Validity of COVID-19 Diagnoses in Canadian Administrative Health Data: A Multi-province, Population-based Study

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Abstract Word Count: 241

Manuscript Word Count: 2495

Keywords: Diagnoses, Administrative Data, Accuracy, International Classification of Diseases

Declaration of Competing Interests: The authors have no potential conflicts of interest to disclose.

Funding Statement: The Canadian Network for Observational Drug Effect Studies (CNODES), a collaborating centre of the Drug Safety and Effectiveness Network (DSEN), is funded by the Canadian Institutes of Health Research (CIHR; Grant # DSE-146021). The funders had no role in the design of the study, analysis, and interpretation of data and in writing of the manuscript.

Abstract

Background: Accurate coding of COVID-19 diagnoses in administrative data benefits population-based studies about the epidemiology, treatment and outcomes of this infectious disease. We describe the validity of COVID-19 diagnoses recorded in hospital discharge abstracts, emergency department (ED) records, and outpatient physician service claims from three Canadian provinces.

Methods: Population-based inpatient, ED, and outpatient records were linked to SARS-coV-2 polymerase chain reaction (PCR) test results from British Columbia, Manitoba, and Ontario from April 1, 2020 to March 31, 2021. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of COVID-19 diagnoses were estimated for each quarter in the study period, overall and by province, age group, and sex.

Results: Our study encompassed over 19.5 million Canadian residents and 13 million SARS-coV-2 test results. Specificity and NPV of COVID-19 diagnoses were consistently high. Overall sensitivity estimates were 86.2%, 60.4%, and 20.3% in the first quarter for inpatient, ED, and outpatient cohorts and 66.2%, 47.5%, and 25.0% in the last quarter, respectively. For inpatients, overall PPV ranged from 50.0% to 66.4% across quarters. For ED patients, overall PPV estimates were 76.9% and 68.3% in the first and last quarter, respectively. For outpatients the corresponding estimates were 6.8% and 29.1%, although they varied by province.

Interpretation: Our multi-province validation study supports the use of inpatient and ED records as an alternative to population-based laboratory data for identification of patients with COVID-19, but does not support the use of outpatient claims for this purpose.

Introduction

Administrative health data are increasingly being used to examine outcomes, risk factors, and treatments at the population level for individuals diagnosed with COVID-19. However, the validity of COVID-19 diagnosis coding in these data is largely unknown outside of inpatient settings.[1-5] Validity may vary between jurisdictions and over time due to variations in testing protocols and diagnosis coding procedures and staff training; but little is known about such variations.

The Canadian Institute for Health Information (CIHI) published its first guidance on the use of the International Classification of Diseases (ICD), 10th revision, Canadian enhancement (i.e., ICD-10-CA) diagnosis codes for COVID-19 patients admitted to Canadian hospitals and emergency departments (ED) in March 2020.[6] Provincial/territorial guidance for diagnosis and fee codes for physician service claims has also been published. For example, Ontario introduced a COVID-19 diagnosis code and fee codes in March 2020 with instructions to use the diagnosis code "when treating patients with suspected or confirmed COVID-19",[7] while the British Columbia Medical Services Plan published COVID-19 codes for "services directly related to COVID-19".[8] To our knowledge, only Wu et al.[3] has studied the validity of COVID-19 diagnosis coding in Canadian inpatient and ED records, although their investigation was limited to data from Alberta. The quality of COVID-19 diagnosis coding in outpatient physician service claims has not been studied.

Information regarding the accuracy of COVID-19 diagnoses in administrative data is important to researchers and readers of studies that use these data to understand COVID-19 epidemiology, treatments and outcomes. Our study aimed to assess the validity of COVID-19

diagnoses recorded in inpatient hospital discharge abstracts, ED records, and outpatient physician service claims in three Canadian provinces.

Methods

Study Design and Data Sources

We undertook a population-based cohort study using administrative health data and SARS-CoV-2 polymerase chain reaction (PCR) laboratory test results from British Columbia, Manitoba and Ontario. The study was conducted by the Canadian Network for Observational Drug Effect Studies (CNODES),[9] at the request of Health Canada.

Four administrative health databases were used in each province: health insurance registry, physician service claims, ED discharge records, and inpatient hospital discharge abstracts. All data sources were linked at the individual level using anonymized personal health insurance numbers. Health insurance registration files capture start and end dates of health insurance coverage, including the date of loss of coverage due to death or migration; demographic and residence location information is also captured. Physician service claims contain information about services provided by specialists and general practitioners; they include the type of service, fee code, date of service, and at least one diagnosis code associated with the reason for the service. The latter are recorded using modifications of the 8th (Ontario) and 9th revisions of ICD (i.e., ICD-8 and ICD-9).[10] We included service claims for all office, phone, and virtual patient consultations, home visits, and long term care visits. ED discharge records contain information about visits to hospital-based EDs, including the date of the visit, chief complaint (i.e., reason for the visit), and diagnoses, which are typically coded using ICD-10-CA. Hospital discharge abstracts contain diagnostic and procedural information for each acute hospital stay, including up to 25 diagnoses coded using ICD-10-CA.

SARS-CoV-2 laboratory test results were captured from records in the Ontario Laboratories Information System, the BC Ministry of Health COVID-19 Test Laboratory Data, and the Manitoba Cadham Provincial COVID-19 Laboratory Testing and Results Database. Throughout the study period there was publicly-available PCR testing for symptomatic individuals in all three provinces.

Study Cohorts

We defined inpatient, ED, and outpatient study cohorts comprised of provincial health insurance registrants with at least one inpatient acute hospital discharge, ED encounter, and outpatient physician service claim, respectively, between April 1, 2020 and March 31, 2021 (Figure 1). The cohorts were further stratified into three-month (quarterly) sub-groups.

Study Measures

Positive test cases, negative test cases and no-test cases were identified from laboratory test results in each quarter. A positive test case had at least one positive PCR test with a specimen collection date within the quarter. A negative test case had at least one negative PCR test with a specimen collection date and no positive PCR tests within the quarter. No-test cases had no PCR tests or only indeterminate PCR tests within the quarter.

An ICD-10-CA code for laboratory-confirmed COVID-19 (U07.1) in any position was used to ascertain diagnosed (i.e., positive) cases in hospital discharge abstracts and ED records. For the inpatient cohort, true positive cases had a specimen collection date for a positive test between (and including) hospital admission and discharge dates. For the ED cohort, a window of up to two days before and two days after the specimen collection date for positive test cases was used to ascertain true positive cases. For the outpatient cohort, COVID-19 coding directives provided by each provincial ministry of health was used for case ascertainment. The diagnosis

codes were 080 (Coronavirus),[7] and 079.82 (COVID-19 Associated Coronavirus),[11] in Ontario and Manitoba, respectively. In British Columbia, case ascertainment was initially based on diagnosis code C19 (Services directly related to COVID-19).[8] This diagnosis code was not associated with any claims during the study period; accordingly, selected fee codes relevant to COVID-19 (13701, 13702, 13707, and 10008) were used for case ascertainment.[8] For outpatients who had multiple encounters with the same physician on the same date, only one consultation was considered. A window of up to two days before and two days after the specimen collection date for a positive test case was used to ascertain true positive cases in physician service claims.

Analyses

Frequencies, percentages, means, and standard deviations (SD) were used to describe the cohort characteristics (i.e., age, sex, income quintile, rural/urban residence). Validity was assessed using sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV). All estimates are reported as percentages with 95% confidence intervals (CIs). Validation measure estimates were produced for each province and for the three provinces combined, for each cohort and quarter. Analyses were also stratified by sex and age group (<65 years, 65-79 years, 80+ years).

To assess the robustness of our findings, we performed four pre-specified sensitivity analyses. In the first, for the inpatient cohort, true positive cases had a specimen collection date for a positive test that extended from seven days before the admission date to the discharge date. In the second, for the inpatient cohort, we used a time window that extended from 14 days before to 14 days after the hospital admission date to ascertain true positive cases consistent with the case definition of Kluberg et al.[1,2] In the third and fourth sensitivity analyses, for the ED and

outpatient cohorts, respectively, we used a time window that extended from five days before to five days after the specimen collection date for a positive test to identify true positive cases.

Results

After applying the study entry criteria, the study cohorts were comprised of approximately 1.3 million inpatients, 3.2 million ED patients, and 15.1 million outpatients (Figure 1). Ontario residents comprised 51.2%, 77.9%, and 67.3% of the inpatient, ED, and outpatient cohorts, respectively. The average age was 55.9 years for the inpatient cohort, 43.3 years for the ED cohort and 44.4 years for the outpatient cohort (Table 1; Tables S1-S3 contain province-specific results). Females comprised 57.2% of the inpatient cohort, 52.1% of the ED cohort, and 54.2% of the outpatient cohort. The outpatient cohort had a lower percentage of individuals in the lowest income quintile than the ED and inpatient cohorts. All cohorts were comprised primarily of urban residents, as expected.

Figures 2 to 4 contain overall estimates of sensitivity, specificity, PPV, and NPV for the inpatient, ED, and outpatient cohorts, respectively, by quarter. Province-specific estimates are reported in Tables 2 to 4; case frequencies to produce these estimates are in Tables S4 to S6. Specificity and NPV estimates were consistently high across all cohorts and quarters and frequently exceeded 95%. Sensitivity and PPV estimates varied by cohort, quarter, and province.

For the inpatient cohort, overall sensitivity was 86.2% (95% CI: 84.2, 88.1) in the first quarter (i.e., Q1); it dropped to 66.2% (95% CI: 64.7, 67.6) in the last quarter (i.e., Q4). Overall PPV was 66.4% (95% CI: 64.5, 68.4) in Q1 and 66.3% (95% CI: 65.0, 67.6) in Q4. The lowest overall PPV was 50.0% (95% CI: 46.8, 53.2) in Q2. Province-specific PPV for Q1 ranged from 30.0% (95% CI: 26.9, 33.0) in British Columbia to 75.0% (95% CI: 73.6, 76.4) in Ontario. In

British Columbia, PPV was low in Q1 and Q2, then increased in Q3 and Q4, while in Ontario, PPV dropped in Q3 and Q4 when compared to Q2.

For the ED cohort, overall sensitivity were 60.4% (95% CI: 58.3, 62.5) in Q1 and 47.5% (95% CI: 46.5, 48.6) in Q4. PPV was 76.9% (95% CI: 75.0, 78.8) and 68.3% (95% CI: 67.2, 69.4) in Q1 and Q4, respectively. Sensitivity was poor for Manitoba throughout the study period, with a maximum estimate of 11.6% (95% CI: 9.5, 13.6) in Q4; PPV was 39.9% (95% CI: 34.1, 45.7) in Q4. In comparison, maximum sensitivity for Ontario was 61.0% (95% CI: 59.7, 62.2) in Q1; PPV in this quarter was 77.0 (95% CI: 75.8, 78.2).

For the outpatient cohort, overall sensitivity was 20.3% (95% CI: 19.4, 21.3) in Q1 and 25.0% (95% CI: 24.6, 25.4) in Q4. Overall PPV was 6.8% (95% CI: 6.5, 7.1) in Q1 and 29.1% (95% CI: 28.7, 29.5) in Q4. Sensitivity improved over time in both Manitoba and Ontario but was low, increasing from 1.3% (95% CI: 0.0, 3.8) and 21.1% (95% CI: 20.6, 21.7), respectively, in Q1, to 6.3% (95% CI: 5.5, 7.2) and 35.6% (95% CI: 35.3, 35.9), respectively, in Q4. In British Columbia, sensitivity declined over time, falling from 10.2% (95% CI: 8.6, 11.8) in Q1 to 2.5% (95% CI: 2.3, 2.6) in Q4; PPV increased slightly from 1.0% (95% CI: 0.9, 1.2) in Q1 to 12.9% (95% CI: 12.2, 13.7) in Q4.

Overall sensitivity and PPV generally increased across age groups in the inpatient cohort, but declined across age groups in the ED and outpatient cohorts (Tables S7-S9). No consistent pattern was observed for sex in overall sensitivity and PPV estimates (Tables S7-S9).

For the pre-defined sensitivity analyses for the inpatient cohort (Tables S10-S11), expanding the duration of the case ascertainment window led to absolute increases in estimated sensitivity of up to 46%, with the largest increase in British Columbia. However, in Manitoba sensitivity was lower in Q1 and Q2 for the sensitivity analysis than for the primary analysis.

Overall, the first sensitivity analysis resulted in greater improvements in estimates of sensitivity and PPV than the second; temporal trends in both measures were similar to those observed in the primary analysis. For the third sensitivity analysis (i.e., ED cohort; Table S12), expanding the duration of the case ascertainment window resulted in absolute increases of up to 10% in sensitivity. Increases in PPV were smaller. For the outpatient cohort, expanding the case ascertainment window led to absolute increases in sensitivity and PPV of up to 18%, although the differences were generally smaller (i.e., less than 5%) for most provinces and quarters (Table S13).

Interpretation

Our multi-province study of the accuracy of COVID-19 diagnoses in inpatient, ED and outpatient records occurred during the first year of the pandemic when SARS-CoV-2 PCR testing was broadly promoted and openly accessible to symptomatic individuals in all three study provinces.[6] We found the accuracy of diagnosis coding for COVID-19 was generally good for inpatient records, moderate for ED records, and poor for outpatient physician encounters, but it varied by province and over time. Generally, sensitivity estimated declined over time and, depending on the province, PPV estimated either improved or remained stable. Expanding the duration of the observation window for ascertaining COVID-19 diagnoses in healthcare records improved sensitivity and PPV estimates, especially for inpatient data, but the effect for outpatient data was generally small.

Our findings for inpatient diagnosis coding are generally consistent with those reported in prior studies.[1-5] For example, using US inpatient data from May to October 2020, Kluberg et al.[1,2] reported sensitivity estimates of 95% and PPV of 81% for ICD-10 U07.1. Similarly, Kadri et al.[4] reported sensitivity estimates of 98% and PPV of 92% from April to May 2020. These

results suggest that during the first year of the pandemic, hospitals were coding COVID-19 diagnoses with moderate to good accuracy. However, given the low and declining sensitivities, epidemiological studies relying on discharge abstracts are likely to underestimate the true burden of disease in hospital.

Our study is among the first to report the accuracy of COVID-19 diagnosis coding in ED records and outpatient physician claims. For the former, performance was noticeably poorer in Manitoba than in the other provinces, particularly for sensitivity. This may be because of differences in data sources; Manitoba does not use the National Ambulatory Care Reporting System for ED records and has fewer fields for diagnosis codes than Ontario and British Columbia. The accuracy of COVID-19 diagnosis coding in outpatient claims was poor in all provinces. Expanding the case ascertainment window resulted in only small improvements in sensitivity and PPV estimates. Our findings for outpatient data may be attributed to limited access to family physicians particularly during the early months of the pandemic, the multiple reasons a person may consult their physician regarding COVID-19, testing-related visits were likely to directed preferentially to hospital- or community-based mass testing clinics rather than doctors' offices, and the time it takes physicians and billing clerks to become accustomed to using new diagnosis or fee codes. Our findings do not support use of physician service claims as a substitute for population-based lab data to identify patients with COVID-19.

Strengths of our study include assessment of coding accuracy in both inpatient and outpatient settings, during multiple time periods, and in three Canadian provinces. Our access to population-wide, community-based PCR laboratory test results made validation possible outside of inpatient hospital settings. Study limitations also merit emphasis. First, the generalizability of our findings, particularly for outpatient physician service claims, is unknown. Each province

implemented its own COVID-19 coding for outpatient claims, with varying directions. Further, SARS-CoV-2 PCR laboratory testing was openly and widely accessible to symptomatic patients throughout the study period. However, broad access to the results of these PCR tests also would be expected to influence diagnosis coding behaviour and completeness. Our findings may not generalize to jurisdictions where SARS-CoV-2 PCR testing policies and practice differed from those in Canada, although many countries appear to have implemented similar testing policies.[12] Finally, given that diagnosis coding validity changed over time, our findings may not generalize beyond the study period.

In summary, we identified variation in the validity of COVID-19 diagnoses recorded in different healthcare settings, geographic areas, and over time, but the overall accuracy of diagnosis codes for COVID-19 case ascertainment were generally good for inpatient records, moderate for ED records, and poor for outpatient records. This study provides valuable insights about the validity of these data sources for COVID-19 case ascertainment that will benefit population-based research and surveillance.

ACKNOWLEDGEMENTS

This study was made possible through data-sharing agreements between the CNODES member research centres and the respective provincial governments of British Columbia, Manitoba (HIPC No. 2020/2021 - 53), and Ontario.

The BC Ministry of Health approved access to and use of BC data facilitated by Population Data BC, for this study. All inferences, opinions, and conclusions drawn in this manuscript are those of the authors, and do not reflect the opinions or policies of the Data Stewards. British Columbia data sources were as follows (https://www2.gov.bc.ca/gov/content/health/conducting-health-research-evaluation/data-access-health-data-central): British Columbia Ministry of Health [creator] (2022): Medical Services Plan (MSP) Payment Information File. BC Ministry of Health [publisher]. MOH (2022); Canadian Institute for Health Information [creator] (2022): National Ambulatory Care Reporting System. BC Ministry of Health [publisher]. MOH (2022); Canadian Institute for Health Information [creator] (2022): Discharge Abstract Database (Hospital Separations). BC Ministry of Health [publisher]. MOH (2022); British Columbia Ministry of Health [creator] (2022): Consolidation File (MSP Registration & Premium Billing). BC Ministry of Health [publisher]. MOH (2022). Parts of this material are based on data and/or information compiled and provided by the Canadian Institute for Health Information (CIHI). This study was supported by ICES, which is funded in part by an annual grant from the Ontario Ministry of Health. The authors also acknowledge the Manitoba Centre for Health Policy for use of data contained in the Manitoba Population Research Data Repository under project #2022-004 (HIPC# 2021/2022-25). Data used in this study are from the Manitoba Population Research Data Repository housed at the Manitoba Centre for Health Policy, University of Manitoba and were derived from data provided by Manitoba Health.

The opinions, results, and conclusions are those of the authors. No endorsement by the provincial governments, data stewards, CIHI, Health Canada or CIHR is intended or should be inferred.

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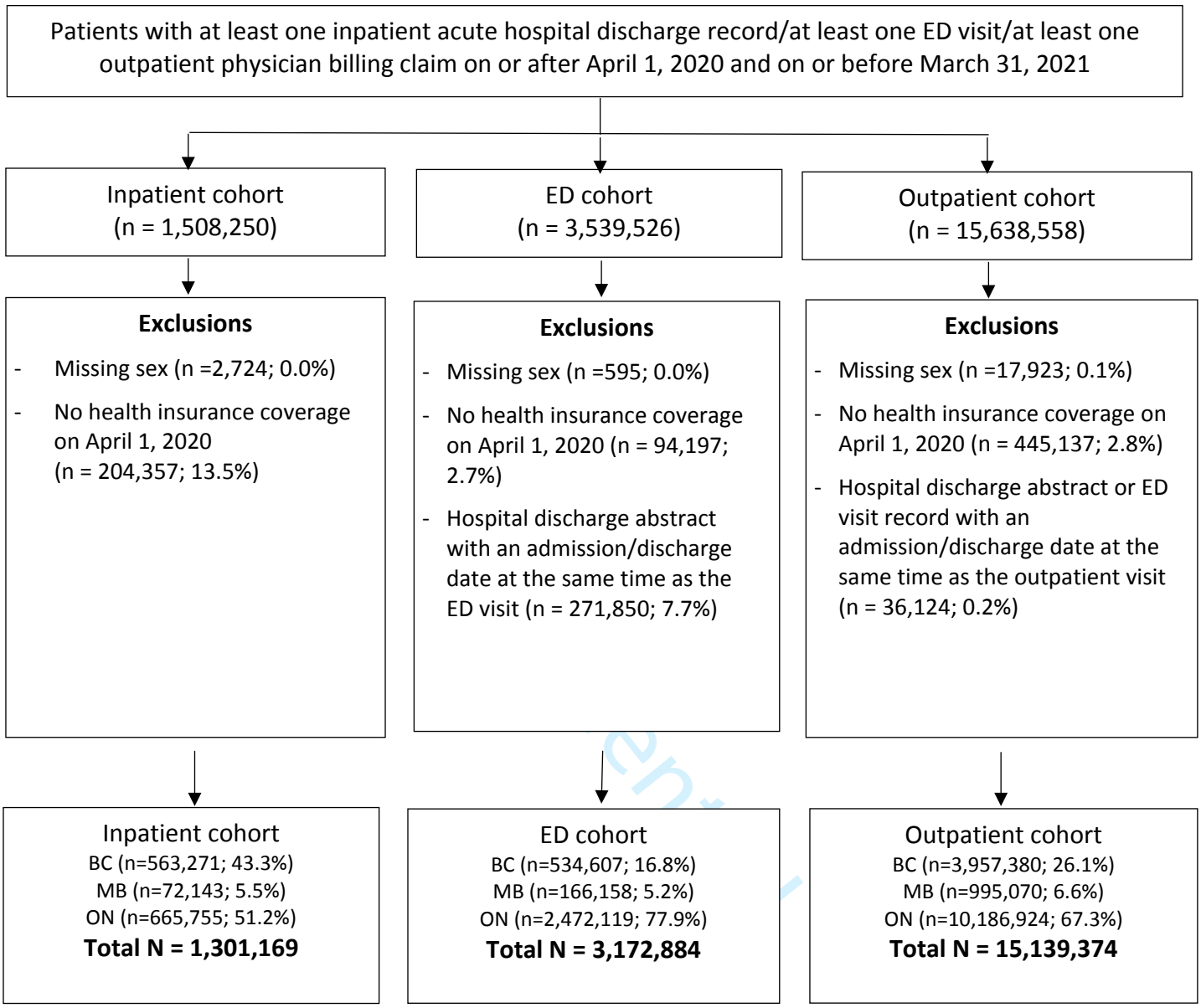
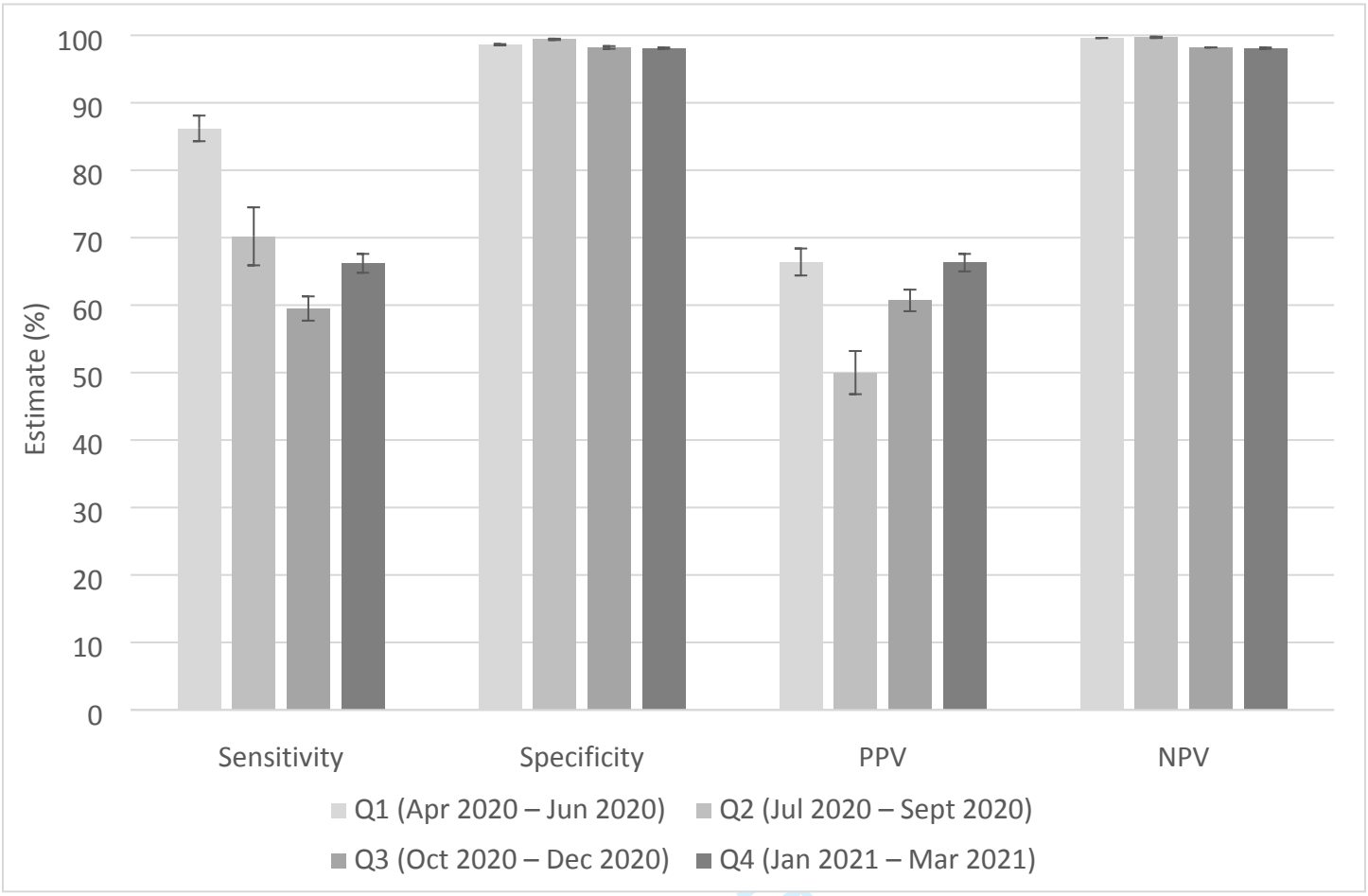
Figure 1. Flow diagram for construction of study cohorts



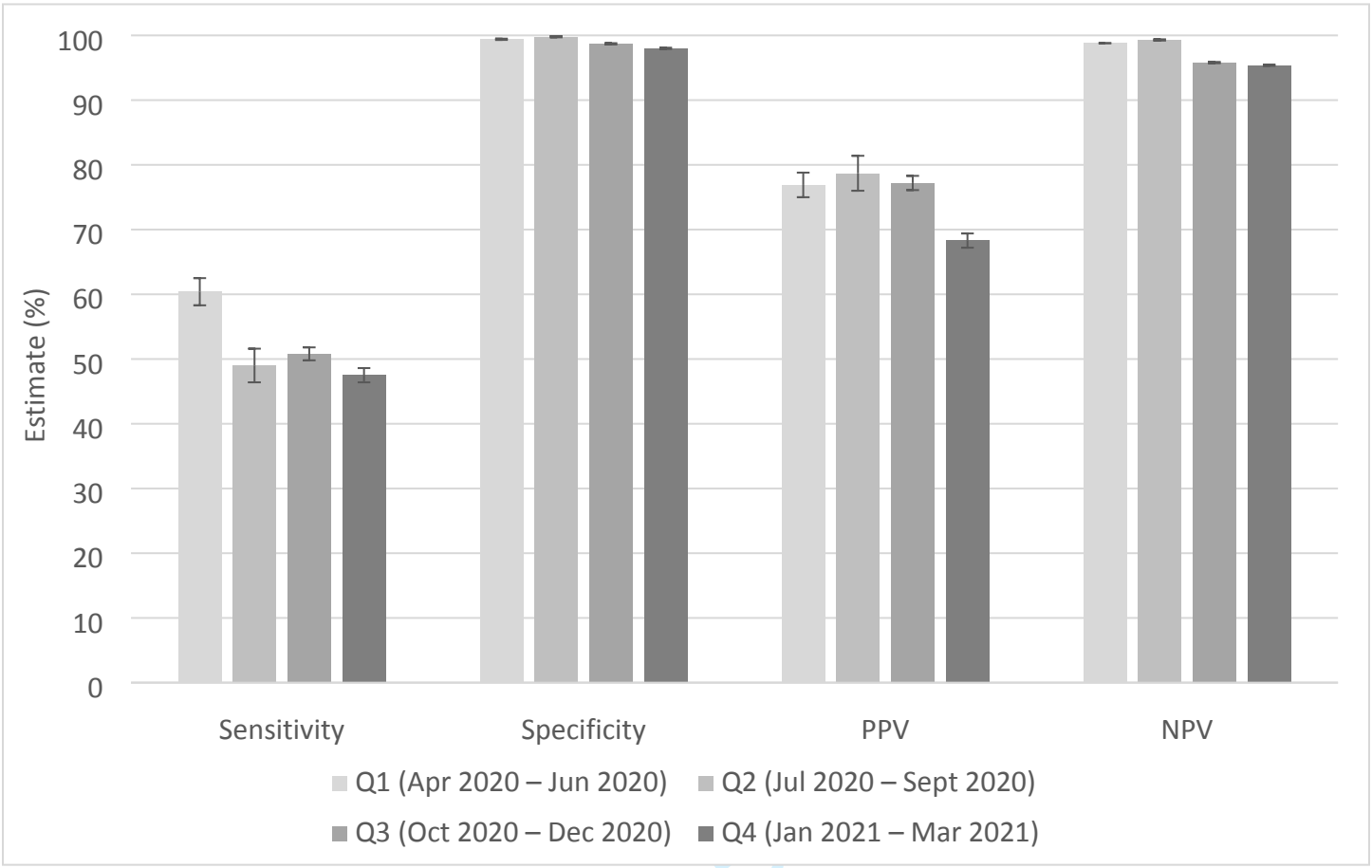
Abbreviations: ED: emergency department; BC: British Columbia; MB: Manitoba; ON: Ontario

Figure 2. Overall validation estimates by quarter (Q): inpatient cohort



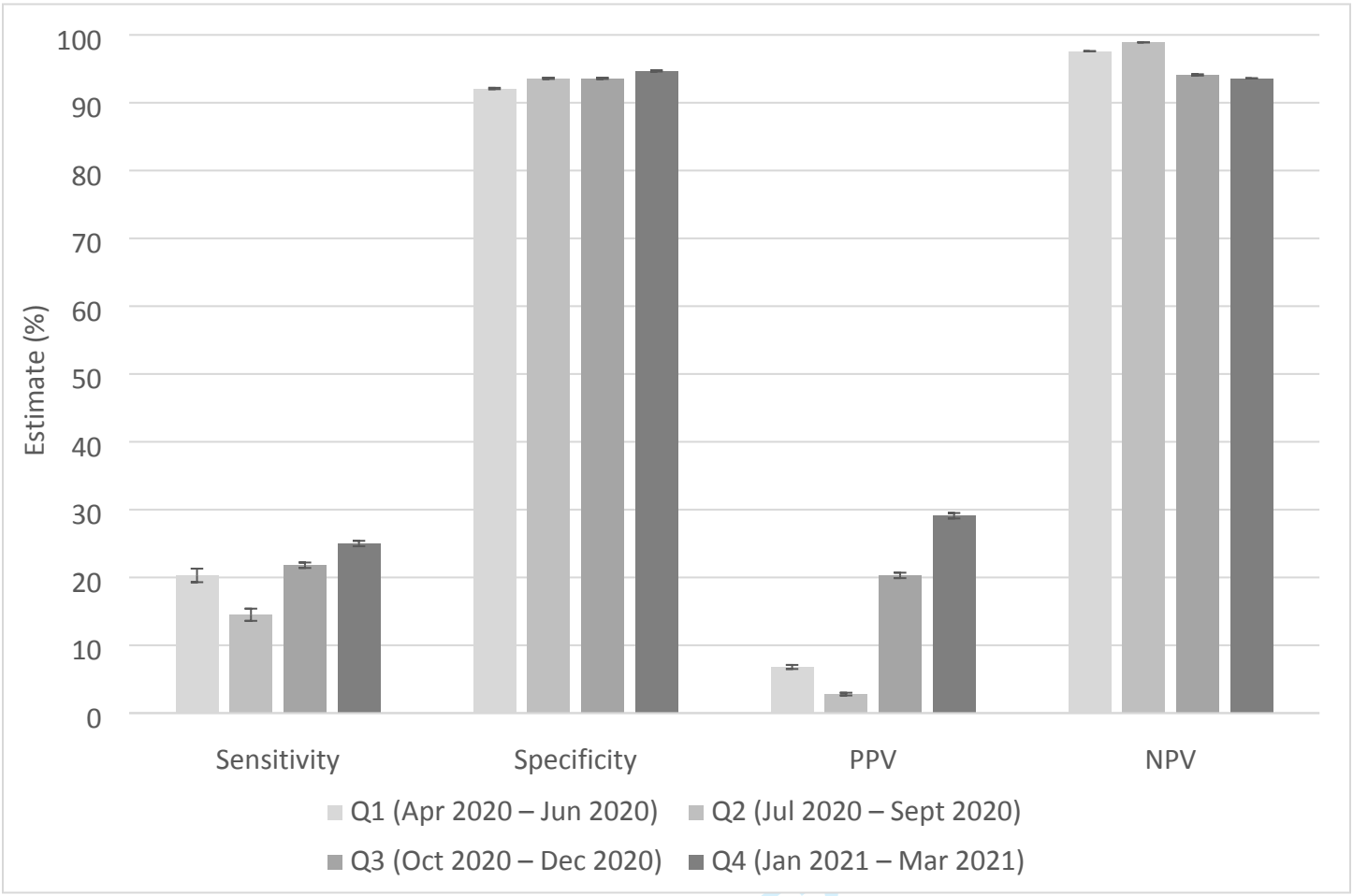
Abbreviations: PPV: Positive predictive value; NPV: Negative predictive value

Figure 3. Overall validation estimates by quarter (Q): Emergency department (ED) cohort



Abbreviations: PPV: Positive predictive value; NPV: Negative predictive value

Figure 4. Overall validation estimates by quarter (Q): outpatient cohort



Abbreviations: PPV: Positive predictive value; NPV: Negative predictive value

Table 1. Characteristics of inpatient, emergency department (ED), and outpatient cohorts

Characteristic	Inpatient	ED	Outpatient
Patients, N	1,301,169	3,172,884	15,139,374
Age, years			
Mean (SD)	55.9 (22.3)	43.3 (23.5)	44.4 (23.3)
<65, n (%)	752,901 (57.9)	2,496,872 (78.7)	11,752,789 (77.6)
65-79, n (%)	352,603 (27.1)	464,006 (14.6)	2,506,922 (16.6)
80+, n (%)	195,665 (15.0)	212,006 (6.7)	879,663 (5.8)
Sex, n (%)			
Males	556,729 (42.8)	1,521,172 (47.9)	6,926,694 (45.8)
Females	744, 440 (57.2)	1,651,712 (52.1)	8,212,680 (54.2)
Income quintile, n (%)			
1st (Lowest)	246,685 (19.0)	639,404 (20.1)	2,463,368 (16.3)
2nd	197,114 (15.2)	559,575 (17.6)	2,370,653 (15.7)
3rd	186,366 (14.3)	549,125 (17.3)	2,460,442 (16.3)
4th	181,575 (13.9)	540,065 (17.0)	2,523,160 (16.7)
5th (Highest)	253,689 (19.5)	570,187 (17.9)	3,043,805 (20.1)
Missing	235,740 (18.1)	314,528 (9.9)	2,277,946 (15.1)
Area of residence, n (%)			
Rural	184,737 (14.2)	442,454 (13.9)	1,690,020 (11.2)
Urban	1,113,889 (85.6)	2,721,432 (85.8)	13,412,772 (88.6)
Missing	2,543 (0.2)	8,998 (0.3)	36,582 (0.2)

Abbreviation: SD: standard deviation

Table 2. Validation estimates (95% confidence intervals) by province and quarter (Q): inpatient cohort

Measure	Q1 Apr 2020 – Jun 2020	Q2 Jul 2020 – Sept 2020	Q3 Oct 2020 – Dec 2020	Q4 Jan 2021 – Mar 2021
		British Columbia		
Sensitivity	88.4 (84.8, 92.1)	56.1 (49.8, 62.4)	52.0 (49.7, 54.3)	53.5 (51.6, 55.4)
Specificity	97.5 (97.3, 97.7)	97.7 (97.5, 97.8)	97.5 (97.4, 97.7)	98.3 (98.2, 98.5)
PPV	30.0 (26.9, 33.0)	17.8 (15.1, 20.6)	46.9 (44.8, 49.1)	58.9 (57.0, 60.9)
NPV	99.9 (99.8, 99.9)	99.6 (99.5, 99.7)	98.0 (97.8, 98.1)	97.9 (97.8, 98.1)
		Manitoba		
Sensitivity	88.9 (77.0, 100.0)	75.4 (67.5, 83.3)	59.1 (56.4, 61.8)	48.2 (44.1, 52.3)
Specificity	99.6 (99.4, 99.7)	99.3 (99.1, 99.5)	95.3 (94.9, 95.6)	98.5 (98.3, 98.7)
PPV	46.2 (32.6, 59.7)	60.6 (52.5, 68.6)	55.4 (52.7, 58.0)	53.6 (49.4, 57.9)
NPV	99.9 (99.9, 100.0)	99.6 (99.5, 99.8)	95.9 (95.5, 96.2)	98.1 (97.9, 98.3)
		Ontario		
Sensitivity	86.0 (84.8, 87.1)	73.0 (70.2, 75.8)	62.3 (61.0, 63.6)	71.0 (70.1,72.0)
Specificity	98.8 (98.8, 98.9)	99.8 (99.8, 99.8)	98.8 (98.8, 98.9)	98.0 (97.9, 98.1)
PPV	75.0 (73.6, 76.4)	73.6 (70.9, 76.4)	68.3 (66.9, 69.6)	68.9 (67.9, 69.8)
NPV	99.4 (99.4, 99.5)	99.8 (99.7, 99.8)	98.5 (98.4, 98.5)	98.2 (98.1, 98.3)

Abbreviations: PPV: Positive predictive value; NPV: Negative predictive value

Table 3. Validation estimates (95% confidence intervals) by province and quarter (Q): Emergency Department (ED) cohort

Measure	Q1 Apr 2020 – Jun 2020	Q2 Jul 2020 – Sept 2020	Q3 Oct 2020 – Dec 2020	Q4 Jan 2021 – Mar 2021
			British Columbia	
Sensitivity	52.4 (46.4, 58.4)	44.3 (40.8, 47.9)	31.8 (30.3, 33.2)	28.7 (27.2, 30.2)
Specificity	99.8 (99.8, 99.9)	99.7 (99.7, 99.8)	98.2 (98.1, 98.3)	98.1 (98.0, 98.3)
PPV	79.1 (73.1, 85.1)	80.0 (76.2,83.8)	61.4 (59.2, 63.6)	58.1 (55.8, 60.4)
NPV	99.4 (99.3, 99.5)	98.6 (98.4, 98.7)	94.0 (93.8, 94.3)	93.8 (93.6, 94.1)
			Manitoba	
Sensitivity	0.09 (0.0, 0.2)	2.6 (0.0, 5.18)	9.9 (8.6, 11.1)	11.6 (9.5, 13.6)
Specificity	100.0 (100.0, 100.0)	99.8 (99.7, 99.9)	97.3 (97.0, 97.5)	98.9 (98.7, 99.0)
PPV	1.00 (1.0, 1.0)	12.1 (1.0, 23.3)	34.2 (30.6, 37.9)	39.9 (34.1, 45.7)
NPV	0.19 (0.1, 0.3)	98.9 (98.7, 99.1)	88.3 (87.8, 88.8)	94.6 (94.2, 94.9)
			Ontario	
Sensitivity	61.0 (59.7, 62.2)	52.3 (50.6, 54.1)	59.0 (58.4,59.7)	52.3 (51.6, 53.0)
Specificity	99.4 (99.3, 99.4)	99.8 (99.8, 99.9)	98.9 (98.8,98.9)	97.9 (97.9,98.0)
PPV	77.0 (75.8, 78.2)	79.6 (77.8, 81.3)	81.3 (80.7, 82.0)	70.0 (69.2, 70.7)
NPV	98.6 (98.6, 98.7)	99.4 (99.4, 99.5)	96.6 (95.6, 96.7)	95.7 (95.6, 95.8)

Abbreviations: PPV: Positive predictive value; NPV: Negative predictive value

Table 4. Validation estimates (95% confidence intervals) by province and quarter (Q): outpatient cohort

Measure	Q1 Apr 2020 – Jun 2020	Q2 Jul 2020 – Sept 2020	Q3 Oct 2020 – Dec 2020	Q4 Jan 2021 – Mar 2021
			British Columbia	
Sensitivity	10.2 (8.6, 11.8)	6.1 (5.4, 6.7)	2.4 (2.2, 2.5)	2.5 (2.3, 2.6)
Specificity	88.5 (88.3, 88.7)	91.7 (91.6, 91.8)	96.9 (96.8, 96.9)	98.2 (98.2, 98.3)
PPV	1.0 (0.9, 1.2)	1.5 (1.4, 1.7)	5.6 (5.2, 5.9)	12.9 (12.2, 13.7)
NPV	98.8 (98.8, 98.9)	97.9 (97.8, 97.9)	92.7 (92.6, 92.7)	90.5 (90.4, 90.6)
			Manitoba	
Sensitivity	1.3 (0, 3.8)	1.7 (0.84, 2.5)	5.0 (4.5, 5.4)	6.3 (5.5, 7.2)
Specificity	99.5 (99.4, 99.5)	99.7 (99.7, 99.8)	96.7 (96.5, 96.8)	95.2 (95.0, 95.3)
PPV	0.6 (0, 1.7)	8.3 (4.3, 12.4)	14.0 (12.8, 15.1)	5.7 (5.0, 6.5)
NPV	99.8 (99.7, 99.8)	98.7 (98.6, 98.7)	90.3 (90.1, 90.4)	95.6 (95.5, 95.8)
			Ontario	
Sensitivity	21.1 (20.6, 21.7)	20.1 (19.3, 20.9)	33.0 (32.7,33.3)	35.6 (35.3, 35.9)
Specificity	92.5 (92.4, 92.5)	93.7 (93.7, 93.8)	92.0 (92.0,92.1)	93.5 (93.4, 93.5)
PPV	8.5 (8.2, 8.7)	3.2 (3.1, 3.3)	22.5 (22.2,22.7)	31.1 (30.8, 31.4)
NPV	97.3 (97.2, 97.3)	99.1 (99.1, 99.2)	95.2 (95.1, 95.2)	94.6 (94.6, 94.6)

Abbreviations: PPV: Positive predictive value; NPV: Negative predictive value

Supplementary Material

Table S1. Characteristics of inpatient cohort by province

Characteristic	British Columbia	Manitoba	Ontario
Patients, N	563,271	72,143	665,755
Age, years			
Mean (SD)	56.7 (20.7)	52.2 (23.8)	55.6 (23.4)
<65, n (%)	325,157 (57.7)	45,422 (63.0)	382,322 (57.4)
65-79, n (%)	169,678 (30.1)	15,918 (22.1)	167,007 (25.1)
80+, n (%)	68,436 (12.2)	10,803 (15.0)	116,426 (17.5)
Sex, n (%)			
Males	259,002 (46.0)	27,484 (38.1)	270,243 (40.6)
Females	304,269 (54.0)	44,659 (61.9)	395,512 (59.4)
Income quintile, n (%)			
1st (Lowest)	74,570 (13.2)	19,335 (26.8)	152,780 (22.9)
2nd	43,965 (7.8)	15,169 (21.0)	137,980 (20.7)
3rd	40,479 (7.2)	13,916 (19.3)	131,971 (19.8)
4th	45,859 (8.1)	12,295 (17.0)	123,421 (18.5)
5th (Highest)	126,662 (22.5)	10,244 (14.2)	116,783 (17.5)
Missing	231,736 (41.1)	1,184 (1.6)	2,820 (0.4)
Area of residence, n (%)			

Rural	71,057 (12.6)	31,228 (43.3)	82,452 (12.4)
Urban	492,214 (87.4)	40,903 (56.7)	580,772 (87.2)
Missing	0 (0.0)	12 (0.0)	2,531 (0.4)

Abbreviation: SD: standard deviation

Table S2. Characteristics of emergency department (ED) cohort by province

Characteristic	British Columbia	Manitoba	Ontario
Patients, N	534,607	166,158	2,472,119
Age, years			
Mean (SD)	44.0 (23.5)	42.0 (24.2)	43.3 (23.5)
<65, n (%)	416,553 (77.92)	131,468 (79.1)	1,948,851 (78.8)
65-79, n (%)	79,409 (14.9)	23,208 (14.0)	361,389 (14.6)
80+, n (%)	38,645 (7.2)	11,482 (6.9)	161,879 (6.5)
Sex, n (%)			
Males	260,531 (48.7)	78,692 (47.4)	1,181,949 (47.8)
Females	274,076 (51.3)	87,466 (52.6)	1,290,170 (52.2)
Income quintile, n (%)			
1st (Lowest)	56,441 (10.6)	41,294 (24.9)	541,669 (21.9)
2nd	28,257 (5.3)	32,655 (19.7)	498,663 (20.2)
3rd	26,088 (4.9)	28,540 (17.2)	494,497 (20.0)
4th	30,000 (5.6)	31,424 (18.9	478,641 (19.4)
5th (Highest)	91,536 (17.1)	30,296 (18.2)	448,355 (18.1)
Missing	302,285 (56.5)	1,949 (1.2)	10,294 (0.4)
Area of residence, n (%)			
Rural	15,314 (2.9)	61,009 (36.7)	366,131 (14.8)

Urban	519,293 (97.2)	105,130 (63.3)	2,097,009 (84.8)
Missing	0 (0.0)	19 (0.0)	8,979 (0.4)

Abbreviation**:** **SD:** **standard** **deviation**

Table S3. Characteristics of outpatient cohort by province

Characteristic	British Columbia	Manitoba	Ontario
Patients, N	3,957,380	995,070	10,186,924
Age, years			
Mean (SD)	45.6 (22.9)	42.4 (23.7)	44.2 (23.4)
<65, n (%)	3,013,785 (76.2)	791,630 (79.6)	7,947,374 (78.0)
65-79, n (%)	701,382 (17.7)	151,703 (15.2)	1,653,837 (16.2)
80+, n (%)	242,213 (6.1)	51,737 (5.2)	585,713 (5.7)
Sex, n (%)			
Males	1,838,783 (46.5)	457,319 (46.0)	4,630,592 (45.5)
Females	2,118,597 (53.5)	537,751 (54.0)	5,556,332 (54.5)
Income quintile, n (%)			
1st (Lowest)	354,954 (9.0)	186,810 (18.8)	1,921,604 (18.9)
2nd	201,328 (5.1)	194,547 (19.5)	1,974,778 (19.4)
3rd	194,709 (4.9)	203,330 (20.4)	2,062,403 (20.2)
4th	231,708 (5.9)	197,987 (19.9)	2,093,465 (20.6)
5th (Highest)	745,651 (18.8)	203,409 (20.4)	2,094,745 (20.6)
Missing	2,229,030 (56.3)	8,987 (0.9)	39,929 (0.4)
Area of residence, n (%)			
Rural	412,296 (10.4)	348,274 (35.0)	929,450 (9.1)
Urban	3,545,084 (89.6)	646,683 (65.0)	9,221,005 (90.5)

Missing	0 (0.0)	113 (0.0)	36,469 (0.4)

Abbreviation: SD: standard deviation

Table S4. COVID-19 diagnosed cases by province and quarter (Q): inpatient cohort

Case Type	Q1 (Apr 2020 – Jun 2020)	Q2 (Jul 2020 – Sept 2020)	Q3 (Oct 2020 – Dec 2020)	Q4 (Jan 2021 – Mar 2021)
		British Columbia		
True Positive	260	134	952	1,400
False Positive	607	618	1,076	975
False Negative	34	105	880	1,216
True Negative	23,447	25,737	42,290	57,899
Total	24,348	26,594	45,198	61,490
		Manitoba		
True Positive	s	86	752	280
False Positive	28	56	606	242
False Negative	s	28	520	301
True Negative	6,251	7,841	12,172	15,767
Total	6,306	8,011	14,050	16,590
		Ontario		
True Positive	2,862	707	3,170	6,350
False Positive	954	253	1,475	2,869
False Negative	468	261	1,920	2,592
True Negative	81,835	113,828	122,061	140,211
Total	86,119	115,049	128,626	152,022

Abbreviation: s = suppressed cell for values under 6

Table S5. COVID-19 diagnosed cases by province and quarter (Q): emergency department (ED) cohort

Case Type	Q1 (Apr 2020 – Jun 2020)	Q2 (Jul 2020 – Sept 2020)	Q3 (Oct 2020 – Dec 2020)	Q4 (Jan 2021 – Mar 2021)
		British Columbia		
True Positive	140	336	1,207	1,024
False Positive	37	84	759	740
False Negative	127	422	2,593	2,544
True Negative	20,068	28,937	40,888	38,628
Total	20,372	29,779	45,447	42,936
		Manitoba		
True Positive	0	s	223	109
False Positive	9	s	428	164
False Negative	18	148	2,032	833
True Negative	9,539	12,920	15,371	14,451
Total	9,566	13,100	18,054	15,557
		Ontario		
True Positive	3,653	1,645	11,710	11,073
False Positive	1,094	423	2,688	4,755
False Negative	2,338	1,499	8,118	10,104
True Negative	168,109	264,129	233,122	223,935
Total	175,194	267,696	255,638	249,867

Abbreviation: s = suppressed cell for values under 6

T able S6. COVID-19 diagnosed cases by province and quarter (Q): outpatient cohort

Case Type	Q1 (Apr 2020 – Jun 2020)	Q2 (Jul 2020 – Sept 2020)	Q3 (Oct 2020 – Dec 2020)	Q4 (Jan 2021 – Mar 2021)
		British Columbia		
True Positive	145	311	854	996
False Positive	13,937	20,101	14,453	6,724
False Negative	1,274	4,826	35,541	39,252
True Negative	107,086	221,715	448,235	373,009
Total	122,442	246,953	499,083	419,981
		Manitoba		
True Positive	s	15	526	203
False Positive	169	165	3,237	3,332
False Negative	s	877	10,108	3,002
True Negative	31,038	64,504	93,690	65,535
Total	31,286	65,561	107,561	72,072
		Ontario		
True Positive	4,095	1,955	26,096	32,389
False Positive	44,223	59,352	90,070	71,676
False Negative	15,278	7,794	52,999	58,681
True Negative	542,811	886,211	1,040,493	1,027,919
Total	606,407	955,312	1,209,658	1,190,665

Abbreviation: s = suppressed cell for values under 6

Table S7. Overall validation estimates (95% confidence intervals) by age group, sex, and quarter (Q): inpatient cohort

	Sensitivity	Specificity	PPV	NPV
Q1 (Apr 2020 – Jun 2020)				
Age Group				
<65	83.9 (80.5, 87.3)	98.6 (98.4, 98.7)	60.1 (57.0, 63.2)	99.6 (99.5, 99.7)
65-79	89.2 (86.1, 92.4)	98.7 (98.4, 98.9)	69.0 (65.5, 72.5)	99.6 (99.5, 99.7)
80+	86.0 (82.6, 89.4)	98.6 (98.3, 98.8)	72.2 (68.7, 75.7)	99.4 (99.3, 99.5)
Sex				
Male	88.2 (85.7, 90.7)	98.4 (98.2, 98.6)	65.5 (62.8, 68.1)	99.6 (99.5, 99.7)
Female	83.8 (80.8, 86.8)	98.8 (98.6, 98.9)	67.6 (64.7, 70.5)	99.5 (99.4, 99.6)
Q2 (Jul 2020 – Sept 2020)				
Age Group				
<65	60.9 (54.1, 67.7)	99.4 (99.3, 99.5)	46.7 (41.7, 51.8)	99.7 (99.6, 99.7)
65-79	76.4 (68.8, 84.0)	99.3 (99.2, 99.5)	48.5 (43.0, 54.0)	99.8 (99.7, 99.9)
80+	79.1 (71.9, 86.3)	99.3 (99.2, 99.5)	56.5 (50.5, 62.5)	99.8 (99.7, 99.8)
Sex				
Male	77.6 (72.1, 83.1)	99.2 (99.1, 99.4)	49.5 (45.4, 53.6)	99.8 (99.7, 99.8)
Female	62.7 (56.2, 69.1)	99.5 (99.4, 99.6)	50.6 (45.7, 55.6)	99.7 (99.6, 99.7)
Q3 (Oct 2020 – Dec 2020)				
Age Group				
<65	46.0 (43.2, 48.8)	98.3 (98.2, 98.5)	52.1 (49.5, 54.7)	97.8 (97.7, 98.0)
65-79	70.2 (66.9, 73.4)	98.2 (98.0, 98.4)	63.4 (60.6, 66.2)	98.6 (98.5, 98.8)
80+	70.7 (67.5, 74.0)	98.2 (97.9, 98.4)	70.1 (67.2, 73.0)	98.2 (98.0, 98.4)
Sex				
Male	66.5 (64.0, 69.0)	97.9 (97.7, 98.1)	60.4 (58.3, 62.5)	98.4 (98.3, 98.5)

Female	52.6 (50.0, 55.3)	98.6 (98.4, 98.7)	61.1 (58.6, 63.5)	98.0 (97.9, 98.1)
		Q4 (Jan 2021 – Mar 2021)		
Age Group				
<65	50.6 (48.3, 52.9)	98.2 (98.1, 98.3)	56.7 (54.5, 58.8)	97.7 (97.6, 97.8)
65-79	76.9 (74.5, 79.3)	98.1 (97.9, 98.3)	69.9 (67.7, 72.1)	98.7 (98.5, 98.8)
80+	80.4 (78.0, 82.7)	97.9 (97.7, 98.2)	75.6 (73.4, 77.9)	98.4 (98.2, 98.6)
Sex				
Male	72.4 (70.5, 74.4)	97.8 (97.6, 97.9)	66.6 (64.9, 68.3)	98.3 (98.2, 98.4)
Female	59.8 (57.7, 62.0)	98.4 (98.3, 98.6)	65.9 (64.0, 67.8)	98.0 (97.9, 98.1)

Abbreviations: PPV: Positive predictive value; NPV: Negative predictive value

Table S8. Overall validation estimates (95% confidence intervals) by age group, sex, and quarter (Q): emergency department (ED) cohort

	Sensitivity	Specificity	PPV	NPV
Q1 (Apr 2020 – Jun 2020)				
Age Group				
<65	63.5 (61.2, 65.8)	99.4 (99.3, 99.5)	78.0 (76.0, 80.0)	98.8 (98.7, 98.8)
65-79	55.7 (49.5, 61.8)	99.6 (99.5, 99.7)	76.7 (70.9, 82.4)	99.0 (98.9, 99.1)
80+	35.7 (28.3, 43.1)	99.4 (99.2, 99.6)	60.4 (51.3, 69.4)	98.3 (98.2, 98.5)
Sex				
Male	63.9 (60.9, 66.9)	99.5 (99.4, 99.6)	80.3 (77.7, 82.9)	98.8 (98.7, 98.9)
Female	57.4 (54.5, 60.3)	99.4 (99.3, 99.5)	74.0 (71.3, 76.6)	98.7 (98.6, 98.8)
Q2 (Jul 2020 – Sept 2020)				
Age Group				
<65	49.3 (46.5, 52.2)	99.8 (99.8, 99.8)	78.9 (76.1, 81.7)	99.3 (99.2, 99.3)
65-79	50.4 (41.5, 59.4)	99.9 (99.8, 99.9)	78.4 (69.7, 87.0)	99.6 (99.5, 99.6)
80+	36.9 (23.5, 50.3)	99.9 (99.8, 100)	73.3 (56.9, 89.8)	99.5 (99.5, 99.6)
Sex				
Male	49.4 (45.6, 53.1)	99.8 (99.8, 99.9)	80.0 (76.4, 83.7)	99.3 (99.2, 99.3)
Female	48.6 (44.9, 52.4)	99.8 (99.8, 99.9)	77.5 (73.8, 81.3)	99.4 (99.3, 99.4)
Q3 (Oct 2020 – Dec 2020)				
Age Group				
<65	52.5 (51.3, 53.7)	98.6 (98.6, 98.7)	77.9 (76.8, 79.0)	95.8 (95.7, 95.9)
65-79	48.2 (45.0, 51.3)	98.8 (98.6, 99.0)	75.5 (72.4, 78.6)	96.1 (95.9, 96.3)
80+	31.3 (27.2, 35.4)	99.0 (98.8, 99.2)	68.4 (62.7, 74.0)	95.4 (95.1, 95.6)
Sex				
Male	53.8 (52.3, 55.3)	98.6 (98.5, 98.7)	79.3 (78.0, 80.7)	95.6 (95.5, 95.8)

Female	47.9 (46.4, 49.4)	98.7 (98.6, 98.8)	75.1 (73.6, 76.6)	95.9 (95.8, 96.0)
		Q4 (Jan 2021 – Mar 2021)		
Age Group				
<65	47.8 (46.7, 49.0)	97.8 (97.7, 97.9)	68.1 (66.9, 69.3)	95.1 (95.0, 95.2)
65-79	50.1 (47.0, 53.1)	98.4 (98.2, 98.6)	69.9 (66.8, 72.9)	96.3 (96.1, 96.5)
80+	37.1 (32.7, 41.5)	99.0 (98.8, 99.2)	68.8 (63.4, 74.1)	96.3 (96.1, 96.6)
Sex				
Male	48.4 (46.8, 49.9)	97.9 (97.8, 98.0)	69.9 (68.3, 71.4)	94.9 (94.8, 95.1)
Female	46.7 (45.2, 48.2)	98.1 (98.0, 98.2)	66.9 (65.3, 68.4)	95.7 (95.6, 95.8)

Abbreviations: PPV: Positive predictive value; NPV: Negative predictive value

Table S9. Overall validation estimates (95% confidence intervals) by age group, sex, and quarter (Q): outpatient cohort

	Sensitivity	Specificity	PPV	NPV
Q1 (Apr 2020 – Jun 2020)				
Age Group				
<65	26.0 (24.7, 27.3)	90.6 (90.4, 90.7)	7.0 (6.6, 7.3)	97.8 (97.8, 97.9)
65-79	13.0 (10.9, 15.1)	94.1 (93.9, 94.3)	4.3 (3.7, 5.0)	98.1 (98.1, 98.2)
80+	8.7 (7.3, 10.1)	96.4 (96.2, 96.6)	9.4 (8.0, 10.9)	96.1 (96.1, 96.2)
Sex				
Male	20.6 (19.2, 22.1)	91.6 (91.4, 91.8)	6.9 (6.4, 7.4)	97.5 (97.4, 97.5)
Female	20.1 (18.9, 21.3)	92.4 (92.3, 92.6)	6.7 (6.3, 7.1)	97.7 (97.7, 97.8)
Q2 (Jul 2020 – Sept 2020)				
Age Group				
<65	15.3 (14.3, 16.4)	92.9 (92.8, 93.0)	2.9 (2.7, 3.1)	98.7 (98.7, 98.8)
65-79	21.1 (17.0, 25.1)	96.6 (96.5, 96.8)	3.9 (3.2, 4.6)	99.5 (99.4, 99.5)
80+	5.0 (2.2, 7.8)	97.4 (97.2, 97.6)	1.5 (0.7, 2.4)	99.2 (99.2, 99.2)
Sex				
Male	14.6 (13.2, 16.0)	93.2 (93.1, 93.3)	3.1 (2.8, 3.4)	98.7 (98.7, 98.7)
Female	14.3 (13.0, 15.6)	93.9 (93.8, 94.0)	2.6 (2.3, 2.8)	99.0 (99.0, 99.0)
Q3 (Oct 2020 – Dec 2020)				
Age Group				
<65	23.5 (23.0, 23.9)	93.1 (93.0, 93.1)	20.5 (20.1, 20.8)	94.1 (94.1, 94.1)
65-79	26.5 (25.1, 27.9)	95.8 (95.7, 96.0)	25.9 (24.7, 27.1)	95.9 (95.9, 96.0)
80+	9.5 (8.4, 10.6)	96.9 (96.7, 97.1)	19.3 (17.3, 21.2)	93.2 (93.1, 93.3)
Sex				
Male	23.0 (22.4, 23.5)	92.9 (92.8, 93.0)	21.7 (21.2, 22.2)	93.4 (93.3, 93.4)

Female	20.8 (20.2, 21.3)	94.1 (94.0, 94.2)	19.1 (18.7, 19.6)	94.6 (94.6, 94.7)
		Q4 (Jan 2021 – Mar 2021)		
Age Group				
<65	25.9 (25.5, 26.4)	94.8 (94.7, 94.8)	31.9 (31.4, 32.3)	93.1 (93.1, 93.2)
65-79	33.9 (32.4, 35.3)	95.0 (94.9, 95.2)	26.7 (25.6, 27.7)	96.4 (96.3, 96.5)
80+	14.9 (13.4, 16.4)	94.3 (94.0, 94.5)	12.9 (11.7, 14.1)	95.1 (95.0, 95.2)
Sex				
Male	25.6 (25.0, 26.2)	94.4 (94.3, 94.5)	31.5 (30.9, 32.1)	92.6 (92.5, 92.7)
Female	24.4 (23.9, 25.0)	95.0 (94.9, 95.1)	27.2 (26.7, 27.7)	94.2 (94.2, 94.3)

Abbreviations: PPV: Positive predictive value; NPV: Negative predictive value

Table S10. Sensitivity analyses of validation estimates (95% confidence intervals) for the inpatient cohort: positive test no more than 7 days before hospital admission date or before discharge date

Measure	Q1 (Apr 2020 – Jun 2020)	Q2 (Jul 2020 – Sept 2020)	Q3 (Oct 2020 – Dec 2020)	Q4 (Jan 2021 – Mar 2021)
		British Columbia		
Sensitivity	97.3 (95.5,99.2)	95.7 (92.9, 98.6)	98.0 (97.2, 98.7)	95.3 (94.4, 96.2)
Specificity	97.1 (96.9, 97.4)	97.2 (97.0, 97.4)	97.9 (97.8, 98.1)	99.1 (99.1, 99.2)
PPV	33.3 (30.2, 36.5)	23.9 (20.9, 27.0)	67.1 (65.0, 69.1)	81.0 (79.4, 82.6)
NPV	99.9 (99.9, 100.0)	100.0 (99.9, 100.0)	99.9 (99.9, 99.9)	99.8 (99.8, 99.9)
		Manitoba		
Sensitivity	90.3 (79.9, 100)	80.4 (73.9, 86.9)	69.7 (67.5, 71.9)	60.2 (56.7, 63.7)
Specificity	99.6 (99.5, 99.8)	99.7 (99.5, 99.8)	98.7 (98.5, 98.9)	99.6 (99.5, 99.7)
PPV	53.9 (40.3, 67.4)	81.0 (74.5, 87.4)	88.0 (86.3, 89.7)	87.2 (84.3, 90.0)
NPV	99.9 (99.9, 100)	99.6 (99.5, 99.8)	95.9 (95.6, 96.2)	98.1 (97.9, 98.3)
		Ontario		
Sensitivity	88.3 (87.3, 89.3)	76.7 (74.2, 79.2)	68.7 (67.5, 69.8)	76.2 (75.5, 77.0)
Specificity	99.6 (99.6, 99.7)	99.9 (99.9, 99.9)	99.6 (99.6, 99.7)	99.4 (99.3, 99.4)
PPV	92.5 (91.7, 93.4)	89.6 (87.7, 91.5)	90.6 (89.8, 91.5)	90.2 (89.6, 90.8)
NPV	99.4 (99.4, 99.5)	99.8 (99.7, 99.8)	98.5 (98.4, 98.5)	98.2 (98.1, 98.3)
		All		
Sensitivity	88.9 (87.3, 90.5)	79.6 (76.0, 83.1)	73.3 (71.7, 74.8)	78.2 (77.0, 79.4)
Specificity	99.2 (99.1, 99.3)	99.5 (99.5, 99.6)	99.2 (99.2, 99.3)	99.3 (99.3, 99.4)
PPV	81.3 (79.5, 83.0)	62.3 (59.1, 65.5)	84.2 (82.9, 85.5)	88.3 (87.4, 89.2)
NPV	99.6 (99.5, 99.6)	99.8 (99.8, 99.8)	98.5 (98.5, 98.6)	98.6 (98.5, 98.7)

Abbreviations: Q: quarter; PV: Positive predictive value; NPV: Negative predictive value

Table S11. Sensitivity analyses of validation estimates (95% confidence intervals) for the inpatient cohort: positive test no more than 14 days before admission date or 14 days after admission date

Measure	Q1 (Apr 2020 – Jun 2020)	Q2 (Jul 2020 – Sept 2020)	Q3 (Oct 2020 – Dec 2020)	Q4 (Jan 2021 – Mar 2021)
			British Columbia	
Sensitivity	90.1 (86.9, 93.2)	65.2 (59.9, 70.6)	64.0 (62.1, 65.9)	63.8 (62.2, 65.4)
Specificity	97.7 (97.5, 97.9)	97.9 (97.7, 98.1)	98.9 (98.8, 99.0)	99.6 (99.6, 99.7)
PPV	35.5 (32.3, 38.7)	26.2 (23.1, 29.3)	77.2 (75.4, 79.0)	90.3 (89.1, 91.5)
NPV	99.9 (99.8, 99.9)	99.6 (99.5, 99.7)	98.0 (97.8, 98.1)	97.9 (97.8, 98.1)
			Manitoba	
Sensitivity	83.3 (66.1, 100)	71.1(62.1, 80.2)	69.0 (66.8, 71.2)	60.3 (56.9, 63.8)
Specificity	99.4 (99.2, 99.6)	99.1 (98.9, 99.3)	98.4 (98.2, 98.6)	99.6 (99.5, 99.7)
PPV	28.9 (16.5, 41.2)	48.6 (40.4, 56.8)	85.4 (83.5, 87.2)	87.7 (84.9, 90.5)
NPV	100.0 (99.9, 100)	99.6 (99.5, 99.8)	95.9 (95.6, 96.2)	98.1 (97.9, 98.3)
			Ontario	
Sensitivity	88.5 (87.5, 89.4)	76.4 (73.9, 78.9)	69.4 (68.3, 70.5)	76.5 (75.8, 77.3)
Specificity	99.7 (99.7, 99.8)	99.9 (99.9, 99.9)	99.8 (99.7, 99.8)	99.5 (99.4, 99.5)
PPV	94.0 (93.2, 94.7)	87.8 (85.7, 89.9)	93.7 (93.0, 94.4)	91.8 (91.2, 92.3)
NPV	99.4 (99.4, 99.5)	99.8 (99.7, 99.8)	98.5 (98.4, 98.5)	98.2 (98.1, 98.3)
			All	
Sensitivity	88.6 (86.9, 90.2)	73.8 (69.9, 77.6)	68.1 (66.5, 69.6)	72.9 (71.7, 74.1)
Specificity	99.3 (99.2, 99.4)	99.5 (99.4, 99.6)	99.5 (99.4, 99.5)	99.5 (99.5, 99.6)
PPV	82.6 (80.8, 84.3)	59.8 (56.6, 63.1)	88.1 (87.0, 89.3)	91.3 (90.5, 92.1)
NPV	99.6 (99.5, 99.6)	99.7 (99.7, 99.8)	98.2 (98.1, 98.2)	98.1 (98.0, 98.2)

Abbreviations: Q: quarter; PV: Positive predictive value; NPV: Negative predictive value

Table S12. Sensitivity analyses of validation estimates (95% confidence intervals) for the emergency department (ED) cohort: 5 days before or after specimen collection date

Measure	Q1 (Apr 2020 – Jun 2020)	Q2 (Jul 2020 – Sept 2020)	Q3 (Oct 2020 – Dec 2020)	Q4 (Jan 2021 – Mar 2021)
			British Columbia	
Sensitivity	54.5 (48.6, 60.3)	46.1 (42.6, 49.6)	36.3 (34.8, 37.8)	33.1 (31.6, 34.6)
Specificity	99.9 (99.8, 99.9)	99.8 (99.7, 99.8)	98.8 (98.7, 98.9)	98.7 (98.6, 98.8)
PPV	85.9 (80.7, 91.0)	86.0 (82.6, 89.3)	75.1 (73.2, 77.0)	71.4 (69.3, 73.5)
NPV	99.4 (99.3, 99.5)	98.6 (98.4, 98.7)	94.0 (93.8, 94.3)	93.8 (93.6, 94.1)
			Manitoba	
Sensitivity	10.0 (0.0, 23.1)	8.1 (3.9, 12.3)	15.5 (14.1, 17.0)	16.3 (14.0, 18.6)
Specificity	99.9 (99.9, 100.0)	99.9 (99. 8, 99.9)	98.2 (98.0, 98.4)	99.2 (99.1, 99.4)
PPV	22.2 (0.0, 49.4)	39.4 (22.7, 56.1)	57.3 (53.5, 61.1)	59.3 (53.5, 65.2)
NPV	99.8 (99.7, 99.9)	98.9 (98.7, 99.0)	88.3 (87.8, 88.8)	94.6 (94.2, 94.9)
			Ontario	
Sensitivity	63.1 (61.9, 64.3)	54.4 (52.7, 56.1)	61.1 (60.4, 61.7)	55.7 (55.0, 56.3)
Specificity	99.6 (99.5, 99.6)	99.9 (99.9, 99.9)	99.3 (99.3, 99.3)	98.6 (98.6, 98.7)
PPV	84.2 (83.2, 85.3)	86.5 (85.0, 88.0)	88.4 (87.9, 88.9)	80.1 (79.5, 80.8)
NPV	98.6 (98.6, 98.7)	99.4 (99.4, 99.5)	96.6 (96.6, 96.7)	95.7 (95.6, 95.8)
			All	
Sensitivity	62.6 (60.6, 64.6)	51.1 (48.5, 53.7)	53.4 (52.3, 54.4)	51.1 (50.1, 52.2)
Specificity	99.6 (99.6, 99.7)	99.9 (99.9, 99.9)	99.2 (99.1, 99.2)	98.7 (98.6, 98.7)
PPV	84.2 (82.5, 85.9)	85.8 (83.5, 88.1)	85.7 (84.8, 86.5)	79.0 (78.0, 79.9)
NPV	98.8 (98.7, 98.8)	99.3 (99.3, 99.4)	95.8 (95.7, 95.9)	95.4 (95.3, 95.5)

Abbreviations: Q: quarter; PV: Positive predictive value; NPV: Negative predictive value

Table S13. Sensitivity analyses of validation estimates (95% confidence intervals) for the outpatient cohort: 5 days before or after specimen collection date

Measure	Q1 (Apr 2020 – Jun 2020)	Q2 (Jul 2020 – Sept 2020)	Q3 (Oct 2020 – Dec 2020)	Q4 (Jan 2021 – Mar 2021)
		British Columbia		
Sensitivity	11.6 (9.9, 13.2)	6.6 (5.9, 7.2)	2.7 (2.5, 2.9)	2.7 (2.5, 2.9)
Specificity	88.5 (88.3, 88.7)	91.7 (91.6, 91.8)	96.9 (96.9, 97.0)	98.3 (98.2, 98.3)
PPV	1.2 (1.0, 1.4)	1.7 (1.5, 1.8)	6.4 (6.0, 6.8)	14.0 (13.3, 14.8)
NPV	98.8 (98.8, 98.9)	97.9 (97.8, 97.9)	92.7 (92.6, 92.7)	90.5 (90.4, 90.6)
		Manitoba		
Sensitivity	3.8 (0.0, 8.0)	5.1 (3.7, 6.5)	9.3 (8.8, 9.8)	10.2 (9.2, 11.3)
Specificity	99.5 (99.4, 99.5)	99.8 (99.8, 99.8)	97.2 (97.1, 97.3)	95.4 (95.2, 95.5)
PPV	1.8 (0.0, 3.7)	26.1 (19.7, 32.5)	27.5 (26.1, 29.0)	9.7 (8.7, 10.6)
NPV	99.8 (99.7, 99.8)	98.7 (98.6, 98.7)	90.3 (90.1, 90.4)	95.6 (95.5, 95.8)
		Ontario		
Sensitivity	30.0 (29.4, 30.6)	31.4 (30.5, 32.2)	41.3 (41.0, 41.6)	42.4 (42.1, 42.7)
Specificity	92.9 (92.8, 92.9)	93.9 (93.8, 93.9)	93.0 (92.9, 93.0)	94.4 (94.4, 94.5)
PPV	13.6 (13.3, 13.9)	5.8 (5.6, 6.0)	32.1 (31.8, 32.4)	41.5 (41.2, 41.8)
NPV	97.3 (97.2, 97.3)	99.1 (99.1, 99.2)	95.2 (95.1, 95.2)	94.6 (94.6, 94.6)
		All		
Sensitivity	28.7 (27.2, 28.9)	30.4 (29.0, 31.8)	37.7 (37.2, 38.2)	41.1 (40.6, 41.6)
Specificity	93.4 (93.3, 93.5)	94.4 (94.3, 94.5)	93.5 (93.4, 93.5)	94.6 (94.5, 94.7)
PPV	11.6 (10.6, 12.5)	6.4 (6.1, 6.7)	32.6 (32.3, 33.0)	41.0 (40.5, 41.4)
NPV	98.7 (94.7, 94.8)	99.1 (99.1, 99.1)	94.7 (94.7, 94.8)	94.6 (94.6, 94.7)

Abbreviations: Q: quarter; PV: Positive predictive value; NPV: Negative predictive value