Epidemic Curves and COVID-19: How to Reduce The Confusion

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Abstract

Introduction: Epidemic curves have played a central role in comparing COVID-19 burden and progression across cities, states, and countries.

Methods: We created a series of epidemic curves for Québec and Ontario, comparing and contrasting different COVID-19 outcomes.

Results: The different epidemic curves of COVID-19 revealed that crude incidence rates displayed larger differences between the two provinces compared to absolute counts. More notable differences between Ontario and Québec were demonstrated when comparing crude rates of hospitalizations to crude rates of confirmed cases in each province. Crude daily hospitalizations revealed twice the magnitude of hospitalizations for Québec from April to May when compared to Ontario.

Conclusions: We recommend using crude rates of hospitalizations, intensive care unit admissions, and mortality for COVID-19 epidemic curve comparison as they reveal important patterns in disease trends, and are more easily comparable between health jurisdictions. A harmonized approach to data presentation is important to not only accurately compare the progression of the pandemic, but also for interpretation of the media and the general public.

Background

In the current context of COVID-19, subnational and national epidemic curves are being compared to understand the progression of the pandemic and for site-specific interpretations. Epidemiologic curves are a common way of displaying outbreak or epidemic data, which have a long history in field epidemiology and in transmission disease modelling (1). An epidemic curve is a graphical representation of the incident cases of disease plotted according to time and provides insight into outbreak characteristics (2). Contextual factors such as screening strategies, diagnostic tests used, reporting practices, and case definitions influence what outcome measures and time units are depicted, making comparison across countries and regions challenging in the context of a pandemic (3).

Various types of COVID-19 epidemic curves have been presented in the literature and by public health authorities, the most common being that of incident cases or cumulative incident cases plotted against the date of symptom onset or date of report (4–6). Other outcomes depicted on COVID-19 epidemic curves include absolute and relative frequencies of confirmation tests, hospitalizations, and deaths (7). Here we compared and contrasted different COVID-19 epidemic curves for Québec and Ontario, the two most populated and COVID-19 affected provinces in Canada, and discussed the associated strengths and weaknesses of the different approaches.

Methods

A series of epidemic curves were created based on laboratory confirmed cases of COVID-19, test runs, hospitalizations, and mortality. Data were obtained from the Institut national de santé publique du Québec and Public Health Ontario websites (7, 8). Date of notification for confirmed cases was used as symptom onset date was not available for Québec. Hospitalizations included in this article are new hospitalizations and it should be noted that Québec uses the date of death notification whereas Ontario uses the date of death. We also calculated the crude rate of the different outcomes per 100,000 population, the proportion of positive tests, and the crude testing rate per 100,000 population. Finally, 7-day moving averages were calculated for daily mortality. We discussed the strengths and weaknesses of each approach and recommend the best strategy for consistent comparisons of epidemic curves across jurisdictions.

Results

Cumulative and incident cases

Cumulative cases are a sum of incident cases over time and provides historic information as well as the number of cases reported each day (Fig. 1A). This format can obscure shorter-term trends, especially as the y-axis maximum increases with the cumulative number of cases reported (9). For example, the jump in cases for Québec on 23 March 2020 (associated with an increase in testing) is no longer apparent in the epidemic curve but would have been in earlier epidemic curves. Daily incident cases is a preferable format to depict daily changes in cases (Fig. 1B). The use of symptom onset date is a more accurate measure in terms of epidemic progression with respect to time as the date of notification results in a time lag that needs to be considered when interpreting any epidemic curve. An important limitation of incident or cumulative confirmed cases is that they are largely influenced by testing capacity and variation in the definition of confirmed cases and screening strategy by jurisdiction, which continues to evolve over time (Additional File 1). Furthermore, absolute values should not be compared across jurisdictions given population size differences.

Crude incidence rate

This relative frequency measure improves comparability between jurisdictions by dividing the absolute number of incident cases by the population size corresponding to the numerator, such as the general population or a more specific at-risk population (e.g., cruise ship population). The crude incidence rate reveals larger differences between Québec and Ontario from mid-March to the end of May, compared to what the cumulative and daily incident curves were suggesting (Fig. 1B). One limitation of this approach is that the intensity of screening may not be proportional to population size. If, for example, a jurisdiction of 10,000 inhabitants tests 10 times more than a jurisdiction of 100,000, the resulting number of cases will be the same at equal prevalence levels, but the crude incidence rate per 100,000 will be 10 times larger in the smaller jurisdiction.

Crude testing rate and test positivity rate

A potential solution to support the interpretation of confirmed cases is the number of COVID-19 tests administered. This is an important marker of the availability of testing in a given area as areas with a higher availability of testing are likely to find more confirmed cases (10). The daily crude testing rate per 100,000 population for Ontario has drastically increased since the beginning of testing and in June, Ontario surpassed Québec in its crude testing rate (Fig. 1C). The daily test positivity ratio (TPR) informs us as to what proportion of the population tested is positive. From 8 June 2020 to 8 July 2020, the TPR for Ontario and Québec averaged 0.8% and 1.3% respectively, down from 1.6% and 4.3% just a month earlier. The TPR provides insight into the magnitude of COVID-19 in a community but is entirely dependent on who is eligible for testing. Furthermore, nasopharyngeal specimens are not always sampled correctly, which can lead to false negative results that can vary between sites (11). There will be more false positive tests as the frequency of the infection decreases, which also complicates the interpretation of this measure.

Hospitalizations and mortality rates

Hospitalizations and intensive care unit (ICU) admissions, as well as mortality are believed to be more reliable indicators to assess COVID-19 burden as they rely less on testing strategy and capacity, and provide measures of epidemic severity (12). Hospitalizations are new inpatient admissions presenting with less severe disease than those admitted to the ICU, which are excluded from this measure. As with incident cases, reporting the relative frequency of daily incident hospitalizations per 100,000 is preferable. Differences in hospital admission protocols, hospital capacities, and approaches for classifying COVID-19 mortality will result in jurisdictional differences in hospitalizations and COVID-19 mortality. The crude daily hospitalization rate shows a relatively stable trend for Ontario with a downward trend beginning in June, whereas for Québec, twice the magnitude of hospitalizations was experienced from April to May, followed by a downward trend similar to Ontario (Fig. 2A). The crude daily ICU admission rate shows again the differences between Québec and Ontario, with Ontario marginally surpassing Québec at the beginning of June although it is more difficult to interpret given the daily fluctuations (Fig. 2B). A moving 7-day average can be useful for such fluctuations, highlighting daily trends while filtering out the noise of daily data. The moving 7-day average highlights the timing of the mortality peaks, with Ontario's occurring slightly before Québec at end of April (Fig. 2C). The magnitude of difference in the crude mortality rate between Québec and Ontario from April to May is particularly striking (Fig. 2D). Having age group specific hospitalizations and mortality would be particularly insightful given the large number of outbreaks reported among nursing and retirement homes - information that is not publicly available for Ontario or Québec.

Discussion

There are several challenges when comparing epidemic curves across jurisdictions that need careful consideration including testing capacity, COVID-19 case and death definitions, reporting delay and underreporting, and demographic differences of the underlying populations. Our recommendations are to use crude rates of hospitalizations, ICU admissions, and mortality. If comparing confirmed cases, the

measure should be presented as a daily crude rate and include the crude testing rate to assist with interpretation.

Conclusions

The different outcomes used when comparing epidemic curves between Ontario and Quebec influenced the interpretation of the COVID-19 situation. It is inevitable that comparisons will be made and indeed, a harmonized approach to core epidemic curve outcomes would be valuable to reduce the confusion in what is being represented and consequently, interpreted by public health officials, the media, and the public. Improving the consistency and clarity will also increase trust between health organizations and the public.

Declarations

Kate Zinszer acknowledges the support of the Fonds de la recherche en santé du Québec (FRQS) as a FRQS Junior 1 Scholar. All data used in this analysis are publicly available through government websites, and therefore, no ethics approval was required for this study.

Authors of this study have no competing interests to declare. Kate Zinszer conceived of the presented idea. Katarina Ost performed the background and literature review, in addition to researching and collecting data sources for the analysis. Mengru Yuan performed analysis of the data with supervision from Kate Zinszer. Helene Carabin contributed to verifying the analysis and presentation of scientific literature findings in the context of the manuscript. All authors discussed the results and contributed to the writing and editing of the final manuscript.

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Figures

Figure 1

Epidemic curves of COVID-19 for Québec and Ontario for a) daily cumulative laboratory-confirmed COVID-19 cases by date of notification; b) daily incident laboratory-confirmed COVID-19 cases and crude incidence rate of laboratory confirmed COVID-19 cases per 100,000 population (line) by date of notification; c) crude daily testing rate of COVID-19 per 100,000 and daily proportion of test positivity of COVID-19 (line) by date of notification. COVID-19 confirmed case data prior to 27 March 2020 was not

available for Québec nor for Ontario prior to 21 January 2020. COVID-19 testing data prior to 12 April 2020 was not available for Ontario and nor for Québec prior to 8 March 2020.

Figure 2

Epidemic curves of COVID-19 for Québec and Ontario for a) daily COVID-19 hospitalizations and crude daily COVID-19 hospitalization rate per 100,000 (line) by date of hospitalization; b) daily COVID-19 ICU admissions and crude daily COVID-19 ICU admission rate 100,000 (line) by date of hospitalization; c)

daily COVID-19 mortality by date of notification with a 7-day average of daily COVID-19 mortality (line). d) daily COVID-19 mortality and crude daily COVID-19 mortality rate per 100,000 (line) by date of notification. COVID-19 hospitalization and ICU admissions data prior to 6 April 2020 was not available for Québec and nor for Ontario prior to 29 March 2020. COVID-19 mortality data was not available prior to 18 March 2020 for Québec and nor for Ontario prior to 2 March 2020.

Supplementary Files

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- [AdditionalFile1.docx](#)