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Income and Education Inequalities in Brain and Central Nervous System Cancer Incidence in Canada: Trends over Two Decades

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The socioeconomic gradient of brain and central nervous system (CNS) cancer incidence in Canada is poorly understood. This study aimed to measure socioeconomic inequalities in brain and CNS cancer incidence in Canada from 1992 to 2010. Using a unique census division level dataset (n = 280) pooled from the Canadian Cancer Registry (CCR), the Canadian Census of Population and the National Household Survey, we measured brain and CNS cancer incidence in Canada. The age-adjusted concentration index (C) was used to measure income- and education-related inequalities in brain and CNS cancers in Canada, and for men and women, separately. Time trend analyses were conducted to examine the changes in socioeconomic inequalities in brain and CNS cancers in Canada over time. The results indicated that the crude brain and CNS cancer incidence increased from 7.29 to 8.17 per 100,000 (annual percentage change: 0.70) over the study period. The age-adjusted C results suggested that the brain and CNS cancer incidence was not generally significantly different for census division of different income and educational levels. There was insufficient evidence to support changes in income and education-related inequalities over time. Since the incidence of brain and CNS cancers in Canada showed no significant association with socioeconomic status, future cancer control programs should focus on other risk factors for this cancer subset.

Key Words Social inequalities, Brain neoplasms, Central nervous system neoplasms, Incidence, Canada

INTRODUCTION

While primary cancers of the central nervous system (CNS) are rare, both benign and malignant brain tumors result in high morbidity and mortality worldwide [1,2]. Recent studies suggest that globally, CNS cancers are becoming more prevalent [3]. In Canada, brain cancer represents the highest proportion of cancer deaths among younger adults and are highly morbid across the lifespan [4]. Environmental factors such as exposure to ionizing radiation and certain occupational hazards have an established relationship with the incidence of CNS cancers [5-8]. However, there remains a lack of evidnce supporting relationships with social determinants of health such as income and education.

To date, some international studies have examined the association between socioeconomic status (SES) and the incidence of cancers originating from the CNS. These studies have yielded mixed findings. A study by Quinn and Babb [9] found the highest income quintile compared to the lowest income quintile in England and Wales had a 25% higher incidence of brain tumors. In their 2015 study on glioblastoma multiforme, the most common form of brain cancer, Muquit et al. [10] used average weekly household income, percentage of unemployment, population density, indices of deprivation and percentage of households with no car as SES measures and found that a higher incidence of glioblastoma existed among those in districts with higher average weekly income and lower unemployment. This positive relationship between higher SES and incidence of brain tumors is consistent with some of the existing literature [9,11,12]. In contrast, other studies suggest that there is no correlation between higher SES and the incidence of brain tumors [13].

Although the current studies highlight the socioeconomic gradient in some types of cancer in Canada [14-23], no study

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quantifies socioeconomic inequalities in the incidence of brain and CNS cancer in Canada. Using the Canadian Cancer Registry (CCR), Canadian Census of Population (CCP), and National Household Survey (NHS) this study fills this gap in the literature by examining income and education inequalities in the incidence of all malignant brain and central nervous system tumors over time from 1992 to 2010. This is the period that the CCR data available for all provinces in Canada at the Statistics Canada's Research Data Centres. The results of this study contribute to our understanding of the SES gradient in brain and CNS cancer incidence in Canada over the past two decades.

MATERIALS AND METHODS

Data

Data were obtained from the CCR, the CCP (1992, 1996, 2001, 2006) and the NHS (2011). The CCR contains information about the incidence of all new cancer cases since 1992 in all provinces and territories in Canada. Data from ten Canadian provinces were included in the study: Newfoundland and Labrador (NL), Prince Edward Island (PE), Nova Scotia (NS), New Brunswick (NB), Quebec (QC), Ontario (ON), Manitoba (MB), Saskatchewan (SK), Alberta (AB), and British Columbia (BC). Territories were not included in the analysis due to the lower number of brain and CNS cancer incidences reported in each year.

The CCR was used to obtain basic demographic information about those diagnosed with brain and CNS cancer and a six-digit postal code corresponding to their location of permanent residence. The Postal Code Conversion File plus Version D software was used to find the Census Division (CD) coordinates of each patient diagnosed with brain and CNS cancer based on their six-digit postal codes in the CCR. The CDs are defined as a group of neighboring municipalities joined together for regional planning and management [24]. Based on this information, the number of new cases of brain and CNS cancer in each CD was calculated.

The CCR does not collect information on the SES of patients. Thus, the CCP and NHS datasets were used to construct a new dataset containing SES (average and median equivalized household income and proportion of individuals with a bachelor's degree or above) and population demographics for each CD in Canada. Based on CD coordinates, the CCP/NHS data were linked to the CCR data as follows: CCP 1992 to CCR 1992-1993, CCP 1996 to CCR 1994-1998, CCP 2001 to CCR 1999-2003, CCP 2006 to CCR 2004-2008, and NHS 2011 to CCR 2009-2010. Since the 2011 CCP does not contain SES information for its respondents, the 2011 NHS was used to obtain relevant income and education data for 2009 and 2010. The linked dataset contained the number of brain and CNS cancer diagnoses, SES, and population characteristics at the CD-level (n = 280) over the period between 1992 and 2010.

Measures

The outcome of interest in this study was brain and CNS cancer incidence. Brain and CNS cancer was defined based on the International Classification of Diseases for Oncology third edition codes C70.0 to 72.9. Average and median household income level and proportion of individuals with a bachelor's degree or above were used as three SES variables in the study. Income and education levels for each CD was obtained from the CCP/NHS database. Annual household income was equivalized as per the Organization for Economic Co-operation and Development (OECD) publications to adjust the household size [25]. This involved dividing household size by the square root of household size when we estimated the average and median household income for each CD.

Statistical analysis

Measuring socioeconomic inequalities

The concentration index (C) approach was used to quantify the degree of socioeconomic inequality in brain and CNS cancer incidence. The C was measured based on the concentration curve and the line of perfect equality, which represents an equal distribution of disease burden across all levels of SES. The concentration curve plots the cumulative incidence of brain and CNS cancer (y-axis) against the cumulative proportion of the population in ascending order of SES. The C is computed as twice the area between the concentration curve and the line of perfect equality. A negative value of the C indicates a disproportionate concentration of brain and CNS cancer incidence among those of lower SES, while a positive value suggests an increased incidence of brain and CNS cancer among those of higher SES. The C ranges from –1 to 1, with 0 representing perfect equality.

The following "convenient regression" formula can be used to estimate the C [26]:

$$2\sigma_r^2\left(\frac{BCI_i}{\mu}\right) = \alpha + \delta r_i + \varepsilon_i, \quad (1)$$

where BCI_i shows CD i's brain and CNS cancer incidence rate, μ is the mean incidence rate for brain and CNS cancer for all CDs, α is the intercept. The r_i is the CD i's fractional rank in the SES distribution, which is calculated as $r_i = i/n$, with i = 1 for the lowest SES and $i = n$ for the highest SES. The σ_r^2 denotes the variance of r_i. The ordinary least squares (OLS) estimate of δ in Equation 1 and its standard error demonstrates the value and the standard error for the crude C, correspondingly. The age-adjusted (also called age-standardized) socioeconomic-related inequality can be calculated using an indirectly standardized concentration index by including the age variable in Equation 1 as follows [27]:

$$2\sigma_r^2\left(\frac{BCI_i}{\mu}\right) = \alpha + \gamma r_i + \beta Age_i + \nu_i, \quad (2)$$

where Age_i indicates the average of individuals in the CD

i and β is the corresponding coefficient for Age_i. The OLS estimate of γ in Equation 2 is the age-adjusted C.

The age-adjusted C was calculated according to three measures of SES (i.e., average and median equivalized household income and proportion of the population with a bachelor's degree or above) for the period between 1992 and 2010 to determine income- and education-related inequalities in brain and CNS cancer incidence. Comparisons were made for the total population and for males and females, separately. The total number of relevant populations in each CD was used to calculate the incidence of brain and CNS cancer as well as the weight in the calculation of the C in each year.

Measuring trends in the incidence and socioeconomic inequalities

Poisson regression was conducted to calculate annual percent change in brain and CNS cancer incidence over the study period. Trend analyses for income- and education-related inequalities were performed by plotting the age-adjusted C on the y-axis against time (19 points corresponding to the years from 1992 to 2010) on the x-axis. The negative (positive) coefficient for the time indicates an increase in the concentration of brain and CNS cancer incidence among low (high) SES Canadian over time. All the analyses were performed in V.15 of the STATA software package (StataCorp, College Station, TX, USA).

Ethics approval

This article does not contain any studies with human participants or animals performed by any of the authors. All data used in this study were accessed from Statistics Canada's Research Data Centre. Statistics Canada ensures ethical handling of all individual- and population-level information. Data accessed through the Research Data Centre is exempt from approval by the Research Ethics Board as per the Tri-council policy statement: Ethical conduct for research involving humans article 2.2 (a).

RESULTS

Crude brain and CNS cancer incidence

Figure 1 depicts the crude incidence rate in brain and CNS cancer per 100,000 population in Canada from 1992 to 2010. The total incidence of brain and CNS cancer has trended upwards from 7.29 per 100,000 in 1992 to 8.17 per 100,000 in 2010. The incidence remained higher in males compared to females over the study period. The time trend analysis indicated that brain and CNS cancer diagnoses per 100,000 in Canada have increased by 0.70 percent each year over the study period. For males, incidence per 100,000 increased by 0.76 percent each year, while for females the increase was 0.61 percent per year over the 19-year period studied.

The crude incidence rate in brain and CNS cancer per 100,000 population for each Canadian province can be found in Table 1. There was no significant increase in brain and CNS cancer diagnoses over time in most provinces. The time trend analysis indicates the greatest annual percentage change in NL&PE with 3.8 percent (P-value = 0.02) from 1992 to 2010.

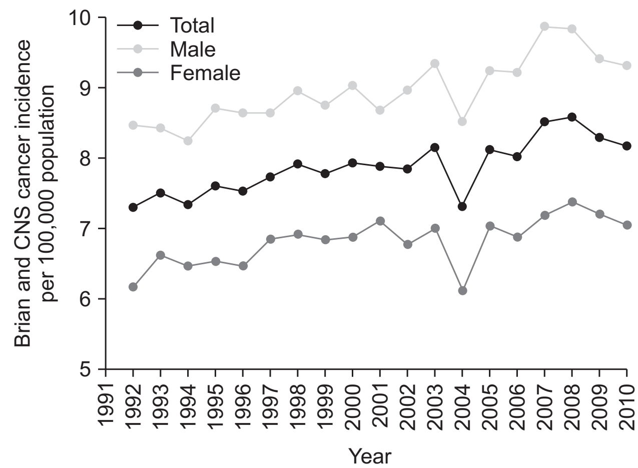

Figure 1. Crude incidence in brain and CNS cancer per 100,000 males, females, and total population of in Canada, 1992 to 2010. CNS, central nervous system.

Socioeconomic Inequalities in brain and CNS cancer incidence

Income-related inequality in brain and CNS cancer incidence

Table 2 reports the magnitude of income-related inequalities, the age-adjusted Cs, in brain and CNS cancer incidence over time. Although the C values have been negative over the majority of the nineteen-year period analyzed, income were not consistently associated with the incidence of brain and CNS cancer to a level of statistical significance. Trend analysis of income-related inequality when we used average equivalized income to measure income-related inequalities in brain and CNS cancer did not change for males or females over time (P-value = 0.902). When we used median equivalized income level in the measurement of income-related inequality, the trend analysis suggested an increase in brain and CNS cancer among those with more income over time (P-value < 0.05). This pattern was also significant for males alone (P-value < 0.02).

Education-related inequality in brain and CNS cancer incidence

Table 3 reports age-adjusted education-related inequalities in brain and CNS cancer incidence over time. Education-inequalities were not consistently associated with the incidence of brain and CNS cancer to a level of statistical significance. There were several years in which a significant education-related inequality existed, but no established trend overall.

Table 1. Crude incidence in brain and CNS cancer per 100,000 population across Canadian provinces, 1992 to 2010

Year	Canada	Male	Female	AB	BC	MB	NB	NS	ON	QC	SK	NL&PE[a]
1992	7.29	8.46	6.16	6.98	7.22	7.9	7	5.64	7.49	7.5	6.69	5.08
1993	7.5	8.42	6.60	6.18	8.4	7.9	6.3	7.89	7.44	7.88	8.24	3.63
1994	7.33	8.24	6.46	6.56	6.82	8.18	6.85	6.11	7.45	8.22	7.17	4.41
1995	7.6	8.71	6.53	6.18	6.96	6.82	8.91	7.78	7.69	8.44	7.68	5.88
1996	7.53	8.63	6.46	6.93	7.52	6.82	6.17	8.89	7.12	8.65	6.66	7.35
1997	7.72	8.63	6.84	6.56	7.52	8.18	8.91	8.33	7.78	8.15	7.17	7.35
1998	7.92	8.96	6.91	6.74	7.38	6.82	8.22	8.89	7.97	8.79	8.7	5.15
1999	7.77	8.75	6.83	6.29	7.95	9.06	8.34	7.8	7.88	7.85	7.79	8.57
2000	7.93	9.03	6.87	6.29	6.89	8.61	7.64	9.47	7.74	9.4	7.79	5.46
2001	7.87	8.68	7.10	6.29	7.95	6.8	6.95	8.36	7.92	8.76	7.27	6.24
2002	7.84	8.96	6.77	7.65	7.82	7.7	9.73	8.36	7.39	8.34	7.27	8.57
2003	8.15	9.34	7.00	7.82	7.55	5.89	9.03	7.24	8.23	8.91	7.27	8.57
2004	7.29	8.52	6.11	5.99	7.42	7.5	9.03	8.86	6.96	8.07	6.81	6.3
2005	8.11	9.24	7.03	6.91	7.3	7.94	9.03	9.41	7.58	9.35	8.39	11.03
2006	8.02	9.21	6.87	6.3	7.17	6.62	9.73	8.86	7.58	9.68	8.39	9.45
2007	8.52	9.87	7.18	6.91	7.68	8.82	9.73	8.3	8.67	9.41	7.86	7.88
2008	8.58	9.84	7.37	8.29	7.68	7.06	8.34	11.63	8.46	9.21	8.91	9.45
2009	8.29	9.41	7.20	7.29	7.17	6.81	9.51	8.28	8.5	8.92	8.43	8.53
2010	8.17	9.32	7.05	6.03	7.75	6.81	6.8	10.48	8.19	9.31	6.44	9.31
APC	0.70	0.76	0.61	0.45	0.07	–0.50	1.35	1.88	0.60	0.93	0.43	3.80
(*P*-value)	(0.64)	(0.59)	(0.70)	(0.78)	(0.97)	(0.74)	(0.36)	(0.19)	(0.69)	(0.51)	(0.78)	(0.02)

CNS, central nervous system; AB, Alberta; BC, British Columbia; MB, Manitoba; NB, New Brunswick; NS, Nova Scotia; ON, Ontario; QC, Quebec; SK, Saskatchewan; NL&PE, Newfoundland and Labrador & Prince Edward Island; APC, Annual percent change. [a]The incidence of brain and CNS cancer in NL and PE were combined to meet the disclosure policy of Statistics Canada's Research Data Centre (RDC).

Table 2. Age-adjusted income-related inequalities in brain and CNS cancer incidence in Canada, 1992 to 2010

Year	The age-adjusted C (95% confidence interval)					
	Average equivalized household income			Median equivalized household income		
	Total	Male	Female	Total	Male	Female
1992	–0.027 (–0.058 to 0.004)	–0.016 (–0.056 to 0.025)	–0.039 (–0.085 to 0.007)	–0.026 (–0.057 to 0.006)	–0.017 (–0.057 to 0.024)	–0.033 (–0.079 to 0.013)
1993	–0.007 (–0.047 to 0.034)	–0.005 (–0.051 to 0.040)	–0.007 (–0.06 to 0.046)	–0.003 (–0.044 to 0.038)	–0.004 (–0.049 to 0.040)	–0.001 (–0.055 to 0.052)
1994	–0.016 (–0.041 to 0.009)	0.001 (–0.029 to 0.031)	–0.037 (–0.078 to 0.003)	–0.005 (–0.032 to 0.023)	0.006 (–0.026 to 0.039)	–0.02 (–0.065 to 0.024)
1995	–0.019 (–0.047 to 0.009)	–0.029 (–0.058 to 0.001)	–0.005 (–0.050 to 0.040)	–0.009 (–0.038 to 0.019)	–0.024 (–0.055 to 0.008)	0.01 (–0.037 to 0.057)
1996	–0.031 (–0.054 to –0.008)[a]	–0.026 (–0.056 to 0.003)	–0.034 (–0.075 to 0.007)	–0.021 (–0.045 to 0.004)	–0.014 (–0.046 to 0.018)	–0.027 (–0.071 to 0.017)
1997	–0.009 (–0.033 to 0.014)	–0.010 (–0.047 to 0.026)	–0.008 (–0.045 to 0.030)	–0.009 (–0.033 to 0.016)	–0.009 (–0.045 to 0.026)	–0.007 (–0.047 to 0.033)
1998	–0.02 (–0.046 to 0.005)	–0.017 (–0.047 to 0.013)	–0.024 (–0.063 to 0.015)	–0.008 (–0.035 to 0.019)	–0.005 (–0.040 to 0.029)	–0.012 (–0.054 to 0.031)
1999	–0.006 (–0.033 to 0.021)	–0.014 (–0.050 to 0.022)	0.005 (–0.031 to 0.040)	0.003 (–0.027 to 0.034)	–0.006 (–0.045 to 0.032)	0.015 (–0.022 to 0.053)
2000	–0.044 (–0.078 to –0.011)[a]	–0.051 (–0.100 to –0.001)[a]	–0.037 (–0.075 to 0.001)	–0.035 (–0.067 to –0.002)[a]	–0.046 (–0.091 to –0.002)[a]	–0.021 (–0.064 to 0.022)
2001	–0.017 (–0.041 to 0.007)	–0.005 (–0.036 to 0.026)	–0.028 (–0.066 to 0.011)	–0.012 (–0.039 to 0.015)	0.001 (–0.031 to 0.034)	–0.025 (–0.069 to 0.02)
2002	–0.018 (–0.048 to 0.013)	–0.027 (–0.066 to 0.013)	–0.012 (–0.049 to 0.024)	–0.012 (–0.036 to 0.013)	–0.027 (–0.066 to 0.013)	0.001 (–0.037 to 0.037)
2003	–0.010 (–0.038 to 0.018)	–0.002 (–0.037 to 0.033)	–0.017 (–0.053 to 0.019)	0.01 (–0.020 to 0.039)	0.017 (–0.014 to 0.048)	0.002 (–0.041 to 0.045)
2004	–0.026 (–0.052 to 0.001)	–0.019 (–0.063 to 0.025)	–0.033 (–0.071 to 0.004)	–0.01 (–0.035 to 0.016)	0.010 (–0.026 to 0.047)	–0.038 (–0.077 to 0.002)
2005	–0.039 (–0.069 to –0.008)[a]	–0.047 (–0.087 to –0.007)[a]	–0.031 (–0.071 to 0.009)	–0.014 (–0.046 to 0.017)	–0.023 (–0.065 to 0.019)	–0.008 (–0.051 to 0.035)
2006	–0.034 (–0.063 to –0.005)[a]	–0.018 (–0.062 to 0.027)	–0.055 (–0.09 to –0.021)[a]	–0.013 (–0.042 to 0.017)	0.018 (–0.023 to 0.058)	–0.053 (–0.089 to –0.017)[a]
2007	–0.003 (–0.028 to 0.022)	0.003 (–0.037 to 0.043)	–0.008 (–0.042 to 0.026)	0.001 (–0.024 to 0.023)	–0.001 (–0.038 to 0.036)	0.002 (–0.038 to 0.042)
2008	–0.002 (–0.030 to 0.026)	0.005 (–0.032 to 0.042)	–0.006 (–0.043 to 0.031)	0.020 (–0.001 to 0.041)	0.028 (–0.006 to 0.063)	0.013 (–0.024 to 0.049)
2009	–0.012 (–0.037 to 0.013)	0.011 (–0.024 to 0.047)	–0.038 (–0.068 to –0.008)[a]	–0.001 (–0.023 to 0.020)	0.014 (–0.019 to 0.047)	–0.019 (–0.051 to 0.014)
2010	–0.036 (–0.072 to 0.001)	–0.047 (–0.091 to –0.002)[a]	–0.018 (–0.061 to 0.025)	–0.003 (–0.041 to 0.035)	–0.003 (–0.049 to 0.042)	–0.002 (–0.044 to 0.040)
Trend (*P*-value)	0.0001 (0.902)	0.0002 (0.857)	–0.0002 (0.748)	0.001 (0.04)	0.0015 (0.020)	0.0002 (0.850)

The inverse of the standard errors of the age-adjusted C were applied as weights in the trend analyses. CNS, central nervous system. [a]Statistically significant age-adjusted C at 95% confidence interval.

Table 3. Age-adjusted education-related inequalities in brain and CNS cancer incidence in Canada, 1992 to 2010

Year	The age-adjusted C (95% confidence interval)		
	Total	Male	Female
1992	–0.039 (–0.073 to –0.005)[a]	–0.031 (–0.072 to 0.009)	–0.045 (–0.093 to 0.003)
1993	–0.01 (–0.057 to 0.037)	0.016 (–0.036 to 0.068)	–0.035 (–0.101 to 0.031)
1994	–0.03 (–0.053 to –0.007)[a]	–0.002 (–0.029 to 0.026)	–0.061 (–0.099 to –0.023)[a]
1995	–0.009 (–0.032 to 0.013)	–0.012 (–0.037 to 0.013)	–0.001 (–0.038 to 0.036)
1996	–0.025 (–0.045 to –0.005)[a]	–0.022 (–0.051 to 0.007)	–0.021 (–0.055 to 0.014)
1997	0.011 (–0.01 to 0.032)	0.009 (–0.025 to 0.043)	0.016 (–0.019 to 0.051)
1998	–0.027 (–0.049 to –0.005)[a]	–0.018 (–0.046 to 0.009)	–0.035 (–0.074 to 0.003)
1999	–0.011 (–0.032 to 0.01)	–0.012 (–0.04 to 0.016)	–0.006 (–0.04 to 0.027)
2000	–0.029 (–0.067 to 0.009)	–0.029 (–0.082 to 0.025)	–0.027 (–0.064 to 0.01)
2001	–0.022 (–0.045 to 0.002)	–0.007 (–0.033 to 0.019)	–0.034 (–0.075 to 0.008)
2002	–0.02 (–0.048 to 0.008)	–0.008 (–0.054 to 0.038)	–0.035 (–0.066 to –0.003)[a]
2003	–0.035 (–0.058 to –0.012)[a]	–0.027 (–0.055 to 0)	–0.041 (–0.077 to –0.005)[a]
2004	–0.025 (–0.047 to –0.004)[a]	–0.035 (–0.07 to 0.001)	–0.011 (–0.042 to 0.021)
2005	–0.025 (–0.057 to 0.007)	–0.011 (–0.055 to 0.032)	–0.04 (–0.077 to –0.003)
2006	–0.027 (–0.053 to –0.001)[a]	–0.018 (–0.052 to 0.017)	–0.038 (–0.072 to –0.003)[a]
2007	0.001 (–0.021 to 0.022)	–0.003 (–0.04 to 0.034)	0.008 (–0.024 to 0.04)
2008	–0.019 (–0.043 to 0.006)	–0.026 (–0.06 to 0.007)	–0.007 (–0.042 to 0.029)
2009	–0.02 (–0.044 to 0.004)	–0.016 (–0.052 to 0.02)	–0.022 (–0.054 to 0.01)
2010	–0.042 (–0.068 to –0.016)[a]	–0.058 (–0.088 to –0.027)[a]	–0.018 (–0.048 to 0.013)
Trend (*P*-value)	–0.0003 (0.677)	–0.0013 (0.112)	0.0007 (0.403)

The inverse of the standard errors of the age-adjusted C were applied as weights in the trend analyses. CNS, central nervous system.
[a]Statistically significant age-adjusted C at 95% confidence interval.

Results of the trend analysis indicated that there was not a significantly increased incidence of brain and CNS cancer among those with less education compared to those with more education (*P*-value < 0.677). There was also no significant time trend when assessed based on gender, although there were more years of significant inequality for females compared to males.

DISCUSSION

This study aimed to assess income-related and education-related patterns in the incidence of brain and CNS cancer in Canada from 1992 to 2010. The descriptive results suggested that the crude incidence of brain and CNS cancer has increased over time. The increases in the incidence rate, however, were not statistically significant in most provinces. These results are consistent with the results of some developed countries, which suggest no statistical increase in brain and CNS cancer incidence over a similar time period [28]. The statistical increase in NL&PE is consistent with a study [29] reporting an increasing incidence of brain cancer in several regions of Spain. Further research is warranted to determine what factors may be contributing to the increase in the incidence of brain and CNS cancer in NL&PE.

Our results assessing trends in income- and education-related inequalities in brain and CNS cancer generally revealed no significant association. The age-adjusted C results suggested negative income and education gradients in the incidence of brain and CNS cancer in Canada. However, the observed income and education-related in brain and CNS cancer were not statistically significant in most years. There is insufficient evidence to suggest any changes in socioeconomic inequalities in brain and CNS cancer. These findings are inconsistent with research from other countries that have found a higher incidence of brain and CNS cancer among those of higher affluence [6,10-12]. This may be partially explained by differences in how socioeconomic variables were operationalized in each study or differences in environmental exposures. Our findings are similar to the study by Nilsson et al. [13] (2018), who similarly used national cancer registry data and population-level statistics to analyze the role of socioeconomic variables in the brain and CNS cancer incidence in Sweden. The authors found no significant relationship between higher income and a higher incidence of brain and CNS cancer.

Additionally, we observed no significant pattern of education-related inequalities in brain and CNS cancer incidence over the study period. This also differs from much of the past literature. In their study of socioeconomic characteristics of patients with glioblastoma multiforme, for example, Muquit et al. [10] (2015) found increased rates of brain and CNS cancer among those with higher education. They posited that those with higher education seek and access medical care earlier and more frequently, leading to increased detection rates. Higher education is also associated with increased health literacy and health behaviors, including accessing medical care

[30]. Our finding of no significant education-inequalities in the incidence of brain and CNS cancer may indicate that these differences are not as common within the Canadian context.

The present study is unique in the literature in that we assessed not only the relationship between brain and CNS cancer incidence and socioeconomic status but also the trends in these relationships over time. However, there were some notable limitations to this study. First, due to the availability of the dataset, SES data from discrete time periods (i.e., CCP years and NHS) were extrapolated to measure socioeconomic inequalities in brain and CNS cancer incidence for multiple years. It is possible that annually updated SES information would display a more robust relationship than can be explored with the present dataset. Third, although some studies indicated that area-based and individual-based estimates of SES are comparable, neighborhood characteristics may not always reflect individual characteristics due to ecological fallacy [31,32]. Since both and area- and individual-level SES were shown to be independently correlated with health outcomes [33], future research should focus on the associations between area- and individual-level SES and brain and CNS cancer incidence in Canada. Fourth, we did not measure socioeconomic inequalities in the incidence of specific brain and CNS tumors (e.g., meningioma, glioblastoma), for which different relationships with SES may exist [11,34]. Thus, further studies are required to measure the socioeconomic gradients in the incidence of specific brain and CNS tumors.

Given the high mortality rates associated with brain and CNS cancer, it is also crucial to gain a deeper understanding of whether socioeconomic inequalities exist for mortality rates for brain and CNS cancer. It is possible that despite an unclear relationship between brain and CNS cancer incidence and socioeconomic variables, those with higher income and education level are receiving better or earlier treatment that decreases their mortality. Thus, future studies should aim to explore further the pattern of socioeconomic inequalities in brain and CNS cancer mortality in Canada.

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CONFLICTS OF INTEREST

No potential conflicts of interest were disclosed.

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