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Past and Future Burden of Inflammatory Bowel Diseases Based on Modeling of Population-Based Data

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BACKGROUND & AIMS: Inflammatory bowel diseases (IBDs) exist worldwide, with high prevalence in North America. IBD is complex and costly, and its increasing prevalence places a greater stress on health care systems. We aimed to determine the past current, and future prevalences of IBD in Canada. **METHODS:** We performed a retrospective cohort study using population-based health administrative data from Alberta (2002–2015), British Columbia (1997–2014), Manitoba (1990–2013), Nova Scotia (1996–2009), Ontario (1999–2014), Quebec (2001–2008), and Saskatchewan (1998–2016). Autoregressive integrated moving average regression was applied, and prevalence, with 95% prediction intervals (PIs), was forecasted to 2030. Average annual percentage change, with 95% confidence intervals, was assessed with log binomial regression. **RESULTS:** In 2018, the prevalence of IBD in Canada was estimated at 725 per 100,000 (95% PI 716–735) and annual average percent change was estimated at 2.86% (95% confidence interval 2.80%–2.92%). The prevalence in 2030 was forecasted to be 981 per 100,000 (95% PI 963–999): 159 per 100,000 (95% PI 133–185) in children, 1118 per 100,000 (95% PI 1069–1168) in adults, and 1370 per 100,000 (95% PI 1312–1429) in the elderly. In 2018, 267,983 Canadians (95% PI 264,579–271,387) were estimated to be living with IBD, which was forecasted to increase to 402,853 (95% PI 395,466–410,240) by 2030. **CONCLUSION:** Forecasting prevalence will allow health policy makers to develop policy that is necessary to address the challenges faced by health systems in providing high-quality and cost-effective care.

Keywords: Crohn Disease; Ulcerative Colitis; Epidemiology; Forecast Modeling.

The prevalence of inflammatory bowel disease (IBD), comprised of Crohn disease (CD) and ulcerative colitis (UC), has been increasing globally, with one of the highest prevalence rates found in Canada.[1–4] The incidence of IBD in the latter half of the 20th century increased significantly in the Western world, which has caused the prevalence to exceed 0.5% in North America.[2]

The steadily rising prevalence of IBD can be attributed to the disease being diagnosed predominantly in young individuals, being chronic and incurable, and having low mortality.[5] With incidence outpacing death, patients with newly diagnosed IBD are continually added to the pool of prevalent patients, leading to the compounding prevalence of IBD over time.[6]

IBD is a complex and costly disease owing to an unpredictable relapsing and remitting course, complications, hospitalizations, surgeries, and use of expensive therapies. Thus, the steady increase in the prevalence of IBD will lead to a substantial increase in the burden borne by health care systems and society.[6]

Abbreviations used in this paper: **AB, Alberta; AR, autoregressive; ARIMA, autoregressive integrated moving average; BC, British Columbia; CD, Crohn disease; CI, confidence interval; IBD, inflammatory bowel disease; MA, moving average; MB, Manitoba; NS, Nova Scotia; ON, Ontario; PI, prediction interval; QC, Quebec; SK, Saskatchewan; UC, ulcerative colitis.**

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WHAT YOU NEED TO KNOW

BACKGROUND AND CONTEXT

The prevalence of Inflammatory Bowel Disease (IBD) in Canada is among the highest in the world and is steadily increasing. However, it is unclear how much the prevalence will increase in the future.

NEW FINDINGS

In forecasting models, the prevalence of IBD, Crohn's disease, and ulcerative colitis are significantly increasing – with some of the highest rates of increase seen within the pediatric and the elderly populations.

LIMITATIONS

This comprehensive analysis encompassing of 95% of the Canadian population lacks the ability to adjust for possible risk factors (eg, smoking) that affect the risk of developing IBD.

IMPACT

We are at a time where defining the future prevalence of disease – to 2030 – is of paramount importance as it will allow us to prepare for the impending burden.

The present study aimed to forecast the future prevalence of IBD in Canada. The Canadian population is ideal for this study because Canada has a very high prevalence of IBD and places a large burden on the single-payer health care system, making it even more important to forecast future changes. Estimating the total number of people diagnosed with IBD will allow health care providers to proactively implement clinical practices and policy interventions to address the impact of the increasing prevalence of IBD.

Methods

Study Population and Data Sources

The Canadian Gastrointestinal Epidemiology Consortium (CanGIEC) is a national collaboration of provincial IBD surveillance cohorts derived from administrative health care databases (Appendix 1). CanGIEC provided retrospective population-based provincial prevalence data of all individuals who qualify for health care, of any age, for Alberta (AB; 2002–2015), British Columbia (BC; 1997–2014), Manitoba (MB; 1990–2013), Nova Scotia (NS; 1996–2009), Ontario (ON; 1999–2014), Quebec (QC; 2001–2008), and Saskatchewan (SK; 1998–2016). These provinces account for approximately 95% of the Canadian population.[7]

Provincial Estimates

The prevalence of IBD, CD, and UC were calculated for each province based on years of available data from the provincial administrative health care databases listed earlier using population values from Statistics Canada (eg, AB historical analysis was from 2002 to 2015 and forecasted from 2016 to 2030).[7] Prevalence rates for each year were standardized for age and sex based on the Canadian population for the associated year.[7]

National Estimates

Canadian population models were calculated by combining the prevalence for the 7 provinces together from 2002 to 2008—these were the only overlapping years when data were available from all provinces. Secondary analyses included sex stratification (male and female) and age stratification into pediatric (AB, BC, MB, ON, QC, and SK: 0–17 years; NS: 0–19 years), adult (AB, BC, MB, ON, QC, and SK: 18–59 years; NS: 20–59 years), and elderly (all provinces: $\geq$60 years) groups.

Statistical Analysis

The primary forecasting analysis was completed using autoregressive integrated moving average (ARIMA) models.[8–10] An ARIMA model is a time series model in which the value being assessed is related back to historical values from periods before the current one; this is a method that has been used in econometric and prevalence forecasting.[8–11] This model was chosen because of its ability to analyze data at a specific period and relate those back to data contained in prior periods while accounting for innate dependence in yearly prevalence data. An ARIMA model is used for the analysis of equidistant, and discrete samples of data in a time series model, which is necessary with the analysis of prevalence data.[9,10] The ARIMA is composed of 3 components (1) autoregressive (AR), model (2) integrated, term and (3) moving average (MA) model.[9–11] The AR model relates the value in a period to historical ones; the integrated term deals with the assumption of stationarity (that the probability distribution, mean and variance, remains constant over time); and the MA model relates the value back to historical residuals.[9–11]

First, the AR term, which integrates the prior values into the current one, can be evaluated using the partial autocorrelation function, delineating the possible lag periods that are to be included in the AR model. There can be more than 1 possibility, and the appropriate AR term is chosen in conjunction with the MA value. Second, the integrated term deals with the stationarity aspect of the data, which is evaluated using the Dickey-Fuller test.[10,11] If there is a lack of stationarity, then differencing is undertaken in an attempt to achieve stationarity.[11] In the present study, when differencing did not achieve stationarity, a log binomial model was used. Log binomial models analyze dichotomous outcomes, similar to logistic regression, but report outcomes as risk rather than odds. With the exception of the pediatrics and ON groups, all populations achieved stationarity, although the elderly group required differencing to achieve stationarity. Third, the MA term is evaluated with an autocorrelation function and, similar to the AR term, can have multiple possible values. Although the AR term and MA term have multiple possible values, and therefore numerous combinations of values, individual models of each possible value are created and evaluated for best fit. The best fitting models were chosen using a combination of the lowest Akaike information criterion, Bayesian information criterion, and root mean square error from each AR–MA combination. If a clear delineation between 2 models could not be made based on these criteria, then a visual inspection of the graph was used (ie, if one of the competing models displayed an incongruous narrowing prediction interval [PI]).

Once the model was selected, prevalence was forecasted. Forecasting was done using a simulation projected to 2030. Prevalence (per 100,000 persons) was forecasted to 2030, and

95% PIs were calculated from the standard deviation derived during forecasting. PIs are probability limits for a forecast that denote a prediction's accuracy.[10] Average annual percentage change, with confidence interval (CI), was calculated for each model based on the forecasted prevalence and associated PI using a separate log binomial model on forecasted values only. The total number of people diagnosed with IBD in 2030 and age- and sex-stratified and disease-specific subsets for CD and UC were calculated using forecasted prevalence multiplied by forecasted population values from Statistics Canada.[12] Analyses were performed using STATA 14.[13] The interactive web-based map was created with ArcGIS Pro 2.3.0 and ArcGIS Online (Environmental Systems Research Institute, Redlands, CA).

Sensitivity Analyses

Four sensitivity analyses were conducted. The first analysis used log binomial models instead of ARIMA. The second sensitivity analysis used ARIMA to contrast the total number of people with IBD (ie, total count) with the calculated prevalence (ie, per 100,000).[7] These first 2 sensitivity analyses were done to assess the validity of the results from the primary analysis. The third sensitivity analysis evaluated provinces with validated coding algorithms for their study populations (AB, MB, and ON); this was done to assess the extent of misclassification bias from provinces with non-validated algorithms. The prevalence for Canada was evaluated using a longer period (2002–2013) to assess the effect that a longer period has on these estimates. In this last sensitivity analysis, NS and QC were removed because data were not available for those provinces for the full 12-year period.

Results

Provincial Analyses

The age- and sex-standardized prevalence of IBD across Canada in 2008 ranged from 445 per 100,000 in QC to 870 per 100,000 in NS (Table 1). The forecasted prevalence of IBD in 2018 for each province ranged from 652 per 100,000 (95% PI 619–686) in MB to 1224 per 100,000 (95% PI 1156–1292) in NS (Table 1 and Figure 1). In 2030, the forecasted prevalence of IBD ranged from 819 per 100,000 (95% PI 723–917) in MB to 1657 per 100,000 (95% PI 1531–1783) in NS (Table 1 and Figure 1). Figure 1 presents the annual actual prevalence of IBD for each province followed by the forecasted prevalence, with associated 95% PI. The forecasted prevalence average annual percentage changes ranged from 2.00% (95% CI 1.29–2.61) in MB to 3.89% (95% CI 3.85–3.94) in ON (Table 1 and Figure 1).

National Analyses

In 2008, the calculated prevalence of IBD in Canada was 510 per 100,000, with CD at 263 per 100,000 and UC at 226 per 100,000 (Table 1 and Figure 2), which equates to 169,564 individuals with IBD. In 2018, the prevalence in Canada was estimated at 725 per 100,000 (95% PI 716–735) for IBD, 368 per 100,000 (95% PI 363–373) for CD, and 322 per 100,000 (95% PI 318–326) for UC; this equates to 267,983 (95% PI 264,579–271,387) individuals with IBD, 135,899 (95% PI 134,065–137,734) with CD, and 118,918 (95% PI 117,424–120,412) with UC (Table 1 and Figure 2).

The average annual percentage change of IBD prevalence in Canada was estimated at 2.86% (95% CI 2.80–2.92; Table 1). The forecasted IBD prevalence in 2030 was 981 per 100,000 (95% PI 963–999), including 493 per 100,000 (95% PI 483–502) with CD and 436 per 100,000 (95% PI 428–444) with UC (Table 1 and Figure 2). The total number of individuals with IBD in 2030 was forecasted at 402,853 (95% PI 395,466–410,240) with IBD, 202,216 (95% PI 198,299–206,133) with CD, and 178,909 (95% PI 175,635–182,184) with UC (Table 1).

When stratifying the population by sex, the male prevalence of IBD was 477 per 100,000 persons in 2008, increasing to 682 per 100,000 persons (95% PI 671–692) in 2018 and 925 per 100,000 persons (95% PI 905–946) in 2030 (Table 1 and Figure 2). The female prevalence showed similar trends, with a prevalence of 542 per 100,000 persons in 2008, 768 per 100,000 persons (95% PI 758–779) in 2018, and 1036 per 100,000 persons (95% PI 1017–1055) in 2030. These 2030 prevalence estimates equate to approximately 188,326 male persons (95% PI 184,110–192,542) and 214,402 female persons (95% PI 210,487–218,317) with IBD (Table 1 and Figure 2). When stratified by age group, the 2008 prevalence of IBD was 62 per 100,000 in children, 622 per 100,000 in adults, and 646 per 100,000 in the elderly (Table 1 and Figure 3). In 2030, the estimated prevalence of IBD was 159 per 100,000 (95% PI 133–185) in children, 1118 per 100,000 (95% PI 1069–1168) in adults, and 1370 per 100,000 (95% PI 1312–1429) in the elderly (Table 1 and Figure 3). These prevalence estimates equate to approximately 12,647 children (95% PI 10,592–14,702), 238,915 adults (95% PI 228,267–249,563), and 160,736 elderly adults (95% PI 153,898–167,574) living with IBD in 2030 (Table 1 and Figure 3). All estimates for CD and UC by sex or age group are presented in Table 1.

Sensitivity Analyses

The first sensitivity analysis using log binomial regression yielded a forecasted IBD prevalence in 2018 at 828 per 100,000 (95% PI 816–839), with an increase to 1459 per 100,000 (95% PI 1421–1497) in 2030 (Appendix 2).

The second sensitivity analysis performed on the total count compared with the calculated prevalence (per 100,000) showed prevalence values that were marginally lower than those found in the primary analysis; this resulted in a forecasted 2030 prevalence of 856 per 100,000 (95% PI 835–876) for all IBD cases, 493 per 100,000 (95% PI 483–502) for CD, and 380 per 100,000 (95% PI 372–388) for UC (see Appendix 2 for further details).

The third sensitivity analysis, using only provinces with validated algorithms, forecasted a prevalence of IBD at 909 per 100,000 (95% PI 842–976) in 2030 (Appendix 2); this 95% PI overlaps with the 95% PI in the primary analysis, suggesting similar results from the primary and sensitivity analyses (Table 1 and Appendix 2).

The fourth sensitivity analysis, removing NS and QC from the model to allow for a longer period of analysis, resulted in values similar to those seen in the

Table 1. Actual and Forecasted Prevalence, Including AAPC, Stratified by Province and Age

	IBD				CD				UC			
	Standardized prevalence per 100,000	Forecasted prevalence per 100,000 (95% PI)		Forecasted AAPC, % (95% CI)	Standardized prevalence per 100,000	Forecasted prevalence per 100,000 (95% PI)		Forecasted AAPC, % (95% CI)	Standardized prevalence per 100,000	Forecasted prevalence per 100,000 (95% PI)		Forecasted AAPC, % (95% CI)
	2008	2018	2030		2008	2018	2030		2008	2018	2030	
AB	529	729 (686–771)	1048 (882–1214)	3.14 (2.12–3.96)	282	352 (333–372)	482 (403–562)	2.71 (1.61–3.59)	183	256 (240–273)	376 (312–441)	3.33 (2.22–4.21)
BC	515	682 (659–705)	912 (841–984)	2.54 (2.07–2.96)	228	295 (285–306)	390 (357–422)	2.41 (1.92–2.85)	259	348 (338–358)	466 (433–499)	2.55 (2.14–2.93)
MB	567	652 (619–686)	819 (723–917)	2.00 (1.29–2.61)	283	316 (299–333)	390 (340–439)	1.84 (1.07–2.49)	285	338 (321–356)	433 (384–483)	2.18 (1.51–2.75)
NS	870	1224 (1156–1292)	1657 (1531–1783)	2.86 (2.55–3.14)	412	554 (522–587)	728 (667–789)	2.55 (2.20–2.86)	350	503 (474–532)	692 (634–750)	3.03 (2.68–3.34)
ON	507	731 (728–735)	1156 (1144–1169)	3.89 (3.85–3.94)	243	335 (332–337)	500 (493–508)	3.40 (3.34–3.47)	247	363 (360–365)	591 (582–600)	4.16 (4.09–4.22)
QC	445	671 (653–690)	940 (905–975)	3.25 (3.12–3.36)	278	427 (415–439)	604 (581–627)	3.37 (3.24–3.49)	168	244 (232–256)	336 (314–357)	3.03 (2.83–3.21)
SK	555	636 (606–666)	893 (707–1080)	2.89 (1.29–4.13)	316	358 (343–373)	491 (399–583)	2.69 1.26–3.82)	239	279 (264–294)	403 (313–493)	3.13 (1.41–4.43)
All	510	725 (716–735)	981 (963–999)	2.86 (2.80–2.92)	263	368 (363–373)	493 (483–502)	2.75 (2.69–2.81)	226	322 (318–326)	436 (428–444)	2.87 (2.81–2.93)
Sex stratification												
Female	542	768 (758–779)	1036 (1017–1055)	2.83 (2.77–2.88)	296	409 (403–415)	542 (531–554)	2.65 (2.59–2.72)	224	321 (317–325)	437 (429–445)	2.92 (2.87–2.98)
Male	477	682 (671–692)	925 (905–946)	2.89 (2.82–2.97)	229	326 (321–331)	441 (432–450)	2.87 (2.80–2.94)	229	323 (319–327)	435 (426–443)	2.81 (2.75–2.88)
Age stratification												
Pediatric (<18)[a]	62	96 (88–104)	159 (133–185)	4.32 (3.57–4.93)	40	58 (52–64)	91 (72–109)	3.76 (2.81–4.50)	19	29 (25–34)	51 (35–66)	4.59 (3.05–5.66)
Adult (18–59)[b]	622	849 (823–876)	1118 (1069–1168)	2.59 (2.43–2.74)	336	453 (430–476)	590 (547–633)	2.48 (2.24–2.70)	262	357 (351–364)	470 (457–483)	2.56 (2.47–2.65)
Elderly (≥60)	646	976 (950–1002)	1370 (1312–1429)	3.24 (3.06–3.40)	275	427 (416–438)	610 (586–633)	3.42 (3.27–3.56)	340	500 (486–513)	691 (660–721)	3.07 (2.89–3.24)

AAPC, average annual percentage change.
[a]Younger than 18 years for AB, BC, MB, ON, QC, and SK and <20 years for NS.
[b]From 18 to 59 years for AB, BC, MB, ON, QC, and SK and 20 to 59 for NS.

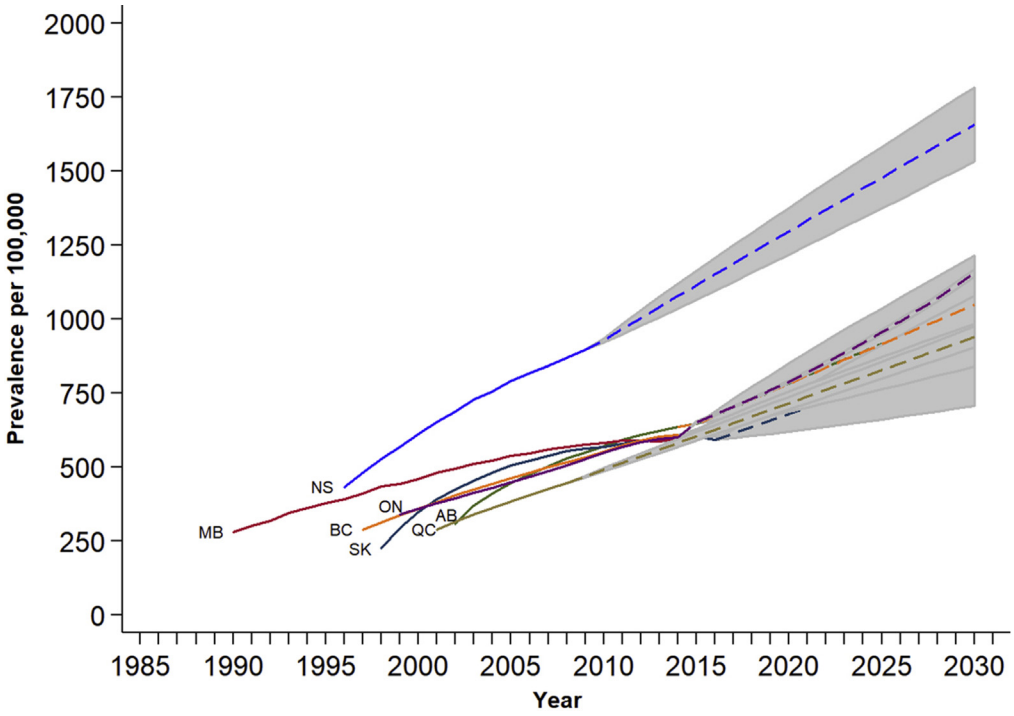

Figure 1. Actual and forecasted prevalence of IBD in Canada by province. Actual prevalence, standardized for age and sex, is denoted by the *solid line*. Forecasted prevalence—analyzed with an ARIMA model and then forecasted until 2030—is indicated by a *dashed line* with the PI highlighted in *gray*. For an interactive map please see https://people.ucalgary.ca/~ggkaplan/IBDCPREV.html

primary analysis, with an IBD prevalence estimate of 700 per 100,000 (95% PI 680–719) in 2018 and 931 per 100,000 (95% PI 882–980) in 2030 (Appendix 2). An interactive web-based map describing the prevalence of IBD across Canada from 2002 to 2030 is available at this link: https://people.ucalgary.ca/~ggkaplan/IBDCPREV.html.

Discussion

We conducted a nationwide study using historical population-based data from 7 provinces to estimate the current, and forecast the future, prevalence of IBD. In 2008, approximately 0.5% of the Canadian population had IBD; by 2018, prevalence was estimated at 0.7%; and, by 2030, it

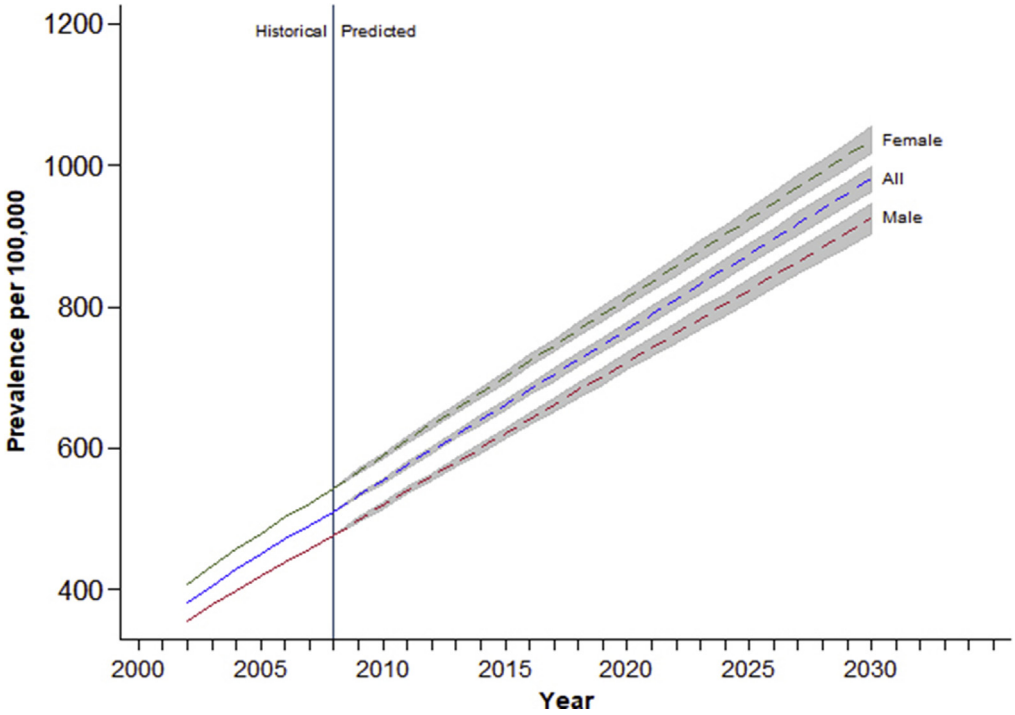

Figure 2. Actual and forecasted prevalence of IBD in male and female patients and total patients in Canada. Actual prevalence, standardized for age and sex, is denoted by the *solid line* and prevalence is calculated through summation of total affected individuals and total population from each province. Forecasted prevalence—analyzed with an ARIMA model and then forecasted until 2030—is indicated by a *dashed line* with the PI highlighted in *gray*.

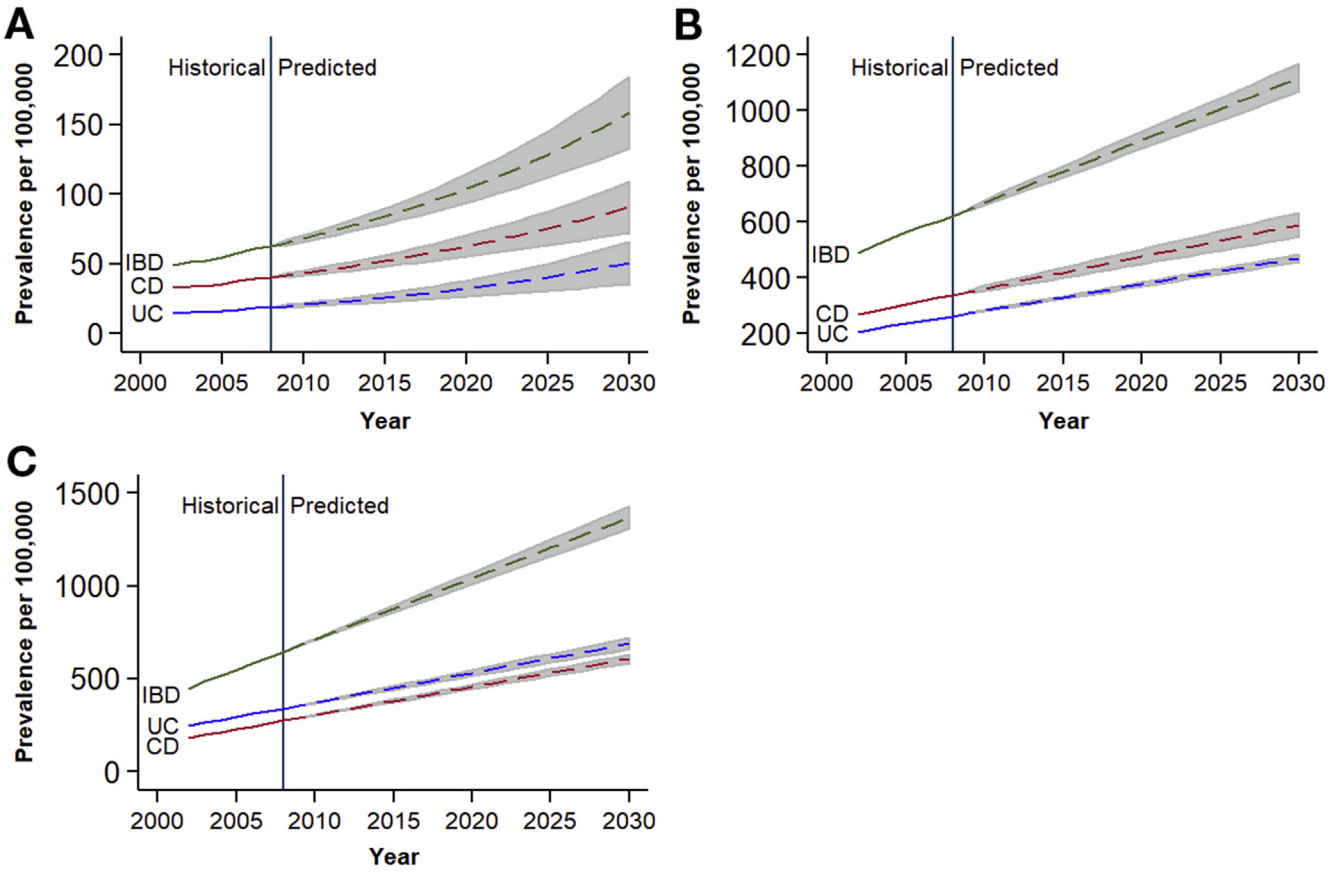

Figure 3. (*A*) Actual and forecasted prevalence of pediatric IBD, CD, and UC in Canada. Actual prevalence, standardized for sex and age, is denoted by the *solid line*. Forecasted prevalence—analyzed with a log binomial model and then forecasted until 2030—is indicated by a *dashed line* with the PI highlighted in *gray*. (*B*) Actual and forecasted prevalence of adult IBD, CD, and UC in Canada. Actual prevalence, standardized for age and sex, is denoted by the *solid line*. Forecasted prevalence—analyzed with an ARIMA model and then forecasted until 2030—is indicated by a *dashed line* with the PI highlighted in *gray*. (*C*) Actual and forecasted prevalence of elderly IBD, CD, and UC in Canada. Actual prevalence, standardized for age and sex, is denoted by the *solid line*. Forecasted prevalence—analyzed with an ARIMA model in which the data underwent differencing and then forecasted until 2030—is indicated by a *dashed line* with the PI highlighted in *gray*.

was forecasted to increase to 1.0%. We estimate that approximately 270,000 Canadians are currently living with IBD and that, by 2030, the Canadian health care systems might be caring for more than 402,000 patients with IBD. Prevalence is increasing in all age groups, but particularly among the elderly because of newly diagnosed seniors and the advancing age of patients with previously diagnosed IBD. Ambulatory clinics in 2030 will be distinctly different from current clinics as health care providers contend with caring for considerably more patients with IBD—including younger newly diagnosed patients and older patients with longer disease duration and comorbidities of advancing age.

The prevalence of IBD is forecasted to increase steadily by 2.86% per year in Canada. As a lifelong disease without a cure, the compounding prevalence of IBD is due to the disparity between incidence and mortality. Because changes in incidence are inherently captured within our models of changing prevalence (a combination of new cases, current cases, and cases removed from the population), we did not separately analyze incidence. As long as the incidence exceeds the mortality, our clinics will continue to add newly diagnosed patients on the foundation of our previously diagnosed patients every year. However, future studies accounting for life expectancy are necessary to establish the threshold that incidence needs to decrease for prevalence to stabilize. Nonetheless, these data should serve as a clarion call to health care systems to prepare their infrastructure, personnel, and resources to manage the rising burden of IBD.

With 95% of the Canadian population represented by our study, the findings are generalizable to other westernized nations with similar rates and demographics of IBD. For example, similar to Canada, the prevalence of IBD is increasing steadily in the United States.[3,14] A series of studies documenting this trend in Olmsted County, Minnesota was published using data ranging from 1940 to 2010.[15,16] In 2001, the prevalence of IBD in Olmsted County was 388 per 100,000 and increased to 533 per 100,000 in 2010; this equates to an estimated 1.64 million individuals living with IBD as of 2010 in the United States.[15–17] If the prevalence increases to the same level as in Canada—0.98% in 2030—more than 3.48 million individuals could have IBD in the United States, more than double the 2010 estimate.[18]

Moreover, similar trends of rising prevalence have been observed in Europe and Australia.[3] Thus, a strategy to address the compounding prevalence of IBD in the Western world is necessary. Although our data are less applicable outside the Western world, where prevalence of IBD remains low, the rapidly increasing incidence of IBD in newly industrialized countries in Asia and Latin America suggests that these countries might begin to experience compounding prevalence analogous to the Western world in a generation from now.[3,5]

Although the exact future prevalence of IBD is unknown, it is apparent that the prevalence will continue to increase—so, how do health care systems adapt? By bringing awareness of this impending burden to the public and physicians alike, we can increase community engagement and bring this disease to the forefront of policy makers' agendas. This awareness could lead to an influx of funding for laboratory and epidemiologic research, which in turn will aid in preventing disease by furthering the knowledge base and thus working to lower the incidence of disease. If we cannot prevent new cases of IBD, then the forecasted increases in prevalence will lead to increased overall costs to health care systems, especially with medications, some of which can exceed tens of thousands of dollars per year per individual. Identifying the current drivers of cost and projecting the costs into the future are paramount to being able to define the future burden of disease, evaluate the future impact on health care systems, and ensure access and affordability. Further, developing alternative care pathways (eg, nurse practitioners) will help to ensure that those with IBD still receive the necessary care without health care systems being overwhelmed.

This study forecasts the future prevalence of IBD, but it is not without limitations. Heterogeneity in prevalence was observed between provinces. NS had the highest prevalence of IBD. Because NS is the only Atlantic province in the dataset, we could not assess whether the high prevalence value was representative of the east coast of Canada or unique to NS. Heterogeneity between provinces can be explained by inherent differences between populations, such as demography, genetic penetrance, and environmental exposures associated with IBD (eg, diet).[5] The models do not directly account for future variations in environmental risk factors (eg, breastfeeding or smoking) that can influence incidence, because these data were not available at the individual level for this cohort.[19] Further, because prevalence was calculated using administrative health care databases, possible misclassification errors in the diagnosis of IBD can occur.[19–22] To overcome this, AB, MB, and ON use validated algorithms, which ensure accuracy of the data based on sensitivity, specificity, and predictive values of diagnostic codes. The other provinces have applied these algorithms without cross-referencing accuracy with chart reviews. However, our sensitivity analysis—evaluating only the provinces with validated algorithms—produced prevalence estimates consistent with our main analyses.[19,21] Also, our national estimates of IBD include all patients with IBD; however, 5.6% of patients have unclassified IBD. These patients have IBD, but the algorithm used to distinguish CD from UC cannot differentiate the specific subtype. In consequence, the CD and UC stratified analyses do not account for these individuals. In addition, provinces report different timeframes based on available data: MB contains the longest period (1990–2013) and QC contains the shortest (2001–2008). Thus, our primary national model was restricted to 2002–2008 that included prevalence data from all 7 provinces. However, a sensitivity analysis of 5 provinces with prevalence data spanning 2002–2013 yielded similar estimates on forecasted prevalence (931 per 100,000 in 2030) compared with our primary national model (981 per 100,000). Further, there is an inherent uncertainty associated with forecast modeling because the methodology forecasts future values that are yet unknown based on an assumption that historical trends (eg, incidence rates) will be similar in the future. To address this, PIs are created that acknowledge this uncertainty and give a range of possible values for the true prevalence. The use of the best fitting models also mitigates this limitation by ensuring that forecasting models are true to the current data. Moreover, sensitivity analyses using alternate forecasting approaches (ie, log binomial modeling) yield similar estimates.

Forecasting the number of people with IBD alone is insufficient in defining the overall burden of IBD. We anticipate that the future landscape of IBD will evolve: increased use of biologics and new therapies in the pipeline, decreasing rates of hospitalization and surgery, and unpredictability of a landmark discovery, including a potential cure.[23,24] Future studies are necessary to integrate rising prevalence with other clinical factors that influence the burden of IBD to the health care system.

Overall, the future prevalence of IBD will lead to an increased stress on health care systems. We are at a time when new policies and innovations in the delivery of IBD care can help ensure that the nearly 4 million patients with IBD in North America (by 2030) will continue to receive the necessary care in the future. If health care systems fail to adjust for the impending burden of IBD, then they will be overwhelmed, and patients might not receive the care they need.

Supplementary Material

Note: To access the supplementary material accompanying this article, visit the online version of *Gastroenterology* at www.gastrojournal.org, and at https://doi.org/10.1053/j.gastro.2019.01.002.

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An interactive web-based map describing the prevalence of IBD across Canada from 2002 to 2030 is available at this link: https://people.ucalgary.ca/~ggkaplan/IBDCPREV.html

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Conflicts of interest

Charles N. Bernstein been on the advisory boards for AbbVie Canada, Ferring Canada, Janssen Canada, Shire Canada, Takeda Canada, Pfizer Canada, and Napo Pharmaceuticals; consulted to 4D Pharma and Mylan Pharmaceuticals; has received educational grants from AbbVie Canada, Pfizer Canada, Shire Canada, Takeda Canada, Janssen Canada; and has been on the speaker's panel for Ferring Canada, Medtronic Canada, and Shire Canada. Harminder Singh is on an advisory board for Merck Canada, Ferring Canada and has a research grant from Merck Canada. Laura E. Targownik is on the advisory board for Takeda, Janssen, AbbVie, Merck, Pfizer, and Ferring; received research funds from Janssen; and is a speaker for Takeda, Janssen, and AbbVie. Gilaad G. Kaplan has served as a speaker for Janssen, AbbVie, and Pfizer and has received research support from Janssen, AbbVie, GlaxoSmithKline, and Shire. Stephanie Coward, Alain Bitton, Anthony R. Otley, Ali Rezaie, Desmond Leddin, Eric I. Benchimol, Fiona Clement, Glen Hazlewood, Geoffrey C. Nguyen, Greg Rosenfeld, J. Antonio Avina-Zubieta, Jennifer L. Jones, Juan Nicolás Peña-Sánchez, Kerry A. McBrien, Kevan Jacobson, Mathew W. Carroll, M. Ellen Kuenzig, Remo Panaccione, Rob Deardon, Susan Jelinski, and Sanjay K. Murthy have no conflicts of interest to declare.

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Appendix 1. Province-Specific Overview

Prevalent cohort availability	AB 2002–2015	BC 1997–2014	MB 1990–2013	NS 1996–2009	ON 1999–2014	QC 2001–2008	SK 1998–2016
Time measure	Fiscal year (April 1–March 31)	Calendar year (January 1–December 31)	Mid-year (July 1)	Calendar year (January 1–December 31)	Fiscal year (April 1–March 31)	Mid-year (July 1)	Fiscal year (April 1–March 31)
Diseases classified	CD, UC, IBD-U, IBD	CD, UC, IBD-U, IBD	CD, UC, IBD	CD, UC, IBD-U, IBD	CD, UC, IBD-U, IBD	CD, UC, IBD	CD, UC, IBD
Identification algorithm validation reference	Rezaie et al, 2012[1]	Rezaie et al, 2012[1]	Bernstein et al, 1999[2]	N/A	Adults: Benchimol et al, 2014[3]; pediatrics: Benchimol et al, 2009[4]	Rezaie et al, 2012[1]	Bernstein et al, 1999[2]
Identification algorithm used	AB (≥2 hospitalizations or 4 physician claims or 2 medical contacts in 2 y)	AB (≥2 hospitalizations or 4 physician claims or 2 medical contacts in 2 y)	MB (5 physician contacts of any combination of outpatient contacts or hospitalizations using Outpatient Physician Database or Hospitalization Database)	AB (≥2 hospitalizations or 4 physician claims or 2 medical contacts in 2 y)	Adults 18–64 y: 5 physician contacts or hospitalizations within 4 y; adults ≥65 y: pharmacy claim for IBD medication + 5 physician contacts or hospitalizations within 4 y; children <18 y: if scoped: 4 OHIP or 2 CIHI-DAD within 3 y; if not scoped: 7 OHIP or 2 CIHI-DAD within 3 y	AB (≥2 hospitalizations or 4 physician claims or 2 medical contacts in 2 y)	MB (≥5 physician contacts or CIHI-DAD records within 2 y of health coverage, and ≥3 separate contacts with <2 y of coverage)
Validity of identification algorithm	Sensitivity 83.4%, positive predictive value 97.4%	N/A	Sensitivity 74.4%–89.2%, specificity 89.8%–93.7%	N/A	Pediatrics (<18 y): sensitivity 86.9%–91.1%, positive predictive value 57.7%–75.2%; adults (18–64 y): sensitivity 76.8%–92.3%, positive predictive value 81.4%; elderly (>64 y): sensitivity 59.3%–78.3%, positive predictive value 71.1%	N/A	N/A
Physician billing (associated with 1 diagnostic code)	Alberta Health Physician Claims	Population Data BC captures all provincially funded health care services data since 1990, including all outpatient medical visits,[5] hospital admissions and discharges,[6] interventions,[5] investigations,[5] demographic data,[7] cancer registry,[8] and vital statistics.[9] Furthermore, Population Data BC encompasses the comprehensive prescription drug database PharmaNet[10]	Manitoba Health Physicians Claims database	MSI	OHIP	RAMQ	Physician Services Claims File: Medical Services Branch (MSB)

Appendix 1. Continued

Prevalent cohort availability	AB	BC	MB	NS	ON	QC	SK
	2002–2015	1997–2014	1990–2013	1996–2009	1999–2014	2001–2008	1998–2016
Hospitalization (associated with 20 diagnostic codes)	CIHI-DAD		CIHI-DAD	CIHI-DAD	CIHI-DAD	MedEcho	Hospital Discharge Abstract Database (CIHI-DAD)
Ambulatory care (including ED visits)	NACRS		Manitoba Health Physicians Claims database	Only day surgery and ED visits	OHIP (1991–2016); NACRS (2002 onward)	MedEcho	MSB and ED visits from NACRS (CIHI NACRS, ED data)
Basic demographic information (date of birth, eligibility, date of death)	Alberta Health Registry		Manitoba Health population registry	Nova Scotia Vital Statistics, Insured Patient Registry	RPDB	RAMQ	PHRS
Sample of previously published articles using algorithm	Frolkis et al, 2014[11]; Kuenzig et al, 2017[12]	N/A	Benchimol et al, 2017[13]; Melesse et al, 2015[14] and 2017[15]; Shaw et al, 2013,[16] 2014,[17] and 2015[18]	Leddin et al, 2014[19]	Benchimol et al, 2014,[20] 2014,[21] and 2015[22]; Bollegala et al, 2017[23]; Nguyen et al, 2015[24]	Bitton et al, 2014[25]	Pena-Sanchez et al, 2017[26]
Cases of IBD in 2008 (real)[a]	18,269	22,937	6516	8104	64,963	35,005	5357
Cases of IBD in 2008 (standardized)[b]	19,039	22,420	6795	8143	65,278	34,567	5643
Population size in 2008	3,595,755	4,499,139	1,197,774	935,865	12,882,625	7,761,504	1,017,346

CIHI-DAD, Canadian Institute for Health Information–Discharge Abstract Database; ED, emergency department; IBD-U, inflammatory bowel disease–unclassified; MSB, Medical Services Billing; MSI, Medical Services Incorporated; N/A, not applicable; NACRS, National Ambulatory Care Reporting System; OHIP, Ontario Health Insurance Plan; PHRS, Person Health Registration System; RAMQ, Régie de l'assurance maladie du Québec; RPDB, Registered Persons Database.

[a]Numbers presented might vary from actual numbers in the original administrative data: suppressed cells occurred in data provided by provinces, which altered the final values contained in the analysis compared with the original.

[b]Numbers were standardized by age and sex based on the Canadian population.[27]

Appendix 2. Sensitivity Analyses of Forecasted Prevalence and AAPC

	IBD			CD			UC		
	Forecasted prevalence per 100,000 (95% PI)		Forecasted AAPC, % (95% CI)	Forecasted prevalence per 100,000 (95% PI)		Forecasted AAPC, % (95% CI)	Forecasted prevalence per 100,000 (95% PI)		Forecasted AAPC, % (95% CI)
	2018	2030		2018	2030		2018	2030	
All log binomial regression	828 (816–839)	1459 (1421–1497)	4.85 (4.74–4.96)	414 (406–422)	706 (680–732)	4.55 (4.40–4.70)	368 (360–375)	652 (626–678)	4.89 (4.72–5.05)
Using population values	684 (673–694)	856 (835–876)	2.23 (2.13–2.32)	368 (363–373)	493 (483–502)	2.75 (2.69–2.81)	303 (300–307)	380 (372–388)	2.23 (2.15–2.32)
Canada (validated algorithms)	681 (661–701)	909 (842–976)	2.52 (2.09–2.91)	319 (307–330)	412 (376–449)	2.25 (1.71–2.74)	309 (289–328)	413 (357–469)	2.55 (1.74–3.23)
Canada (without NS or QC: 2002–2013)	700 (680–719)	931 (882–980)	2.52 (2.25–2.77)	327 (317–336)	425 (400–450)	2.33 (2.02–2.61)	328 (316–340)	438 (409–468)	2.57 (2.24–2.88)

AAPC, average annual percentage change.