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Brain cancer and occupational exposure to magnetic fields among men: results from a Canadian population-based case-control study

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Background The relationship between occupational exposure to magnetic fields and brain cancer in men was investigated using population-based case-control data collected in eight Canadian provinces. Emphasis was placed on examining the variations in risk across different histological types.

Methods A list of occupations was compiled for 543 cases and 543 controls that were individually matched by age. Occupations were categorized according to their average magnetic field exposure through blinded expert review (<0.3, 0.3–<0.6, and ≥0.6 μT). In total, 133 cases (14%) and 123 controls (12%) were estimated to have at least one occupation whereby magnetic field exposures exceeded 0.3 μT. Odds ratios (OR) were generated using conditional logistic regression, and were adjusted for suspected occupational risk factors for brain cancer.

Results A non-significantly increased risk of brain cancer was observed among men who had ever held a job with an average magnetic field exposure >0.6 μT relative to those with exposures <0.3 μT (OR = 1.33, 95% CI : 0.75–2.36). A more pronounced risk was observed among men diagnosed with glioblastoma multiforme (OR = 5.36, 95% CI : 1.16–24.78). Moreover, a cumulative time weighted index score of magnetic field exposure was significantly related to glioblastoma multiforme ($P = 0.02$). In contrast, magnetic field exposures were not associated with astrocytoma or other brain cancers.

Conclusions Our findings support the hypothesis that occupational magnetic field exposure increases the risk of glioblastoma multiforme.

Keywords Magnetic fields, brain cancer, occupation

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The aetiology of brain tumours is not well understood. Ionizing radiation and a genetic predisposition have been implicated as risk factors, however, they are thought to account for a small proportion of all such tumours.[1] Positive associations between brain cancer and other occupational exposures such as vinyl chlorides,[2–4] pesticides[5] and electromagnetic fields[6] have been observed in some studies, but, taken as a whole, the results are inconclusive. Efforts to clarify the role of these factors are needed, particularly in light of the extremely poor prognosis for patients diagnosed with these neoplasms.[7]

During the past decade, a number of studies have examined the relationship between occupational exposure to magnetic fields and the occurrence of brain tumours. Several of these studies were performed within electric utility industry workers and incorporated detailed exposure assessments obtained using either personal monitoring devices or other sampled measures

taken from relevant work-sites.[8–15] Despite elaborate efforts to characterize exposure to 50/60 Hz power frequency magnetic fields, the findings of these studies have been equivocal. This may partly be due to the size of the cohorts that have typically yielded a small number of cases, and consequently, limited the power of the study to detect effects. Inconsistent results have also been obtained from a series of population-based case-control studies that investigated the association between occupational magnetic field exposures and brain cancer.[16–21] Many of these studies did present risk estimates across different histological types of brain cancer. However, several were limited by either small sample sizes,[8,10,12,17] crude assessment of exposure,[16,18,22,23] incomplete occupational history,[19] lack of data on potential occupational confounders,[11,17,23] and the use of decedent rather than incident cases.[13,16,18,24,25] The identification of brain cancer cases using death certificates is particularly problematic as such tumours may represent a metastatic spread from a cancer that originated at another anatomical site.[26]

The results from both *in vivo* and *in vitro* studies suggest that if exposures to 60 Hz magnetic fields increase the risk of cancer, it is through the promotional stage of the carcinogenic process. In the traditional multistage model, tumour promotion is regarded as an extended process that requires prolonged or repeated exposure to the promoting agent.[27] Continued exposure to promoting or co-promoting agents after tumour development may cause the tumour to evolve with increased metastatic properties.[28] Tumour promoters are characterized by the existence of a threshold, prolonged exposure and reversibility of effects.[29] The present study was undertaken to explore the relationship between occupational magnetic field exposures and different histological types of brain cancer. Elevated risks for more aggressive subtypes of brain cancer would support the hypothesis that magnetic fields act as tumour promoter.

Using data collected through the Canadian National Enhanced Cancer Surveillance System (NECSS), we examined the relationship between occupational exposure to magnetic fields and brain cancer using several different exposure indices. Occupational magnetic field exposure assessment was performed by an expert review that was blinded to the case-control status of the subjects. An important strength of this study is the ability to derive magnetic field exposures indices that take into account the complete occupational history of each subject. Perhaps more importantly, the size of the study is sufficiently large to perform risk assessment across different histological types of brain cancer.

Subjects and Methods

The NECSS was designed to investigate environmental causes of cancer using population-based data. The case-control component of the NECSS collected data between January 1994 to August 1997 in eight Canadian provinces (Newfoundland, Prince Edward Island, Nova Scotia, Ontario, Manitoba, Alberta, Saskatchewan and British Columbia). The collection of data was conducted through the co-operation of Health Canada and the provincial cancer registries. All brain cancer cases included in the NECSS were confirmed histologically and cases were defined according to the International Classification of Diseases, Ninth Revision (ICD-9) rubric 191.[30] Benign brain tumours were not included in these analyses. Analyses are based on a total of 543 brain cancer cases that were categorized by histological type using the International Classification of Diseases for Oncology (ICD-O)[31] using the codes shown in Table 1.

Table 1 Brain cancers ascertained among men in the National Enhanced Cancer Surveillance System (NECSS) case-control study, by histological type, 1994–1997

Histological type	ICD-O Codes 1991[a]	No. of cases
Astrocytoma	9384, 9400–9421	214
Glioblastoma multiforme	9440–9442	198
Other	9380, 9382, 9391, 9392, 9424, 9430, 9450, 9451, 9460, 9470, 9473	115
Unknown	8000, 8010, 8900, 9150, 9505, 9990	16
Total		543

[a] ICD-O codes given by the World Health Organization.[31]

The participating provinces attempted to identify eligible brain cancer cases as early as possible in the registration process in order to minimize the loss of subjects due to severe illness or death. Of these eligible cases, data were not collected among those who had died (23%) or for whom physician consent was not granted (10.2%). Among those cases that were sent questionnaires 63% were completed, while the corresponding response rate from the control population was approximately 65%.

Frequency matching was employed by the investigators of the NECSS to select population-based controls so as to achieve a similar age and sex distribution to all cancer cases. There were subtle differences in the methods that were used to select controls in each participating province. In Prince Edward Island, Nova Scotia, Manitoba, Saskatchewan and British Columbia, provincial health insurance plans were used to obtain a random age- and sex-stratified sample of the provincial population. In each of these provinces, more than 95% of residents are covered by these public plans; those excluded include current military personnel and their families and indigenous peoples who are covered by other plans. Newfoundland and Alberta used random digit-dialling to recruit controls while Ontario used Ministry of Finance data to create a stratified random sample.

Mailed questionnaires were used to obtain information on subjects' residential and occupational histories and on other risk factors for cancer. When necessary, telephone follow-up was used to clarify responses. The NECSS questionnaire was designed to collect data on ethnicity, education, income, smoking, height, weight, exposure to specific occupational carcinogens, physical activity, diet two years before interview (60-item food-frequency questionnaire) and general changes in diet compared with 20 years ago. Subjects were asked whether they had ever been occupationally exposed to 17 different agents. Of these, the following exposures have been identified as possible risk factors for brain cancer: pesticides, herbicides, radiation sources, and vinyl chlorides.

Each subject was asked to report on all the jobs they had held for at least one year and all Canadian residences that they had lived in for at least one year. For each job, subjects were asked to describe their job-title, company name, work location, duties, the starting and ending calendar year of employment, and information on exposure to workplace odours and tobacco smoke. Residential data that was collected included address, the

occupancy period and the source of water, the type of heating used and the number of smokers they lived with.

Although the NECSS also collected data among women, we decided to restrict magnetic field exposure assessment and analysis to men for several reasons. First, because most occupational studies of electromagnetic fields have been conducted using male workers, there was limited data to characterize occupational exposures to magnetic fields for women. Second, restricting analyses among men facilitated comparisons with previously published studies. Finally, as the median (or mean) age of the female brain cancer cases was 52 years, it was anticipated that as a whole, there would be little variation in occupational exposure to magnetic fields as few women in this population-based study would have been employed in occupations characterized by jobs with high magnetic field exposures in their distant past.

It was determined *a priori* that occupational magnetic field exposure would not be assigned by using occupational coding, but rather through a manual inspection for each subject of several key variables through expert review. Controls were individually matched to cases because it would have been quite onerous to code all occupations held by the entire control population, and the matching procedure ensured that the age distributions of the case and control populations were similar. Specifically, one control was randomly selected for each case and matched within a single year of age. In total, 543 controls were chosen in this manner from the pool of 4823 NECSS controls with completed questionnaire data.

A list of all the occupations held was compiled for the cases and matched controls. Each occupation was assigned an exposure value based on a time-weighted average magnetic flux density for full-time workers. This exposure assessment also incorporated questionnaire data that were collected on the job duties and the employment location. The categories of average exposure were: <0.3, 0.3–<0.6, and ≥ 0.6 μT. The lower cutpoint of 0.3 μT was chosen to provide reasonable assurance that occupational exposures in the upper two categories were greater than background exposure levels that workers receive at home. Information about the distribution of residential exposures was obtained from a Canadian study of residential magnetic field exposures and childhood leukaemia.[32] It has been estimated that the cutpoint of 0.3 μT corresponded to the 82th percentile for adult exposures in the same homes.[33] The occupational exposure categorizations were derived through expert review (D Agnew) of the employment variables described above and were performed blinded to case-control status. There were a total of 3808 unique character string job title descriptors. The assignment of exposure relied on results from published reports[9,34–37] and consultations with occupational hygienists specializing in the area of electromagnetic fields. For some occupations that could not be readily classified, field measurements were performed using a Drexel Corporation Magnum 310 magnetic field monitor. The upper 0.6 μT limit was chosen as it was double the lower cutpoint, and split the job titles with >3 mG into two groups with number of job titles in the ratio of 2:1. Examples of highly exposed occupations (≥ 0.6 μT) included: sheet metal workers, telephone cable splicer, projectionists (motion pictures), welders, electricians, electronic assemblers, and electric utility workers. Incomplete questionnaire data prevented us from classifying 42 (1.3%) of the occupations held by the study subjects.

Odds ratios (OR) were estimated using conditional logistic regression which took into account the matched design of the study. Five different magnetic field exposure indices were modelled. These included the highest average occupational exposure to magnetic fields (<0.3, ≥ 0.3, ≥ 0.6 μT) and the magnetic field exposure received in the job held the longest (<0.3, 0.3–<0.6 and ≥ 0.6 μT). To evaluate the effect of magnetic field exposures received early or later on in life, we calculated the risk of brain cancer based on exposure categorizations for subjects' first and last held jobs. The last index we examined was a cumulative time-weighted occupational magnetic field exposure score that was calculated by taking into account exposure at each job (E), the duration of employment (D) and whether the work was full-time (F). Mathematically, the cumulative index score was calculated as follows:

$$MF_{index} = \sum_{i=1}^{i=j} E_i \times D_i \times F_i$$

where E = 0 for jobs with average occupational exposures of <0.3 μT
= 1 for jobs with average occupational exposure 0.3–<0.6 μT
= 2 for jobs with average occupational exposure ≥ 0.6 μT
j = the total number of jobs held
D = duration of employment (in years)
and F = 1 for full-time employment
= 0.5 for part-time or seasonal employment.

Several variables were evaluated to determine whether they confounded the results. These included self-reported occupational exposures to vinyl chloride, herbicides, pesticides and radiation sources. Similar to the assignment of magnetic field exposures, an index of exposure to ionizing radiation was also constructed through a manual review of the occupational variables for each job. Cases and controls were classified as having an annual exposure <1 or ≥ 1 mSv (milliSievert).

Results

A total of 543 brain cancer cases (ICD-9: 191) formed the basis of this analysis (Table 1). Of these cases, 214 were astrocytomas, 198 were glioblastoma multiforme, 115 were classified into the 'other category'. Sixteen cases could not be categorized because they were lacking histological data.

The frequency distribution of several key variables is presented for both cases and controls in Table 2. The matched design of the study ensured identical age distributions in the case and control series; 64% of the cases were ≥ 45 years of age. The average number of jobs held by each subject and the length of employment were similar between cases and controls. Likewise, the total number of subjects with reported workplace exposures to pesticides, herbicides, radiation sources and vinyl chloride did not differ appreciably by case-control status. Eighty-six per cent (86%) of jobs held by cases were determined to have an average magnetic field exposure of <0.3 μT. Among controls, the corresponding percentage was 88%. Based on our three-level exposure categorization, 845 subjects (78%) did not experience a change in the average level of exposure to magnetic fields based on their lifetime occupational history. Of those that did

Table 2 Characteristics of study subjects, by case-control status

Variable	Cases	Controls
Age at interview (years)		
<35	88	94
35–44	108	112
45–54	129	131
55–64	122	120
65–74	93	86
75	3	3
Average number of jobs held	3.6 (SD = 2.2)	3.5 (SD = 2.1)
Average length of time spent in each job (in years)	8.1 (SD = 9.3)	8.3 (SD = 9.5)
Subjects who worked with the following for more than one year		
Pesticides	77	80
Herbicides	65	65
Radiation sources	32	36
Vinyl chloride	7	9
Total no. of jobs held according to average exposure to magnetic fields		
<0.3 μT	1690	1654
0.3–<0.6 μT	164	162
⩾0.6 μT	71	53
Exposure could not be assigned	32	10
Total subjects	543	543

experience such a change, 12% of the subjects experienced one change while the remaining 10% experienced two or more changes during their occupational history. A greater number of occupations among cases (n = 32) relative to controls (n = 10) could not be categorized according to the average level of magnetic field exposure. We were unable to classify these occupations because subjects did not provide data that described either their job-title or duties.

A statistically not significant increased risk of brain cancer was observed among those subjects who had ever held a job having average magnetic field exposures >0.6 μT relative to those whose highest level was <0.3 μT (OR = 1.33, 95% CI : 0.75–2.36) (Table 3). When analyses were restricted to those cases diagnosed with a glioblastoma multiforme, the resulting risk estimate was considerably higher (OR = 5.36, 95% CI : 1.16–24.78). No significant differences in risk were observed based on the highest level of occupational magnetic field exposure ever received were for those diagnosed with astrocytomas or other brain cancers. Similar results were obtained when risk assessment was performed using the average occupational magnetic field exposure received in the longest held job (results not shown). Specifically, among those subjects diagnosed with glioblastoma multiforme, the risk estimates were most pronounced among subjects whose longest held job had an average exposure that exceeded 0.6 μT when compared to those with exposures <0.3 μT (OR = 3.70, 95% CI : 0.96–1.20); the corresponding OR for all brain cancers combined was 1.27 (95% CI : 0.64–2.53).

The results obtained from modelling the relationship between the incidence of brain cancer and the constructed index that represents a cumulative lifetime occupational magnetic field exposure score is presented in Table 4. Consistent with our previous findings, this continuous index of magnetic field exposure was not significantly related to the incidence of all brain cancers, astrocytomas nor other brain cancers. However, for those diagnosed with glioblastoma multiforme, this exposure index was significantly related to case-control status as indicated by the Wald χ^2 statistic (P = 0.02), and upon categorization, those subjects that had an index score ⩾8 had an OR of 2.58 (95% CI : 1.15–5.82) relative to those with a score of zero (results not shown).

Table 3 The risk of brain cancer according to the highest average level of occupational magnetic field exposure ever received, by histological type, Canadian National Enhanced Cancer Surveillance System (NECSS), male participants, 1994–1997

Highest average occupational exposure magnetic fields ever received	Cases	Controls	Odds ratio[a]	95% CI	Odds ratio[b]	95% CI
All brain cancers						
<0.3 μT[c]	410	420	1.0		1.0	
⩾0.3 μT	133	123	1.11	0.84–1.48	1.12	0.83–1.51
⩾0.6 μT	42	29	1.38	0.79–2.42	1.33	0.75–2.36
Astrocytomas						
<0.3 μT	163	160	1.0		1.0	
⩾0.3 μT	51	54	0.93	0.60–1.44	0.93	0.59–1.47
⩾0.6 μT	12	16	0.61	0.26–1.49	0.59	0.24–1.45
Glioblastoma multiforme						
<0.3 μT	143	156	1.0		1.0	
⩾0.3 μT	55	42	1.50	0.91–2.46	1.48	0.89–2.47
⩾0.6 μT	18	6	5.50	1.22–24.8	5.36	1.16–24.78
Other						
<0.3 μT	92	94	1.0		1.0	
⩾0.3 μT	23	21	1.11	0.59–2.10	1.10	0.58–2.09
⩾0.6 μT	9	7	1.50	0.53–4.21	1.58	0.56–4.50

[a] Unadjusted odds ratio obtained from the conditional logistic model.

[b] The odds ratio was adjusted for occupational exposure to ionizing radiation and vinyl chloride.

[c] Referent group.

Table 4 Parameter estimates obtained by modelling the relationship between brain cancer and a cumulative index of occupational magnetic field exposure using conditional logistic regression, by histological type, Canadian National Enhanced Cancer Surveillance System (NECSS), male participants, 1994–1997

Histological type of cancer	Parameter estimate[a] for cumulative index of magnetic field exposure	Standard error	Odds ratio[b]	*P*-value[c]
All brain cancers	0.0173	0.0107	1.02	0.10
Astrocytomas	–0.0096	0.0192	0.98	0.62
Glioblastoma multiforme	0.0415	0.0177	1.04	0.02
Other	–0.0169	0.0335	0.98	0.61

[a] The parameter estimate was adjusted for exposure to ionizing radiation and vinyl chloride.

[b] This odds ratio represents the change in risk of cancer per unit increase in the cumulative index of magnetic field exposure.

[c] The *P*-value was calculated using the Wald χ^2 test statistic.

The risk of brain cancer based on the average field exposure of the subject's first or last held job is presented in Table 5. Among subjects diagnosed with glioblastoma, the OR among those with averages exposures >0.6 μT relative to those with exposures <0.3 μT were 4.81 (95% CI : 0.94–24.71) and 12.59 (95% CI : 1.50–150) for the first and last held job respectively. However, differences between these two risk estimates should be interpreted cautiously as only one control had an average exposure ⩾0.6 μT in the last held job.

Discussion

We found that as a whole, brain cancer was not significantly related to occupational exposure to magnetic fields. However, when the analyses were restricted by histological type, four indices of occupational magnetic fields (highest exposure received, exposure during first job, exposure during last job, exposure during longest held job, and cumulative exposure) were positively associated with glioblastoma multiforme. In contrast, no significant associations were observed with astrocytomas or other brain cancers. The large variation in risk between astrocytomas and glioblastoma multiforme requires comment. These two cancers account for approximately 80% of all gliomas.[26] It is generally accepted that astrocytic gliomas that are classified as grades 1 and 2 are classified as astrocytomas and the more aggressive forms (grades 3 and 4) are classified as glioblastomas.[26] Indeed, cases of glioblastoma multiforme often evolve from less malignant forms of astrocytoma, although some cases rise *de novo*.[26] The results from *in vivo* and *in vitro* work suggest that if magnetic fields influence carcinogenesis, it is through a promoting effect.[27,34,38] For example, 60 Hz magnetic field exposures were recently shown to increase the rate of proliferation in astrocytoma cells and potentiate the effect of the phrobol ester PMA.[39] Continued exposure to promoting or co-promoting agents after tumour development may cause the tumour to evolve with increased invasive and metastatic properties.[28] Although the underlying mechanisms of carcinogenesis continue to be widely debated, the increased risk due to

Table 5 The risk of brain cancer according to the occupational magnetic field exposure received in the first and last held job, by histological type, Canadian National Enhanced Cancer Surveillance System (NECSS), male participants, 1994–1997

Average occupational exposure to magnetic fields	Earliest held job				Last held job			
	Cases	Controls	Odds ratio[a]	95% CI	Cases	Controls	Odds ratio[b]	95% CI
All brain cancers								
<0.3 μT[c]	458	474	1.0		475	490	1.0	
⩾0.3–<0.6 μT	43	48	0.89	0.57–1.37	46	41	1.13	0.72–1.79
⩾0.6 μT	21	12	1.72	0.80–3.66	16	11	1.50	0.69–3.28
Astrocytomas								
<0.3 μT	180	187	1,0		186	187	1.0	
⩾0.3–<0.6 μT	19	20	0.81	0.43–1.53	21	20	0.98	0.50–1.92
⩾0.6 μT	7	4	1.51	0.45–5.38	5	7	0.71	1.22–2.27
Glioblastoma multiforme								
<0.3 μT	163	174	1.0		171	184	1.0	
⩾0.3–<0.6 μT	15	16	1.21	0.55–2.66	17	12	1.99	0.83–4.81
⩾0.6 μT	10	3	4.81	0.94–24.71	8	1	12.59	1.50–105.6
Other								
<0.3 μT	101	100	1.0		105	105	1.0	
⩾0.3–<0.6 μT	8	7	1.11	0.37–3.33	6	7	0.83	0.25–2.70
⩾0.6 μT	3	5	0.65	0.15–2.77	2	3	0.62	0.10–3.76

[a] Unadjusted odds ratio obtained from the conditional logistic model.

[b] The odds ratio was adjusted for occupational exposure to ionizing radiation and vinyl chloride.

[c] Referent group.

exposure to magnetic fields that was found for more aggressive malignancies (i.e. glioblastoma multiforme) is consistent with the hypothesis that magnetic fields act at the promotional stage.

It is possible that our results may be biased due to non-response in the case and control series. Since questionnaires were not mailed out to cases known to be deceased, our analyses does not include aggressive forms of brain cancer that were rapidly fatal. To the extent that physician consent was not given due to the poor health of the cancer patient, additional cases of advanced disease will also be excluded. In total, almost one-third of eligible cases were excluded either because the subject had died, or consent was not given by the physician to approach patients diagnosed with brain cancer. Of the remaining cases, 63% participated in the study. Therefore, if magnetic field exposures act as a promoter of brain cancer, our risk estimates would be attenuated because the risk profiles of less aggressive brain cancer cases may be more similar to the profiles in the controls.

A large Tri-Utility study that employed personal monitoring to construct a job-exposure matrix of magnetic field exposures found an elevated risk of brain cancer among those with high cumulative exposures.[9] The Tri-Utility study has a considerable number of strengths including a relatively large sample (n = 250), and workplace exposures that were inferred using personal monitoring worn by a sample of current workers. The investigators found that those workers having a cumulative exposure to magnetic fields that exceeded the median exposure (3.15 μT-years) had a twofold increase in brain cancer risk (OR = 2.0, 95% CI : 0.98–3.9). Contrary to our findings, the increased brain cancer risk in the Tri-Utility study was observed among those cases diagnosed with an astrocytoma. Their findings should be interpreted with caution as there were only five cases in the exposed population, and there were differences in the follow-up procedures of workers from the Ontario, Quebec and French utilities. Furthermore, electric utility workers represent a select subset of individuals that are likely to exhibit less variation with respect to magnetic fields exposures, demographic characteristics and other occupational exposure than encountered in our population-based sample of individuals.

Many occupations with greater than background levels of exposure to magnetic fields are also associated with higher exposure to electric fields. A re-analysis of the French component of the Tri-Utility study observed a positive relationship between occupational exposure to electric fields and the incidence of brain cancer and benign tumours.[40] In particular, subjects having exposures in the 90th percentile had an OR of 3.1 (95% CI : 1.1–8.7) relative to the baseline group. On the other hand, a re-analysis of the Ontario data found no association between cumulative electric field exposure and the incidence of brain tumours.[8] Occupational data for electric field exposures were not assembled for the subjects that we analysed, and therefore, our risk estimates were unable to be adjusted for the potential confounding influence of these exposures.

Our results are consistent with findings from a Swedish case-control study of occupational and residential exposure to magnetic fields[11] that observed a significant relationship between magnetic field exposure and the incidence of astrocytomas grades III and IV (or glioblastoma multiforme). A non-significantly increased risk of astrocytoma grades III and IV was observed among those having both residential and occupational exposure >0.2 μT (OR = 2.2, 95% CI : 0.6–8.5). The precision of this estimate was limited by the fact that only three cases had high exposures to both residential and occupational magnetic fields. Unlike the Swedish study which only took into account one occupation held by the subject (based on census data), our analyses considered all occupations held. Although we were unable to model residential magnetic field exposures, in general, the weak correlation between home and workplace exposures[41] reduces the likelihood that our results will be confounded.

More recently, it has been suggested that the failure to consider magnetic field frequencies <20 Hz that emanate from radial tyres may compromise risk estimates obtained from epidemiological studies.[42] If exposures <20 Hz are relevant to the biological mechanisms associated with the development of brain tumours then our risk estimates may be understated due to increased exposure misclassification.

We also evaluated the relationship between the total number of years spent in occupations with exposures of (1) 0.3–0.6 μT and (2) >0.6 μT. However, the precision of the parameter estimates that were derived for these two continuous measures of exposures was limited by the small number of subjects that had such exposure. For example, only 4.1% of subjects had average occupational magnetic fields that were ⩾0.6 μT, while 16.1% had exposures that were 0.3–<0.6 μT. For this reason, we have presented results based on the cumulative measure of magnetic field exposure that combines information across the three possible job exposure categories. Comparative analyses of the risk of glioblastoma multiforme between the first and last held jobs revealed a more pronounced risk for those jobs held more recently. However, caution should be exercised when interpreting this finding due to the small number of subjects with exposure ⩾0.6 μT and the width of the accompanying confidence intervals.

The results of this study support the hypothesis that occupational magnetic field exposures play a role in the aetiology of brain cancers. Despite a sample size that is considerably larger than most studies of brain cancer and magnetic field exposure, these findings must still be interpreted cautiously due to a smaller number of cases within each histological grouping and the unavailability of direct sampled measures of field exposure. Nonetheless, the elevated risk of glioblastoma multiforme is of significance and replication of this study result should be pursued in another population.

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KEY MESSAGES

- This study examined the relationship between occupational exposure to magnetic fields and the incidence of brain cancer in a population-based sample of Canadians.
- A positive and statistically significant relationship was found between average levels of occupational magnetic field exposure and the incidence of glioblastoma multiforme, which is a more aggressive subtype of brain cancer.
- These results support the hypothesis than magnetic fields play a role in the development of brain tumours, and that they may exert an influence as tumour promoters.

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