80-2-138,* published by the U.S. Dept. of Commerce, Bureau of the Census in June 1983.

The 30 census tracts used for the 1985-97 calculations totaled nearly 121,000 persons in 1990, while the 35 census tracts used for the 1979-84 portion of the analysis totaled nearly 154,000 persons in 1980. For both time periods combined, the race/ethnicity composition of census tract 98.10 (about 95-96% white, non-Hispanic) was similar to the comparison areas, ranging between 87-92% white, non-Hispanic. The brain tumors diagnosed in the comparison population were about 93-96% white, non-Hispanic compared to 96% white, non-Hispanic in census tract 98.10.

E. Case interviews

We conducted follow up telephone interviews with cases or surviving family members of cases reported as residing in block groups where statistical elevations were observed, i.e., block groups 2 and 3. No statistical testing was performed on the results of the interviews. The interviews were intended to provide descriptive epidemiologic information for the purpose of exploring whether it was plausible that disease was associated with radiofrequency radiation from the antennas. The information gathered consisted of length of residence in the Lookout Mountain area prior to diagnosis (to determine whether length of residency was consistent with expected latency), whether the Lookout Mountain antenna farm can be seen from the home, approximate distance of the home from the antenna towers, the person's occupation (a potential confounder), and whether there were close blood relatives who had a brain tumor. Questions about distance from the towers and whether there is direct line of sight to the towers from the listed residence were intended as an estimate of radiofrequency exposure. Broadcast signal intensity has been shown to decrease rapidly with distance from the signal and is effectively attenuated or shielded by mountains, buildings or even large trees.

III. RESULTS

Tables 1a, 2a, and 3a show the number of brain and CNS tumors (combining benign and malignant tumors) diagnosed in census tract 98.10 during 1979-97 while Tables 1b, 2b, and 3b are restricted to persons with malignant tumors.

For tables 1a, 2a, and 3a, the observed number of cases in the entire census tract was close to the expected number based on the age and sex of the residents and using comparison areas of census tracts socioeconomically similar to census tract 98.10. A total of 26 brain and CNS tumors were diagnosed during 1979-97 in the entire census tract among men and women compared to about 23 tumors expected for an O/E ratio of 1.12. This is within expected statistical limits. The O/E ratio for males of 1.41 (16 tumors compared to about 11 expected) and the O/E ratio for females of 0.84 (10 tumors compared to about 12 expected) were also within expected statistical variation.

Individual block group O/E ratios for benign and malignant tumors combined were all within expected statistical variation except for females in block group 2 whose ratio of 5.02 (three tumors compared to less than one expected) during 1985-97 was statistically high. No male cases were diagnosed in block group 2 in the 1985-97 time period but one male from block group 2 was diagnosed with a malignant tumor in 1980 (see Figure 4). The O/E ratio for males and females combined in block group 2 was within expected statistical variation. The histology for the tumors of all three female cases was the same: benign meningioma. The histology for the one male case diagnosed prior to 1985 was astrocytoma. The length of time the four persons with brain tumors had lived in block group 2 prior to diagnosis was based on interviews and was as follows: 18 years, 18 years, 18 years, and 22 years.

Individual block group O/E ratios for malignant tumors only are displayed in Tables 1b, 2b and 3b. Risk ratios were all within expected statistical variation except for males in block group 3. There were four cancers observed in males in block group 3 during the time period 1985-97 with approximately one expected--an O/E ratio of 4.40 (95% CI: 1.20-11.25, $p<0.05$). The histologic type for the four cancers diagnosed in males was listed as 1 astrocytoma and 3 glioblastomas. The length of time persons with brain tumors had lived in block group 3 prior to diagnosis was calculated based on information from four interviews (3 male cases and 1 female case) and varied as follows: 3 years, 5 years, 26 years, 26 years.

Table 4 summarizes data collected by telephone interview for 1985-97 cases in block groups 2 and 3. All three females in block group 2 had lived in residences that had direct line of sight to the antenna towers. None had ever worked in an occupation associated with increased incidence of brain tumor. Interview results for one case in block group 2 diagnosed prior to 1985 were not included in Table 4, but personal information was consistent with that reported for other cases diagnosed from 1985-1997 (i.e., had lived in the area 10 years or more at the time of

diagnosis, could see the antennas from the residence, had not worked in an occupation associated with an increased risk of brain tumor). In block group 3, four of five individuals or a surviving family member were successfully contacted. All of the interviewed individuals had worked in an occupation associated with an increased risk of brain tumor, and all reported having direct line of sight to the antenna towers from the residence at the time of diagnosis. No one from either block group reported a history of head injury or radiation therapy for medical conditions prior to diagnosis.

Figure 2 is a graph indicating the number of cases in the entire census tract by year of diagnosis of the tumor and Figures 3-7 are similar data displays by block group. The graphs were constructed to explore whether there was temporal clustering of cases. No statistical tests were performed. Two cases occurred in one calendar year in block group 4/5 (1984 and 1996) and block group 7 (1996). In the other four block groups only one case occurred in any single calendar year. Because no cases occurred in block group 6 for the 1979-1997 time period, no figure is provided for this block group. The graphs for the entire tract and block groups 3 and 7 (Figures 1, 5 and 7 respectively) all show an increase in the number of cases in the early to mid-1990s, however, the population of the entire tract increased about 50% between 1980 and 1990 and 84% between 1980 and 1997.

IV. DISCUSSION

The study design used in this block group level analysis of cancer incidence is ecologic, as was the June 1998 study of the entire census tract 98.10. Epidemiologic studies with this type of design do not allow definitive conclusions to be made about a cause and effect relationship with any particular potential exposure, such as electromagnetic radiation from broadcast antennas.[24] Ecologic epidemiologic studies are frequently conducted around communities adjacent to suspected environmental exposures since they can readily and inexpensively use data routinely reported to cancer registries and allow citizens to compare cancer incidence in their community to incidence rates in a similar comparison population not affected by the environmental exposure of concern.[12-14] Observed differences between communities, however, are not necessarily attributable to the hypothesized exposure. Lack of reliable data for critical exposure variables such as a measurement of individual exposure, in- and out-migration, other exposures inside or outside the home, or length of residence may result in misclassification bias in studies of this nature. Furthermore, inherent in this study design is that information on some potential confounders may be lacking and the data cannot be easily adjusted for confounding effects other than age, sex, and perhaps race/ethnicity.

Data on individual-level exposures to electromagnetic radiation were not collected in this study, and geographic area (assigning cases to block group area) was used as a surrogate for exposure. Preliminary spot radiofrequency (RF) measurements from the Lookout Mountain area taken by local scientists in collaboration with Colorado State University in the fall of 1998 indicated that the intensity of RF exposure is highly dependent on whether a residence has an

unobstructed direct line of sight to the antennas. Because of the complex topography in the census tract, RF exposure within some block group boundaries is not uniform, and therefore, block group is at best a crude measure of exposure.

Telephone interviews of cases from block groups 2 and 3 indicated that all residences had direct line of sight to the antennas from their residence listed at the time of interview, but this information does not confirm or quantify "exposure" or make meaningful comparisons to non-cases. Variations in RF exposure to residents may have occurred over time for several reasons: more antennas were installed, changes occurred in broadcast frequency and intensity, and objects (e.g., buildings, trees) that could obstruct RF exposure were constructed, grew, or were removed. Lack of historical exposure data also results in uncertainty about what is the appropriate time period to examine. Radiofrequency exposures from Lookout Mountain antennas could have begun in the 1950s, but cancer registry data were not available until 1979. The latency of brain tumors may be less than 10 years, but in the absence of complete information about incident cases occurring in the 1950s, 1960s, and 1970s, the scientific review panel could only examine incidence data on brain/CNS tumor occurrence reported to the state Cancer Registry since 1979, when complete cancer reporting began for the Denver Metro area.

While an association between exposure to ionizing radiation and an increased risk of developing a brain tumor has been demonstrated in many epidemiological studies, the link between brain tumor occurrence and nonionizing radiation such as radiofrequency fields (in the 300Hz to 300 Ghz range) is less conclusive. There is an established association in the scientific literature of brain tumor and occupational exposure to electromagnetic radiation. This association was also noted in a 1998 NIH Working Group Report on 50-60 Hz field exposures (power line frequency), but it is not clear if health outcomes from exposure to this type of extremely low frequency radiation can be extrapolated to radiofrequency field exposures.[15] Studies of RF exposure in residential settings have shown mixed results in terms of health outcome of affected populations and have had poor estimates of RF exposure.[9,16-20,22] Thermal effects (tissue heating) from exposure to high intensity RF are well established. However, a specific mechanism of harm from non-thermal effects of exposure to lower intensity RF fields, more typical of residential exposures, has not been established to our knowledge. Not knowing a specific mechanism of interaction or associated exposure dose of concern impedes our ability to interpret the study results.

There is a well recognized association in the epidemiological literature between socioeconomic status (SES) and brain tumor occurrence, with risk increasing with higher SES.[6,7,25] In this study, an attempt was made to control for potential bias from differences in SES by limiting the comparison population used to estimate expected case counts to only those census tracts in metro Denver that were within $5,000 of the median household income of census tract 98.10. Median income for each block group was also compared to median household income for the entire census tract. While there was considerable variation in the median household income of individual block groups within census tract 98.10, ranging in the 1990 census from $26,326 to

$96,626, it was the judgment of the panel that selecting income-matched comparison populations for each block group would result in small comparison populations, thereby introducing increased statistical error into the calculations. Based on a comparison of the June and July 1998 analyses, it is unlikely that closer adjustment for income, block group by block group, would make any significant difference in the study results.

The histology or cell type of a cancer may offer clues to whether an elevated observed/expected cancer ratio is indicative of a possible association with a particular environmental exposure or possibly a chance occurrence. Differences were noted in the histologic type for cases residing in block group 2 compared to those in block group 3. All three of the individuals with tumors diagnosed between 1985 and 1997 in block group 2 had benign meningiomas whereas the persons with tumors in block group 3 were diagnosed with malignant astrocytomas and glioblastomas. There is a previously demonstrated association of increased risk of meningioma from exposure to ionizing radiation, while the histologic cell types of brain tumors in studies of EMF exposure have been mixed, the majority being astrocytomas and glioblastomas.[26-29] Further, all cases diagnosed from 1985-1997 for block group 2 were female, while four of five cases from block group 3 occurred in males.

The scientific panel considered whether the statistically significant findings in this study could be due to chance. Twenty-four statistical tests were performed: six male and six female tests for malignant tumors and six male and six female tests for all tumor types combined. It could be argued that 5% of the tests of O/E ratios would be statistically significant (2.5% increased and 2.5% decreased) by random chance. If this reasoning were applied to the present study, one would expect 2.5% of 24 tests or 0.6 tests to have statistically increased O/E ratios on the basis of chance--instead, two elevated O/E ratios were observed. Additionally, one would expect 0.6 statistical tests to have statistically decreased O/E ratios--instead zero were observed.

The scientific literature generally points to an association between residential radiofrequency exposure and childhood leukemia. One additional consideration, therefore, is the absence of a finding of an increased incidence of childhood leukemia in block groups 2 and 3, although there may be explanations for this negative result that are unrelated to RF exposure.

In summary the scientific panel found some evidence that supported and some that did not support an association of RF exposure from the antennas with brain and CNS tumors. The findings the panel consider to be *consistent* with an association were as follows:

a) statistically significant O/E ratios in block groups 2 and 3, which are the block groups in closest proximity to the antenna towers;
b) 100% of cases or their survivors indicated there was a direct line of sight or unobstructed view of the towers from the case's residence;
c) the duration of residence in the case's home prior to diagnosis of disease was >10 years in all block group 2 cases. The latency, or time between exposure and clinical recognition of disease, is believed to be at least 5 years and usually more than 10

years for environmental exposure and cancer; and

d) in block group 2, there were no family members of cases with a history of brain tumor and none of the cases worked in an occupation associated with an increased risk of brain tumor, indicating that these factors, at least, did not appear to be confounders.

The findings the scientific panel considered to be *inconsistent* with an association were as follows:

a) the duration of residence in the case's home prior to diagnosis of disease was <5 years in two of the four block group 3 cases, which increases the likelihood that the causative agent had occurred prior to the time these individuals moved into the Lookout Mountain area;
b) the occupational history, i.e. an alternate exposure source, was positive in all of the block group 3 cases;
c) the gender of cases contributing to statistically significant O/E ratios was different between block groups 2 (all female) and 3 (all male)--although when cases diagnosed prior to 1985 are considered, there are cases of both genders in both block groups. Findings are generally strengthened when both genders show a similar pattern of excess numbers of a particular type of cancer, because exposures found in or around the home would be expected to affect both genders. There is no indication in the scientific literature that exposure to EMR would selectively affect one gender and not the other;
d) the number of cases that lead to either statistically significant or non-significant results was small: (i) with one fewer case in either block groups 2 or 3, the O/E ratios would have been greater than 1.0 but would not have been statistically significant; (ii) if block groups 2 and 3 had been combined, the O/E ratios for cases diagnosed not only from 1985-1997, but also from 1979-1997, would not be statistically significant; (iii) an increase by 1 case in block group 7 would have made the O/E ratio for malignant tumors for this block group statistically significant, although this block group is distant from the towers; these three findings illustrate that the O/E ratios and statistical tests were quite sensitive to the small numbers of cases in the studied population; and
e) there were no obvious patterns or sudden increases seen in the figures showing the occurrence of cases by year of diagnosis, indicating the cases were not grouped in block groups 2 and 3 differently in time than other block groups, such as block group 7 which is distant from the towers.

As presented in the scientific panel's original protocol, the results of this ecologic study cannot produce conclusive information about cancer causation[2]. Rather, the goal of the scientific advisory panel was to determine if there are data which support an association between the observed elevated risk ratios for brain and CNS tumors and radiofrequency exposure from the broadcast towers. If supportive information could be identified, the panel could then recommend

a more focused investigation. However, the inconsistencies identified above--particularly differences between the two block groups in the cell types of the tumors and gender of the affected persons--weaken the hypothesis of a common etiology of elevated brain and CNS tumors in these two block groups.

V. RECOMMENDATIONS

There remain public health questions as to whether brain and CNS tumors in residents of block groups 2 and 3 could be associated with radiofrequency exposure from Lookout Mountain antenna towers. The State Health Department will continue to be vigilant by regularly monitoring cancer incidence in the area and will report to citizens if changes are observed. When the year 2000 census data become available, this will be used to update expected counts. Furthermore, the Department will monitor national and international studies and published scientific literature on the health effects of RF exposure.

What CDPHE recommends at this time is further scientific study designed to overcome the limitations of the present study and advance knowledge concerning health effects associated with radiofrequency exposure because the scientific evidence is currently inadequate. Research is needed to determine whether there is an association between brain tumors and non-occupational radiofrequency exposure. However, further epidemiologic study to investigate cancer outcomes will likely not be fruitful in the Lookout Mountain region because the population is small, which limits the statistical power to detect an adverse health effect if one exists. Data from other locales may be useful for shedding light on the issue because if there is a consistent pattern of increased brain tumor incidence in proximity to antennas emitting radiofrequency EMR, this will increase confidence that the present study is not due to random chance. Other studies could explore health outcomes besides cancer, such as sleep disorders.

The Colorado Department of Public Health and Environment does not recommend that residents of block groups 2 and 3 sell their homes and vacate the area, does not recommend that healthy residents of block groups 2 and 3 consult with their physician to obtain screening for brain or CNS tumors (such as an MRI or CT scan of the brain), and does not recommend that existing antennas cease operation or be removed.

VI. REFERENCES

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Table 1a - Number of **Males** with Brain and CNS Tumors **(Benign + Malignant)**[1] Compared to the Expected Number in Census Tract 98.10 by Block Group

Place	Time Period	Observed	Expected	O/E Ratio	P value	95% C.I.
Entire Tract	1979-97	16	11.346	1.41	NS	0.81-2.29
Block Group 1	1979-97	2	2.103	0.95	NC	NC
Block Group 2	1985-97	0	0.572	0.00	NC	NC
Block Group 3	1985-97	4	1.482	2.70	NS	0.74-6.91
Block Group 4&5	1979-97	3	3.067	0.98	NS	0.20-2.87
Block Group 6	1979-97	0	0.390	0.00	NC	NC
Block Group 7	1979-97	6	2.897	2.07	NS	0.76-4.51

[1]--"Benign + malignant" includes all tumors, i.e., benign, in-situ, malignant, and uncertain.
NC = not calculated; statistical test not calculated if the observed number was <3.
NS = not statistically high or low, i.e. p>0.05

Table 1b - Number of **Males** with Brain and CNS Tumors **(Malignant only)** Compared to the Expected Number in Census Tract 98.10 by Block Group

Place	Time Period	Observed	Expected	O/E Ratio	P value	95% C.I.
Entire Tract	1979-97	13	7.158	1.82	NS	0.97-3.11
Block Group 1	1979-97	2	1.314	1.52	NC	NC
Block Group 2	1985-97	0	0.351	0.00	NC	NC
Block Group 3	1985-97	4	0.910	4.40	<0.05	1.20-11.25
Block Group 4&5	1979-97	1	1.975	0.51	NC	NC
Block Group 6	1979-97	0	0.246	0.00	NC	NC
Block Group 7	1979-97	5	1.798	2.78	NS	0.90-6.50

NC = not calculated; statistical test not calculated if the observed number was <3.
NS = not statistically high or low, i.e. p>0.05

Table 2a - Number of **Females** with Brain and CNS Tumors **(Benign + Malignant)**[1] Compared to the Expected Number in Census Tract 98.10 by Block Group

Place	Time Period	Observed	Expected	O/E Ratio	P value	95% C.I.
Entire Tract	1979-97	10	11.877	0.84	NS	0.40-1.54
Block Group 1	1979-97	1	2.020	0.50	NC	NC
Block Group 2	1985-97	3	0.598	5.02	<0.05	1.04-14.68
Block Group 3	1985-97	1	1.573	0.64	NC	NC
Block Group 4&5	1979-97	3	4.003	0.75	NS	0.15-2.19
Block Group 6	1979-97	0	0.373	0.00	NC	NC
Block Group 7	1979-97	2	2.687	0.74	NC	NC

[1]--"Benign + malignant" includes all tumors, i.e., benign, in-situ, malignant, and uncertain.
NC = not calculated; statistical test not calculated if the observed number was <3.
NS = not statistically high or low, i.e. p>0.05

Table 2b - Number of **Females** with Brain and CNS Tumors **(Malignant only)** Compared to the Expected Number in Census Tract 98.10 by Block Group

Place	Time Period	Observed	Expected	O/E Ratio	P value	95% C.I.
Entire Tract	1979-97	7	5.272	1.33	NS	0.53-2.74
Block Group 1	1979-97	1	0.902	1.11	NC	NC
Block Group 2	1985-97	0	0.273	0.00	NC	NC
Block Group 3	1985-97	1	0.741	1.35	NC	NC
Block Group 4&5	1979-97	3	1.717	1.75	NS	0.36-5.12
Block Group 6	1979-97	0	0.162	0.00	NC	NC
Block Group 7	1979-97	2	1.217	1.64	NC	NC

NC = not calculated; statistical test not calculated if the observed number was <3.
NS = not statistically high or low, i.e. p>0.05

Table 3a - Number of **Males and Females Combined** with Brain and CNS Tumors **(Benign + Malignant)**[1] Compared to the Expected Number in Census Tract 98.10 by Block Group

Place	Time Period	Observed	Expected	O/E Ratio	P value	95% C.I.
Entire Tract	1979-97	26	23.223	1.12	NS	0.73-1.64
Block Group 1	1979-97	3	4.123	0.73	NS	0.15-2.13
Block Group 2	1985-97	3	1.170	2.56	NS	0.53-7.49
Block Group 3	1985-97	5	3.055	1.64	NS	0.53-3.83
Block Group 4&5	1979-97	6	7.070	0.85	NS	0.31-1.85
Block Group 6	1979-97	0	0.763	0.00	NC	NC
Block Group 7	1979-97	8	5.584	1.43	NS	0.62-2.81

[1]--"Benign + malignant" includes all tumors, i.e., benign, in-situ, malignant, and uncertain.
NC = not calculated; statistical test not calculated if the observed number was <3.
NS = not statistically high or low, i.e. p>0.05

Table 3b - Number of **Males and Females Combined** with Brain and CNS Tumors **(Malignant only)** Compared to the Expected Number in Census Tract 98.10 by Block Group

Place	Time Period	Observed	Expected	O/E Ratio	P value	95% C.I.
Entire Tract	1979-97	20	12.430	1.61	NS	0.98-2.49
Block Group 1	1979-97	3	2.216	1.35	NS	0.28-3.95
Block Group 2	1985-97	0	0.624	0.00	NC	NC
Block Group 3	1985-97	5	1.651	3.03	NS	0.98-7.08
Block Group 4&5	1979-97	4	3.692	1.08	NS	0.29-2.76
Block Group 6	1979-97	0	0.408	0.00	NC	NC
Block Group 7	1979-97	7	3.015	2.32	NS	0.93-4.78

NC = not calculated; statistical test not calculated if the observed number was <3.
NS = not statistically high or low, i.e. p>0.05

Table 4 - Summary of telephone interviews for brain/CNS tumor patients living in block group 2 or 3, diagnosed between 1985-1997.

Interview Question	Block Group 2 (n=3)	Block Group 3 (n=4)
Lived in area less than 5 years [% answering *yes*]	0	50
Lived in area 5 years or more [% answering *yes*]	100	50
Lived in area 10 years or more [% answering *yes*]	100	50
Close blood relative with brain tumor [% answering *yes*]	0	25
Can see antenna from home [% answering *yes*]	100	100
Worked in occupation associated with an increased risk of brain tumor***** [% answering *yes*]	0	100*****
Lived 1 mile or less from antennas [% answering *yes*]	100	50
Lived 1 to 2 miles from antennas [% answering yes]	0	50

***** Occupations associated in the scientific literature with an increased risk of brain tumor include electrical workers (i.e., lineman, electrical engineer, technician/assembler), work in electronics or telecommunications industry, radio/TV repairman, pilot/aircraft worker, farm/agricultural worker, work with solvents or paints, work in rubber or petrochemical industry.

Occupations of persons in Block Group 3 included pilot/aircraft worker (commercial or military), electrical work (computer software testing), and work with radar (meteorlogical research).