Geographic variation and factors associated with colorectal cancer incidence in Manitoba

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ABSTRACT

OBJECTIVES: Although individuals living in areas with lower household income have been shown to have higher rates of mortality from colorectal cancer (CRC), findings on the effect of income on CRC incidence in countries with universal health care have been inconsistent. There are limited data from Canada. We investigated the geographic variation and factors associated with CRC incidence in Manitoba, a central Canadian province.

METHODS: The Manitoba Cancer Registry and Manitoba Health population registry were used to determine age-sex-standardized CRC incidence rates between 1985 and 2012, which were geocoded to 498 small geographic areas (SGAs). The 2001 Canadian Census was used to determine the socio-demographic characteristics of the SGAs. Bayesian spatial Poisson modelling was used to assess geographic variation and factors associated with CRC incidence.

RESULTS: CRC incidence in SGAs ranged from 11 to 1026 per 100 000 population per year. Importantly, in the fully adjusted model there was no significant association between either average household income or proportion of recent immigrants in the SGAs and CRC incidence. Individuals living in urban areas had an overall lower CRC incidence (incidence rate ratio: 0.76; 95% credible interval: 0.58–0.98).

CONCLUSIONS: In a province with a universal health care system, our study suggests there are no disparities in CRC incidence by socio-economic level of the areas of residence. Rural areas should be a focus of CRC reduction initiatives in Manitoba. Similar analysis in other jurisdictions should be performed to evaluate the effect of the characteristics of SGAs on CRC incidence in different settings and target some of the efforts to reduce CRC burden.

KEY WORDS: Epidemiology; spatial analysis; variation in risk; disparities

La traduction du résumé se trouve à la fin de l'article.

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Colorectal cancer (CRC) remains one of the most common causes of cancer-related morbidity and mortality in North America.¹ The incidence of CRC has been decreasing in the United States (US) since the 1990s and in Canada since the early 2000s.^{1,2} However, the reduction in CRC-induced morbidity and mortality has not been uniform among all groups. In the US, there has been lower CRC mortality reduction among individuals in lower income groups.³ Higher CRC incidence among individuals living in areas of lower socio-economic status (SES) has also been reported in the US.⁴ Many of the health care disparities observed there have often been attributed to the lack of access to universal health care. The framework of fundamental social causes (“resources that can be used to avoid risks or to minimize the consequences of disease once it occurs”⁵ including “money, knowledge, status and availability of social support”³) predicts that when a new resource becomes available (e.g., screening for cancer), it will be more readily accessed by people who already have resources, leading to earlier and more rapid reduction in disease incidence and mortality in that group. This framework may be used to understand and predict gaps and disparities in health outcomes. It is important to determine whether Canadian provinces are able to minimize such expected disparities.

In addition, in order to target efforts to decrease CRC morbidity and mortality, it is important to determine the groups with

the worst CRC outcomes. There are limited data on variation (or lack of it) in CRC outcomes among different socio-economic groups in Canada and no published data on spatial variation of CRC incidence by neighbourhood of residence. Studies on the association of SES and CRC incidence have been limited to those from Ontario between the mid-1980s and mid-1990s.^{6,7} Canada is a country with a universal health care plan in each province and population-based CRC screening programs in most provinces, which should lead to lower disparities. However, we recently reported an increase in CRC mortality among individuals residing in lower income areas in Manitoba, one of the central Canadian provinces.⁸ This could be due to biological differences in CRC,

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environmental differences (e.g., diet), delayed diagnosis of CRC or worsening survival after CRC diagnosis (due to inadequate treatment or response to treatment), or multiple factors. The implications for public health are vastly different for delayed diagnosis, biological differences, and worsening survival.

In the current study, we assessed the geographic variation in CRC incidence and the area of residence characteristics associated with CRC incidence in a universal health care system. In particular, we were interested to determine the variation of CRC incidence by average household income in area of residence. The overall objective was to inform the targeted efforts to reduce CRC burden.

METHODS

Data sources and study measures

This study was performed in the central Canadian province of Manitoba, which has a stable population of approximately 1.2 million inhabitants, according to the 2011 Statistics Canada Census.⁹ Comprehensive universal health care coverage is provided to all the provincial residents by Manitoba Health, Seniors and Active Living (MH), the publicly funded health insurance agency of the Government of Manitoba. MH maintains several electronic databases to administer the services provided. These include a Population Registry of permanent residents in the province, which records the date of birth, sex, place of residence, migration in and out of the province, and death.

CancerCare Manitoba is the provincial cancer agency that maintains the Manitoba Cancer Registry (MCR), a population-based cancer registry in use since 1956. Cancer stage has been collected by the MCR since 2004. The accuracy of data in the MCR is regularly audited and documented.¹⁰ For the current study, CRC cases diagnosed between 1985 and 2012 were identified from the MCR using ICD-9-CM codes 153.0–154.1 and 159.0 (for cases diagnosed before 2002) and ICD-10-CA codes C18.0–C18.9, C19, C20, and C26.0 (from 2002 onwards). Cancers occurring in and proximal to the splenic flexure were categorized as proximal CRCs and those distal to the splenic flexure as distal CRCs.

Each CRC case was geocoded to the 498 small geographic areas (SGAs) in Manitoba using a combination of the six digit postal code and the municipal code of residence at the time of CRC diagnosis. These 498 SGAs were the geographic units used in the analyses.

The population counts in each of the neighborhoods on July 1 of each year were determined from the MH Population Registry. The characteristics (mean annual household income, proportion of recent immigrants [percentage of the population reporting in 2001 that they immigrated to Manitoba from outside Canada since 1961], proportion with visible minority status, and unemployment status) of the 498 SGAs were determined from the 2001 Statistics Canada Census data. Unemployment rate was defined as the percentage of the population who were unemployed and eligible for labour force participation (persons actively looking for work aged 15 and older). All areas located within Winnipeg, which is the only city in Manitoba with a population >50 000, were considered urban.

Statistical analysis

Spatial variation in CRC incidence across Manitoba was calculated for the years 1985–2012 using age- and sex-standardized rates in the 498 SGAs. To control for potentially unstable rate estimates

resulting from small case counts in areas with small populations, rate estimates were smoothed using Bayesian spatial Poisson hierarchical models, which incorporated two random variables indicating geographic variation and any other unspecified variation across study areas.¹¹ Using hierarchical models, the incidence rate in each area was smoothed by pooling information from the neighbouring areas to generate stable rate estimates.¹² Details of the Bayesian models used in this analysis are discussed elsewhere.¹¹ The deviance information criterion was used for model selection. ArcGIS version 10.3 (Environmental Systems Research Institute, US) was used to produce choropleth maps of rates.

Bayesian Poisson regression models were developed to ascertain the association between the characteristics of the SGAs and CRC incidence. The CRC incidence rates were standardized by age and sex to the 2001 Canadian population before being incorporated into the models. All models were fitted to area-level data. Age was divided into eight categories (0–49, 50–59, 60–64, 65–69, 70–74, 75–79, 80–84, and 85+). Other potential explanatory variables (average annual income, percentage of recent immigrants, percentage visible minority, unemployment rate) were categorized using Jenks natural breaks classification method, which attempts to find natural break points in the data when identifying category cut-offs.¹³ Age- and sex-adjusted models were first developed to determine the association with each factor individually, and then a fully adjusted/saturated model containing multiple factors to determine the independent associations was developed. Unemployment rate was not included in the saturated model as it was likely associated with income level.

Stratified analyses were performed to determine associations with the CRC site (proximal to splenic flexure and distal), stage at diagnosis (early [stage I and II] and late [stage III and IV] stage), and associations in different time periods of CRC diagnosis (1985–1993; 1994–2003; 2004–2012). Stage analysis was restricted to CRC cases diagnosed between 2004 and 2012 because the MCR has been recording stage at diagnosis since 2004. There are differences in the biology and phenotype of CRC occurring in the proximal part of the colon, as compared with those occurring in the distal colon.^{14,15} Hence, the effect of behavioural and lifestyle risk factors may vary by the subsite of CRC. Several studies suggest that all commonly used CRC screening tests are less effective in reducing proximal CRC incidence,^{16–19} and therefore variation in CRC incidence due to differences in CRC screening rates are more likely to affect distal CRC incidence.

The modelling results are based on posterior probability and presented as incidence rate ratios (IRR) and corresponding 95% credible intervals (CI, equivalent to confidence intervals in non-Bayesian analyses). The WinBUGS software package (MRC Biostatistics Unit, Institute of Public Health, United Kingdom) was used for all Bayesian analyses.

RESULTS

A total of 19 484 CRC cases (7097 proximal, 11 270 distal, and 1117 site unspecified) were diagnosed in Manitoba between 1985 and 2012. There were 3324 individuals with early stage CRC and 3361 with late stage CRC between 2004 and 2012. Overall, the annual age-sex-standardized incidence of CRC (per 100 000) in Manitoba decreased from 69 in 1985 to 59 in 2012. Proximal CRC decreased from 23 in 1985 to 18 in 2012, and distal CRC decreased from 43 in

Table 1. Colorectal cancer incidence counts and rates (per 100 000) in Manitoba by sex and age, 1985–2012

Age group	Male		Female		Total	
	Count (%)	Rate	Count (%)	Rate	Count (%)	Rate
All CRC						
Overall	10 433 (100)	66	9051 (100)	56	19 484 (100)	61
00–49	716 (7)	6	594 (7)	5	1310 (7)	6
50–59	1520 (15)	87	1105 (12)	63	2625 (14)	75
60–64	1278 (12)	184	853 (10)	117	2131 (11)	150
65–69	1553 (15)	267	1027 (11)	159	2580 (13)	210
70–74	1672 (16)	349	1265 (14)	218	2937 (15)	278
75–79	1647 (16)	450	1464 (16)	294	3111 (16)	360
80–84	1179 (11)	493	1321 (15)	347	2500 (13)	403
85+	868 (8)	507	1422 (16)	377	2290 (12)	417
Proximal CRC						
Overall	3289 (100)	21	3808 (100)	24	7097 (100)	22
00–49	217 (7)	2	168 (4)	2	385 (5)	2
50–59	366 (11)	21	359 (9)	20	725 (10)	21
60–64	350 (11)	50	323 (9)	44	673 (10)	47
65–69	429 (13)	74	400 (11)	62	829 (12)	67
70–74	523 (16)	109	560 (15)	97	1083 (15)	102
75–79	603 (18)	165	691 (18)	139	1294 (18)	150
80–84	442 (13)	185	637 (17)	167	1079 (15)	174
85+	359 (11)	210	670 (18)	177	1029 (15)	187
Distal CRC						
Overall	6635 (100)	42	4635 (100)	29	11 270 (100)	35
00–49	469 (7)	4	404 (9)	4	873 (8)	4
50–59	1110 (17)	63	707 (15)	40	1817 (16)	52
60–64	881 (13)	127	496 (11)	68	1377 (12)	97
65–69	1040 (16)	179	571 (12)	88	1611 (14)	131
70–74	1070 (16)	223	644 (14)	111	1714 (15)	162
75–79	976 (15)	266	682 (15)	137	1658 (15)	192
80–84	666 (10)	279	583 (13)	153	1249 (11)	201
85+	423 (6)	247	548 (12)	145	971 (9)	177

1985 to 34 in 2012. As expected, individuals older than 85 had the highest overall CRC incidence, and men had higher rates than women (Table 1).

Figure 1 depicts the choropleth map of age-sex-standardized CRC incidence rates (adjusted for all the factors in the saturated model), which ranged from 10.6 to 1026 (per 100 000) in 1985 to 2012. Higher CRC incidence rates were observed in the northern part of the province, some SGAs in the southern part of the province, and Winnipeg. The choropleth maps for three time periods (1985–1993; 1994–2003; 2004–2012) demonstrated consistent patterns: a reduction in overall CRC incidence over time in Manitoba but increasing rates in the northern part of the province and a very few SGAs with the highest CRC incidence (data not shown). Similar patterns were observed in the choropleth maps of age-sex-standardized CRC incidence rates without adjustment of other factors (data not shown).

In the age-sex-standardized regression models for CRC incidence from 1985 to 2012, the overall incidence rates of proximal colon and distal colon CRC among those living in the SGAs with the highest proportions of immigrants or visible minorities were approximately 20%–30% lower than among those residing in the SGAs with the lowest proportions of immigrants or visible minorities, although the IRR for all CRC among SGAs with the highest proportion of recent immigrants was marginally statistically non-significant (upper 95% CI reached 1.0) (Table 2). There was no relationship with income level, urban/rural residence, or unemployment rates.

In the saturated model (Table 3), individuals living in urban areas had a lower CRC incidence, while those residing in SGAs with 6%

to <19% of visible minorities had higher CRC incidence, particular for proximal CRC. There were no significant associations with any other factors. The analysis stratified for the different time periods did not suggest any temporal patterns (Table 3).

In the analysis stratified for CRC stage at diagnosis, individuals residing in SGAs with 9% to <20% of recent immigrants had a higher incidence of early stage (stage I and II) distal CRCs. There were no other significant associations with CRC stage at diagnosis (Table 4).

DISCUSSION

In this population-based study from a province with universal health care, we report no effect of the average income level of the SGA of residence on CRC incidence; lower overall CRC incidence in urban areas; increasing incidence in the northern part of the province; and a very few SGAs (in southwest rural Manitoba) with persistent high CRC incidence.

We had previously reported increasing CRC mortality among those living in lower income areas in Manitoba.⁸ Our current study suggests that delayed/late stage diagnosis is likely not a major contributor to such differences in Manitoba. We have also reported lower CRC screening rates in areas with lower mean household income in Winnipeg.²⁰ The current analysis suggests that lower screening rates (approximately 16% difference in 2012 between those living in highest vs. lowest income areas) alone may not be responsible for the differences in CRC mortality demonstrated previously. It is indeed reassuring that there are no disparities by income in CRC incidence (and limited variation in most of the SGAs) in our universal health care system. This may be due to the

Figure 1. Smoothed colorectal cancer incidence rates (per 100 000), adjusted for all the factors in the saturated model, province of Manitoba and city of Winnipeg, Manitoba, 1985–2012, age-sex-standardized to the 2001 Canadian population

Table 2. Age- and sex-standardized Bayesian Poisson regression analysis of colorectal cancer (CRC) incidence in Manitoba, 1985–2012*

Parameter	Comparison	All CRC		Proximal CRC		Distal CRC	
		Count (%)	IRR (95% CI) [†]	Count (%)	IRR (95% CI) [†]	Count (%)	IRR (95% CI) [†]
Region (Manitoba)	Rural	8388 (43)	1.00 (–)	3101 (44)	1.00 (–)	4801 (43)	1.00 (–)
	Urban	11 096 (57)	0.94 (0.79–1.13)	3996 (56)	0.91 (0.73–1.18)	6469 (57)	1.06 (0.86–1.32)
Annual income	<\$47,000	4715 (24)	1.00 (–)	1623 (23)	1.00 (–)	2793 (25)	1.00 (–)
	\$47,000–\$85,000	13 471 (69)	1.02 (0.91–1.13)	5007 (71)	0.95 (0.84–1.06)	7709 (68)	1.13 (0.99–1.28)
	>\$85,000	1298 (7)	1.10 (0.89–1.36)	467 (7)	1.02 (0.81–1.28)	768 (7)	1.23 (0.96–1.56)
Recent immigrants (%)	<9	8559 (44)	1.00 (–)	3131 (44)	1.00 (–)	4922 (44)	1.00 (–)
	9 to <20	7993 (41)	1.02 (0.89–1.18)	2950 (42)	0.98 (0.85–1.15)	4593 (41)	1.15 (0.96–1.35)
	20 to <40	2932 (15)	0.76 (0.62–0.95)	1016 (14)	0.74 (0.59–0.94)	1755 (16)	0.73 (0.57–0.94)
Visible minority (%)	<6	12 117 (62)	1.00 (–)	4485 (63)	1.00 (–)	6938 (62)	1.00 (–)
	6 to <19	5238 (27)	1.17 (1.01–1.34)	1876 (26)	1.10 (0.94–1.28)	3058 (27)	1.12 (0.94–1.32)
	19 to <48	2129 (11)	0.81 (0.66–1.00)	736 (10)	0.78 (0.61–0.98)	1274 (11)	0.77 (0.60–0.99)
Unemployment rate (%)	<9	17 263 (89)	1.00 (–)	6368 (90)	1.00 (–)	9917 (88)	1.00 (–)
	9 to <19	1864 (10)	0.97 (0.82–1.14)	630 (9)	1.05 (0.87–1.26)	1117 (10)	0.90 (0.74–1.09)
	19–35	357 (2)	1.03 (0.87–1.20)	99 (1)	1.08 (0.91–1.27)	236 (2)	0.94 (0.77–1.14)

* Adjusted for only age and sex.

[†] Incidence rate ratio (95% credible interval).

Table 3. Multivariate (saturated) Bayesian Poisson regression analysis of colorectal cancer (CRC) incidence in Manitoba by time period of colorectal cancer diagnosis

Parameter	Comparison	All CRC*	Proximal CRC*	Distal CRC*
1985–2012				
Region (Manitoba)	Rural	1.00 (–)	1.00 (–)	1.00 (–)
	Urban	0.76 (0.58–0.98)	0.86 (0.64–1.14)	0.91 (0.64–1.31)
Annual income	<\$47,000	1.00 (–)	1.00 (–)	1.00 (–)
	\$47,000 to \$85,000	1.07 (0.95–1.21)	0.97 (0.86–1.10)	1.11 (0.96–1.30)
	>\$85,000	1.04 (0.82–1.30)	0.91 (0.72–1.17)	1.12 (0.86–1.46)
Recent immigrants (%)	<9	1.00 (–)	1.00 (–)	1.00 (–)
	9 to <20	1.01 (0.83–1.23)	0.98 (0.80–1.21)	1.08 (0.86–1.37)
	20 to <40	0.81 (0.55–1.22)	0.80 (0.52–1.18)	0.72 (0.44–1.15)
Visible minority (%)	<6	1.00 (–)	1.00 (–)	1.00 (–)
	6 to <19	1.19 (1.01–1.42)	1.21 (1.02–1.45)	1.16 (0.94–1.41)
	19 to <48	1.00 (0.66–1.52)	0.92 (0.59–1.41)	1.05 (0.65–1.70)
1985–1993				
Region (Manitoba)	Rural	1.00 (–)	1.00 (–)	1.00 (–)
	Urban	0.83 (0.63–1.14)	0.81 (0.46–1.41)	1.10 (0.70–1.66)
Annual income	<\$47,000	1.00 (–)	1.00 (–)	1.00 (–)
	\$47,000 to \$85,000	1.04 (0.91–1.19)	0.80 (0.62–1.04)	0.92 (0.75–1.12)
	>\$85,000	1.03 (0.78–1.34)	1.05 (0.65–1.72)	1.06 (0.72–1.56)
Recent immigrants (%)	<9	1.00 (–)	1.00 (–)	1.00 (–)
	9 to <20	0.95 (0.76–1.19)	1.03 (0.68–1.58)	0.95 (0.68–1.34)
	20 to <40	0.78 (0.48–1.23)	0.90 (0.40–2.02)	0.57 (0.28–1.14)
Visible minority (%)	<6	1.00 (–)	1.00 (–)	1.00 (–)
	6 to <19	1.05 (0.86–1.30)	1.27 (0.88–1.83)	1.13 (0.84–1.51)
	19 to <48	1.10 (0.68–1.81)	0.66 (0.28–1.55)	0.84 (0.42–1.68)
1994–2003				
Region (Manitoba)	Rural	1.00 (–)	1.00 (–)	1.00 (–)
	Urban	0.90 (0.68–1.22)	1.08 (0.73–1.69)	0.88 (0.63–1.24)
Annual income	<\$47,000	1.00 (–)	1.00 (–)	1.00 (–)
	\$47,000 to \$85,000	1.03 (0.90–1.18)	0.88 (0.74–1.04)	1.08 (0.92–1.28)
	>\$85,000	0.94 (0.73–1.22)	0.80 (0.56–1.13)	1.19 (0.85–1.65)
Recent immigrants (%)	<9	1.00 (–)	1.00 (–)	1.00 (–)
	9 to <20	0.97 (0.78–1.20)	0.95 (0.72–1.25)	1.08 (0.82–1.40)
	20 to <40	0.68 (0.43–1.07)	0.70 (0.38–1.29)	0.77 (0.43–1.37)
Visible minority (%)	<6	1.00 (–)	1.00 (–)	1.00 (–)
	6 to <19	1.21 (0.99–1.48)	1.04 (0.80–1.33)	1.22 (0.96–1.55)
	19 to <48	1.15 (0.72–1.88)	1.12 (0.59–2.07)	1.19 (0.65–2.14)
2004–2012				
Region (Manitoba)	Rural	1.00 (–)	1.00 (–)	1.00 (–)
	Urban	0.96 (0.75–1.23)	1.18 (0.79–1.78)	0.87 (0.62–1.26)
Annual income	<\$47,000	1.00 (–)	1.00 (–)	1.00 (–)
	\$47,000 to \$85,000	0.98 (0.87–1.12)	1.01 (0.87–1.18)	1.14 (0.97–1.33)
	>\$85,000	0.92 (0.73–1.17)	0.88 (0.63–1.20)	1.01 (0.76–1.37)
Recent immigrants (%)	<9	1.00 (–)	1.00 (–)	1.00 (–)
	9 to <20	1.14 (0.93–1.40)	1.08 (0.85–1.37)	1.12 (0.88–1.40)
	20 to <40	1.05 (0.67–1.60)	0.78 (0.46–1.33)	0.84 (0.50–1.41)
Visible minority (%)	<6	1.00 (–)	1.00 (–)	1.00 (–)
	6 to <19	1.04 (0.88–1.26)	1.14 (0.90–1.46)	0.94 (0.77–1.16)
	19 to <48	0.86 (0.56–1.35)	0.92 (0.52–1.58)	1.05 (0.62–1.81)

* Incidence rate ratio (95% credible interval).

public health campaigns, which have also led to the highest CRC screening rates in Canada.²¹ The nature of Manitoba's universal health care plan (no premiums, comprehensive coverage of all residents irrespective of their age or SES, and continuous efforts to reduce potential SES disparities in access to health care services across the province) may also be contributing to the lack of CRC incidence variability by income. Our results are in contrast to the higher CRC incidence consistently reported among individuals living in lower SES areas in the US.^{4,22} Prior studies from Ontario, Canada, reported a small increase in CRC incidence among the lower SES groups between the mid-1980s and the mid-1990s (men: 10%–25%; women: 0%–15%).^{6,7} The data from Europe have been inconsistent.^{22,23} Differences in health care systems, public health campaigns, unique social and lifestyle risk factors (for example, smoking rates), and ethnic variations could be contributing to these differences.

We have identified a few SGAs with persistent higher CRC incidence, which could be one of the foci of the provincial

screening and cancer prevention programs. One of the important implications of our work is that analyses similar to ours should be performed in other jurisdictions to direct their public health efforts to improve CRC outcomes.

The increasing CRC incidence in the northern parts of the province, which have a much higher proportion of First Nations people, is compatible with other reports of increasing CRC incidence among First Nations people.²⁴ The reasons for this change in CRC epidemiology is likely multifactorial, including changing lifestyles, increasing prevalence of CRC risk factors (such as smoking and obesity), and lower CRC screening rates in First Nation communities.^{25,26}

In multivariable analysis, we are reporting higher CRC incidence in rural areas, which suggests that these areas should be one of the foci of CRC reduction initiatives in Manitoba. Whether the overall lower incidence in urban areas is due to differences in CRC screening rates, lifestyle, or behavioural risk factors should be assessed in future studies.

Table 4. Saturated Bayesian Poisson regression analysis for association of characteristics of small geographic areas of residence with colorectal cancer (CRC) incidence by stage at diagnosis (2004–2012)

Parameter	Comparison	All CRC*	Proximal CRC*	Distal CRC*
Stage I and II				
Region (Manitoba)	Rural	1.00 (–)	1.00 (–)	1.00 (–)
	Urban	0.90 (0.61–1.33)	0.63 (0.38–1.07)	1.19 (0.81–1.73)
Annual income	<\$47,000	1.00 (–)	1.00 (–)	1.00 (–)
	\$47,000 to \$85,000	1.03 (0.87–1.21)	0.98 (0.80–1.19)	1.03 (0.87–1.21)
	>\$85,000	0.92 (0.68–1.26)	1.18 (0.78–1.74)	0.91 (0.65–1.28)
Recent immigrants (%)	<9	1.00 (–)	1.00 (–)	1.00 (–)
	9 to <20	1.20 (0.92–1.57)	1.08 (0.76–1.54)	1.32 (1.01–1.72)
	20 to <40	0.97 (0.56–1.73)	0.79 (0.38–1.69)	1.18 (0.64–2.17)
Visible minority (%)	<6	1.00 (–)	1.00 (–)	1.00 (–)
	6 to <19	1.08 (0.86–1.35)	1.36 (0.99–1.86)	0.88 (0.69–1.13)
	19 to <48	0.77 (0.43–1.40)	1.11 (0.51–2.40)	0.72 (0.37–1.38)
Stage III and IV				
Region (Manitoba)	Rural	1.00 (–)	1.00 (–)	1.00 (–)
	Urban	1.27 (0.83–2.04)	0.96 (0.62–1.55)	1.04 (0.74–1.47)
Annual income	<\$47,000	1.00 (–)	1.00 (–)	1.00 (–)
	\$47,000 to \$85,000	0.98 (0.83–1.14)	0.98 (0.82–1.17)	1.00 (0.86–1.18)
	>\$85,000	0.99 (0.74–1.31)	0.98 (0.68–1.42)	1.01 (0.72–1.40)
Recent immigrants (%)	<9	1.00 (–)	1.00 (–)	1.00 (–)
	9 to <20	1.11 (0.87–1.40)	1.17 (0.88–1.56)	1.15 (0.88–1.49)
	20 to <40	1.01 (0.62–1.66)	0.69 (0.35–1.33)	1.11 (0.60–2.01)
Visible minority (%)	<6	1.00 (–)	1.00 (–)	1.00 (–)
	6 to <19	1.01 (0.81–1.24)	1.11 (0.85–1.47)	0.98 (0.77–1.26)
	19 to <48	0.87 (0.53–1.47)	1.33 (0.67–2.67)	0.92 (0.49–1.73)
Stage IV only				
Region (Manitoba)	Rural	1.00 (–)	1.00 (–)	1.00 (–)
	Urban	1.00 (0.66–1.55)	0.88 (0.50–1.61)	0.88 (0.52–1.60)
Annual income	<\$47,000	1.00 (–)	1.00 (–)	1.00 (–)
	\$47,000 to \$85,000	0.87 (0.74–1.03)	0.86 (0.68–1.11)	0.90 (0.72–1.14)
	>\$85,000	0.90 (0.63–1.27)	0.96 (0.58–1.56)	0.88 (0.55–1.39)
Recent immigrants (%)	<9	1.00 (–)	1.00 (–)	1.00 (–)
	9 to <20	1.19 (0.91–1.55)	1.40 (0.93–2.06)	1.23 (0.85–1.77)
	20 to <40	1.02 (0.54–1.90)	1.01 (0.39–2.62)	1.11 (0.48–2.51)
Visible minority (%)	<6	1.00 (–)	1.00 (–)	1.00 (–)
	6 to <19	1.19 (0.92–1.54)	1.14 (0.80–1.64)	1.22 (0.86–1.76)
	19 to <48	0.90 (0.46–1.71)	0.75 (0.29–1.96)	0.86 (0.37–2.08)

* Data reported as incidence rate ratio (95% credible interval).

In age- and sex-adjusted analysis, the SGAs with the highest proportion of recent immigrants and visible minorities had lower CRC incidence; however, since there was no difference in the multivariable analysis adjusted for income and urban/rural residence, these SGAs need similar attention. In the multivariable analysis, SGAs with an intermediate proportion of recent immigrants had higher incidence of early stage distal CRC. Similarly, there was increased CRC incidence, in particular proximal CRC, among SGAs with an intermediate proportion of visible minorities. However, these effects were not seen for the SGAs with the highest proportion of recent immigrants or visible minorities. Hence these findings in stratified analysis may be a chance finding and need further evaluation in additional studies. It is also possible the populations in SGAs with intermediate proportions of immigrants and/or visible minorities may be different from those in the SGAs with the highest proportion of immigrants/visible minorities. Certain ethnicities, such as African Americans, have been reported to have a higher proportion of proximal CRC and Asians/Pacific Islanders a higher proportion of distal CRC.^{27,28}

There are several strengths and limitations of our study. This is a population-based study and therefore is not subject to selection bias. We studied and stratified for colonic site of CRC, stage of CRC and time periods, and found mostly consistent results. However, we report an ecological analysis, and hence our results should be interpreted in the context of area of residence, although prior

studies from the province have reported a strong correlation between area level incomes and self-reported household incomes.²⁹ We used the data from a single census year (2001) to determine the characteristics of SGAs. However, characteristics such as relative average neighbourhood income have not changed over time.

In conclusion, our study suggests that universal health care combined with public health education initiatives seem to be helping eliminate disparities in CRC incidence by income level – an important and reassuring finding. Analysis similar to ours should be performed in other jurisdictions to identify SGAs and SGA characteristics with the highest CRC incidence in order to develop targets for enhanced CRC prevention and control activities.

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RÉSUMÉ

OBJECTIFS : Il a été démontré à maintes reprises que les résidents des zones où le revenu des ménages est faible présentent des taux de mortalité due au cancer colorectal (CCR) plus élevés, mais l'effet du revenu sur l'incidence du CCR dans les pays dotés d'un système de soins de santé universel ne fait pas l'unanimité. Les données du Canada en la matière sont limitées. Nous avons étudié la variation spatiale de l'incidence du CCR et les facteurs associés au Manitoba, une province du centre du Canada.

MÉTHODE : Le Registre du cancer du Manitoba et le registre de la population de Santé Manitoba ont servi à déterminer les taux d'incidence du CCR standardisés pour l'âge et le sexe entre 1985 et 2012; ces taux ont ensuite été géocodés selon 498 petites régions géographiques (PRG). Le Recensement du Canada du 2001 a servi à déterminer le profil sociodémographique de ces PRG. Un modèle bayésien d'analyse de données spatiales et de régression de Poisson a servi à évaluer la variation spatiale de l'incidence du CCR et des facteurs associés.

RÉSULTATS : L'incidence du CCR dans les PRG variait de 11 à 1 026 pour 100 000 habitants par année. Il est important de noter que dans le modèle entièrement rajusté, aucune association significative n'a été observée entre le revenu moyen des ménages ou la proportion d'immigrants récents dans les PRG, et l'incidence du CCR. Les résidents des agglomérations urbaines présentaient dans l'ensemble une plus faible incidence de CCR (rapport de taux d'incidence : 0,76; intervalle de crédibilité de 95 % : 0,58–0,98).

CONCLUSIONS : Dans une province dotée d'un système de soins de santé universel, notre étude indique qu'il n'y a aucune disparité dans l'incidence du CCR selon le niveau socioéconomique des régions de résidence. Les milieux ruraux devraient faire l'objet d'initiatives de réduction du CCR au Manitoba. Des analyses semblables devraient être effectuées dans d'autres collectivités publiques pour évaluer l'effet des caractéristiques des PRG sur l'incidence du CCR dans différents milieux et pour cibler une partie des efforts de réduction de la charge de morbidité de ce cancer.

MOTS CLÉS : épidémiologie; analyse spatiale; variation du risque; disparités