Public Health Ontario | Santé publique Ontario

EVIDENCE BRIEF

What Does it Mean for COVID-19 to be 'Endemic' and When Will We Get There?

December, 2021

Key Messages

- Several factors support the likelihood of Coronavirus Disease 2019 (COVID-19) becoming endemic rather than eradicated, including high transmissibility of severe acute respiratory coronavirus 2 (SARS-CoV-2), the trajectory of other coronaviruses, existing animal reservoirs, evidence of waning immunity and breakthrough infections, low and uneven vaccine coverage, a lack of global coordination of disease elimination measures, the inability of existing vaccines to eliminate the risk of infection and onward transmission, and the ability of SARS-CoV-2 to mutate and escape existing immunity.

- Modelling studies suggest that COVID-19 will become endemic, and that the transition to endemicity will be characterized by 'waves' of cases, where subsequent waves will have progressively smaller peaks. It is also suggested that once endemicity has been reached, COVID-19 could become less virulent, with infections becoming less severe.

- The publications reviewed all emphasize the importance of maintaining high levels of population immunity for a lower risk transition to and maintenance of endemic COVID-19. However, the duration of immunity and optimal booster dose programming (i.e., who and when), is not well understood yet. In addition, in the endemic context, correlates of immunity will need to be monitored to detect waning, but validated and widely available tests also do not yet exist.

- Along with population immunity, virus evolution is another determinant of the transition to and maintenance of endemicity; however, it is unknown if and when a SARS-CoV-2 variant with significant immune escape will emerge.

- Public health measures remain important in the transition to endemic COVID-19. Gradual lifting of measures allows time to observe the epidemiological trends after changes in measures, so the data can inform subsequent policy changes to remaining public health measures. A gradual lifting of measures can also mitigate the risk of surges in cases, hospitalizations, and deaths.

Issue and Research Question

The (COVID-19) pandemic has been reported to be the health crisis of our lifetime[1] and is responsible for taking the lives of millions of people globally.[2] Since the start of the pandemic, SARS-CoV-2 has evolved, resulting in new variants with higher disease severity and transmissibility (i.e., higher viral load and shorter incubation period) compared with previous SARS-CoV-2 strains, after controlling for other variables.[3] Currently, the Delta variant (B.1.617.2, first identified in India) remains the dominant variant of concern

(VOC) in Ontario.[4] The introduction of vaccines has helped to reduce the impact of COVID-19 by protecting people against severe disease and death. The evidence indicates that it is not possible to reach elimination; therefore, it is important to consider the public health implications of global endemicity.[1]

Broadly, an endemic disease refers to a disease that is consistently present in a population within a limited geographical area and is characterized by a dramatic reduction in the prevalence of infection compared to the epidemic phase.[5,6] The pathogen may occasionally cause outbreaks or seasonal epidemics, but the disease burden is manageable for the healthcare system (e.g., seasonal influenza).[7] Reaching an endemic state depends on factors such as the pathogen's basic reproduction number (R_0), the extent of vaccination or natural immunity against the infection, and how fast immunity wanes.[8] The endemic equilibrium (a term used in modelling studies that denotes the endemic phase) is obtained when R_0 is less than or equal to one.[8] Previous infectious diseases that were once considered pandemic, transitioned to become endemic, such as influenza and the common cold.[9] It has been described that, similar to these other endemic diseases, COVID-19 will become endemic.[9,10] However, because cases are still increasing in some jurisdictions and there are still a large number of susceptible individuals, the current COVID-19 context is still considered pandemic.[7,11]

As the world approaches the second year since the COVID-19 pandemic was declared,[12] some jurisdictions are beginning to use the word 'endemic' when referring to COVID-19.[13,14] However, a consensus definition for how endemic COVID-19 is defined (e.g., thresholds for vaccination coverage, COVID-19 hospitalization rate, etc.) and what public health measures look like in the transition to and in the endemic phase (e.g., what long-term public health measures, if any, should remain), does not yet exist.[14] This evidence brief describes the literature for why COVID-19 is likely to become endemic, what endemic COVID-19 might look like in terms of epidemiology, and some considerations for the transition to and maintenance of endemic COVID-19 (e.g., public health measures, surveillance etc.).

Methods

A literature search was conducted in November 2021 by Public Health Ontario (PHO) Library Services to find articles that address endemic COVID-19. The search involved one database (Ovid MEDLINE) and preprints. Search terms included, but were not limited to: modelling and COVID-19. The full search strategy is available upon request. Three additional papers were identified by subject matter experts.

Articles were eligible for inclusion if they discussed: epidemiological modelling in the context of COVID-19, thresholds (e.g., vaccine coverage, vaccine effectiveness, hospitalization rate) in order to have an endemic state, goals for endemic COVID-19, or what public health efforts look like in the context of endemic COVID-19. Articles were excluded if they parameterized or fitted models using mostly data from before March 1, 2021, in order to limit studies to the context of the Delta variant, vaccination, and waning immunity. Studies using data from low-middle income countries were also excluded because they may not be as relevant to the Ontario context (e.g., differences in vaccine coverage and history of infections).

The titles and abstracts of all library search results were screened by one reviewer and 20% of results were screened independently by two reviewers, with any discrepancies resolved through discussion. Full texts of eligible titles and abstracts were retrieved and screened for eligibility by one reviewer. Consensus on included studies was achieved through discussion. A quality assessment tool was not used; however, quality of included studies and relevance to the Ontario context was assessed by subject matter experts.

Main Findings

Literature Search

A total of 711 records were retrieved from library searches, from which 131 articles were included for full-text review after title and abstract screening. Three additional articles were provided by subject matter experts. Nine articles met the inclusion criteria and are included in this evidence brief.

Why COVID-19 Is Likely To Become Endemic?

An infectious disease that is in an epidemic state will naturally transition to either an endemic state or eradication. This transition occurs because a virus runs out of susceptible individuals, causing the reproduction number to fall and an observed decrease in prevalence of infection to occur.[8] It is not yet clear whether the COVID-19 pandemic will become endemic or eradicated. Across the studies, reviews and commentaries described here, it was consistently reported that COVID-19 would reach endemicity.[7,8,11,15-19] One of the publications reported the results of a survey that asked more than 100 immunologists, infectious disease researchers and virologists currently studying COVID-19 whether it could be eradicated.[11] Of the respondents, 89% said COVID-19 would likely or very likely become endemic.[11]

Key factors that make endemic COVID-19 likely include the following: current vaccines do not eliminate the risk of infection, immunity (both vaccine-induced and from infection) to SARS-CoV-2 wanes,[8,11,15] high transmissibility of SARS-CoV-2 (specifically the Delta variant),[16,17] current vaccines only decrease viral shedding and do not block transmission,[7,15,19] vaccine coverage has not reached the very high levels necessary to control case growth in the Delta context (nor is it expected to reach this level due to vaccine uptake),[7,8] lack of global coordination of disease elimination measures,[7] existing animal reservoirs,[18] and lastly, the virus could evolve to escape existing immunity.[7,11] SARS-CoV-2 also shares some characteristics of other coronaviruses that evolved to become endemic, suggesting that SARS-CoV-2 could as well.[15]

What does endemic COVID-19 look like?

Four of the included studies used modelling as a means to better understand the trajectory of COVID-19 in reaching both disease-free equilibrium and endemic equilibrium.[15-17,20] Though the specific parameters and measures varied across the studies, the studies used either the susceptible-infected-recovered (SIR) model, deterministic age-structured model, or simple ordinary equation model. The findings suggest that it could take years or possibly decades to reach endemic COVID-19,[11,16] and it depends on how quickly populations develop immunity.[11] Study models predict that the transition to endemic COVID-19 will be characterized by waves,[17,20] where a period of increased incidence of COVID-19 infections will occur every one to three years,[16] mostly a result of seasonality[8] or new variants.[7] It is predicted that the subsequent waves will have progressively smaller peaks.[16] One study used data and models for England to project the dynamics of COVID-19 over a two-year time-frame.[20] The model predicted that without boosters, there will be another wave in England in early 2022 that will surpass their January 2021 second wave.[20] Several studies suggested that once endemicity has been reached, COVID-19 will become less virulent, with infections becoming less severe.[7,8,15,19] This decreased severity is assumed partly due to the fact that new infections will occur in children, who experience less severe infection, and re-infection will occur in individuals who have some protection from natural and vaccine-induced immunity.[8]

The commentaries and reviews described here reference other coronaviruses as a possible way to predict the future of the COVID-19 pandemic.[7,11,15,18,19] However, deferring to the trajectory of other

coronaviruses is complicated by the fact that SARS-CoV-2 has a unique combination of characteristics not seen in other coronaviruses, such as high virulence and asymptomatic transmission.[8]

What is the role of public health measures in the transition to and during endemic COVID-19?

One of the studies reviewed created a model that considered the following parameters: reduced public health restrictions for individuals with immunity certificates; imperfect vaccine effectiveness; rates of (re-)vaccination and waning immunity; fraction of never-vaccinated individuals; and, the increased transmissibility of the Delta variant.[17] The authors reported unfavourable epidemic dynamics for a wide range of scenarios. The authors found that compared to the Alpha variant (B.1.1.7, first detected in the United Kingdom), the Delta variant has considerably narrower options for reducing public health measures for people with immunity certificates without increasing cases (owing to increased transmissibility and reduced vaccine effectiveness). Therefore, immunity certificates alone are likely insufficient in the transition to endemic COVID-19.[17]

A review of vaccine-driven COVID-19 pandemic exit strategies explored if significant public health measures would still be needed after high vaccination coverage.[7] Based on an estimated reproduction number of 4.5 to 6 for the Delta variant, and roughly 80% vaccine effectiveness, the authors concluded that vaccination alone is insufficient for a safe transition from pandemic to endemic COVID-19; a minimum of public health measures are needed to prevent overburdened healthcare systems and excess morbidity and mortality.[7] A similar finding was reported by another study that stated that public health measures are equally as important as vaccines for the control of COVID-19.[16] The authors conclude that in the endemic state, most public health measures could be lifted; but only after high vaccination coverage is reached, otherwise there can be runaway outbreaks.[7]

In terms of how to go about relaxing public health measures, a "calibrated transition approach" has been suggested.[7] This would maintain public health measures in general, with relaxed measures only for vaccinated individuals (i.e., use of immunity certificates), until a target vaccination level is reached, at which point most measures can be gradually relaxed. The gradual relaxing of measures is described as key because potential variants present a high risk unknown, and time is needed to observe the epidemiological trends following the lifting of any public health measures so that the data can inform policy changes to the remaining measures.[7] Gradual lifting of measures also minimizes the risk of surges in cases, hospitalizations, and deaths. One of the reviews proposed three domains for public health measures: border controls, case-based non-pharmaceutical interventions (public health measures), and community-based public health measures. These domains were calibrated across three states: the pandemic state, transition state, and endemic state.[7] In the transition state, the authors state that measures should suppress transmission while ramping up vaccine coverage. Border measures and contact tracing and testing are important and can be enhanced to rapidly identify and isolate cases. Community-based public health measures could gradually be lifted as vaccine coverage increases, in particular for vaccinated individuals in low-risk settings.

How vaccines and immunity impact the transition to endemic COVID-19?

Immunity, either natural or vaccine-induced, can promote endemicity in a population by decreasing the probability of immune individuals becoming infected, decreasing the transmission of the virus (and therefore protecting those not immune), and decreasing the severity of infection.[8] COVID-19 vaccines have been shown to not only provide protection from severe disease, but may limit transmission of COVID-19 in the event of a breakthrough infection.[8] As such, maintaining high levels of population immunity through COVID-19 vaccination is critical for a lower risk transition to and maintenance of

endemicity.[7,16,19] One study suggested that a higher target vaccination coverage is needed in vulnerable populations, beyond the overall population coverage.[7]

Models predicting the future of COVID-19 are complicated by the unknowns of the current vaccines and differences in vaccine programs across jurisdictions. For example, the effect of vaccination after infection compared to no previous infection, or the rate of waning immunity from infection compared to vaccination, may result in different levels of protection for different amounts of time. One study assumed uniform vaccine effectiveness across populations in their modelling, but noted this as a limitation since evidence shows that different vaccine technologies, different dosing schedules, and age of recipients, can impact vaccine effectiveness.[15] Nevertheless, overall, the literature included in this review concluded that the maintenance of immunity is critical to keeping cases low in the endemic context.[7,8,11,15-19]

There is evidence that mild or asymptomatic COVID-19 infection results in more rapid waning of immunity than symptomatic disease.[19] The study that used data and models for England to project the dynamics of COVID-19 over a two-year time-frame found that if boosters offer high and long-lasting effectiveness, they may help in the transition to endemicity by pushing the 'waves' of higher prevalence to be later and smaller.[20] Further, boosters may be required in the context of endemic COVID if virulent cases continue to persist[7,15] and due to waning.[17] However, if less virulent cases of infection ensue or there is sufficient cross-reactive immunity boosted by regular natural infections, then boosters may not be required.[15,19]

What is the role of age in the transition to endemic COVID-19?

When COVID-19 becomes endemic, it is possible new infections will predominantly occur in children (usually before the age of six) who are not yet vaccinated, since adults will already have vaccine-induced or natural immunity against infection.[11,15] It was further suggested that because COVID-19 is mild in younger individuals,[8,11,15] it is expected that the course of infection in the endemic phase will be mildly symptomatic since children can help mitigate disease severity.[15] It was also suggested that if booster immunity is long lasting in the younger population, it would push new waves of infection to be later and smaller.[20]

Surveillance

Across the literature reviewed, there was consensus that maintaining high levels of immunity is critical for the transition to and maintenance of endemic COVID-19.[7,8,11,15-19] This requires an appropriate surveillance system to identify cases and monitor immunity. In transitioning to endemicity, as public health measures are lifted, the resulting infections and disease can be monitored to ensure the data are consistent with the expected trends and remain manageable for the health system.[7] Surveillance systems will need to be equipped to identify asymptomatic cases, which can result in the spread of COVID-19 and even impair outbreak recognition. Monitoring the severity of breakthrough infections can help to determine if SARS-CoV-2, like other pathogens that have become endemic, will become avirulent as the population becomes more immune.[15] Data accounting for age, infection severity, vaccination history, and prior infection history (potentially including other viruses) can help detect attenuation of SAR-CoV-2 over time, which would suggest it is becoming endemic. In contrast, SARS-CoV-2 could acquire sufficient mutations to result in a new epidemic or pandemic patterns, which also requires effective surveillance.[18]

Discussion and Conclusions

Several studies describe that COVID-19 will become endemic for several reasons, including: current vaccines do not eliminate the risk of infection, immunity (both from vaccine or infection) to SARS-CoV-2 wanes,[8,11,15] high transmissibility of SARS-CoV-2 (specifically the Delta variant),[16,17] current vaccines only decrease viral shedding and do not block transmission,[7,15,19] vaccine coverage has not reached the approximately 95% threshold necessary for eradication in the Delta context (nor is it expected to reach this level due to vaccine upake), [7,8,21] lack of global coordination of disease elimination measures,[7] existing animal reservoirs,[18] the ability of the virus to evolve to escape existing immunity,[7,11] and lastly, SARS-CoV-2 shares some characteristics of other coronaviruses that evolved to become endemic, suggesting that SARS-CoV-2 could follow a similar trajectory.[15]

Maintaining high levels of population immunity is critical to a low risk transition to endemic COVID-19 and maintaining endemic equilibrium; however, the data on waning of booster-induced immunity does not exist yet, nor is there validated and operationalized testing and screening for correlates of immunity to detect possible waning. In theory, susceptibility to infection will wane faster than pathology and infectiousness.[8] This is based on the evidence that COVID-19 reinfections do occur, but the disease is milder than a primary infection, suggesting infection-blocking immunity wanes faster than disease-reducing immunity.[8] The safe transition from pandemic COVID-19 to endemic COVID-19 and maintaining endemic equilibrium is further threatened by SARS-CoV-2 evolution and the possibility of a variant with significant immune escape. Judicious use of public health measures such as masking and immunity certificates could reduce the risk while transitioning to endemic COVID-19, along with pandemic preparedness plans informed by the COVID-19 pandemic experience.

COVID-19 models can help inform the transition out of pandemic COVID-19, but the relevance, reliability, and validity of a model is dependent on the data used to parameterize and test the model. For example, studies may be fitted with data based on different vaccine technologies, which have different vaccine effectiveness and different rates of waning. Differences in vaccines may account for some of the variability in the models described here, and also means that models could be less accurate for some settings. Modelling studies are also limited in their ability to accurately predict social behaviours in the context of COVID-19 because past and future behaviours are not only based on the public health measures in place, but also perceived risk and therefore willingness to adhere to public health measures,[22] which changes over time. Even assuming a rigorous model that provides estimates for cases, hospitalizations etc. for endemicity, it is up to a society to agree on whether the outcomes of these thresholds are acceptable.[14] For example, the burden of disease from influenza is estimated to be 291,243 to 645,832 global deaths annually.[23] Societal values and priorities also influence the level of risk that is acceptable with respect to unknowns such as any long-terms effects of COVID-19 infection and duration and severity of long COVID across age groups, which includes children, for whom risk thresholds may be lower.[24]

A number of pieces of evidence and considerations have emerged since the publication of the studies, reviews, and commentaries described here. For example, COVID-19 vaccines are being rolled out for 5-11 year olds. It remains unknown what level of vaccination coverage will be achieved in this age group, what the real world vaccine effectiveness will be, the rate of waning, and what breakthrough infections will look like in terms of onward transmission and disease severity. Treatments for COVID-19 are also advancing,[7,16,25,26] which could impact the immunity thresholds or mortality risk at endemic equilibrium. Although modelling studies that used data from before March 2021 was an exclusion criteria, it is possible some models were parameterized or informed by evidence from the pre-Delta COVID-19 pandemic. Fitting models with local, current data would be most relevant.

There remain several unknowns about SARS-CoV-2. For example, as more of the world develops immunity, is SARS-CoV-2 evolution slowing down or accelerating? How long does the protection against severe COVID-19 disease last? If immunity against severe infection is lifelong, morbidity and mortality rates could be lower in the endemic phase. It is possible that COVID-19 will exhibit seasonality, and cases will start to cluster in time and in a predictable way. The apparent lack of seasonal pattern to date might simply reflect the impact of lifting and implementing public health measures at different times in different jurisdictions. Seasonality of COVID-19 could benefit preventive efforts due to predictability.

Implications for Practice

- Vaccination has been shown to provide better immune protection than natural infection, and in an endemic context, circulating SARS-CoV-2 may or may not be sufficient to maintain levels of immunity in the population. Mass vaccination clinics may be most effective at preventing further destabilization of the pandemic and easing the transition to endemicity.[27] Improving vaccine coverage is critical to reaching endemicity.

- It has been estimated that assuming a vaccine effectiveness of 87% against Delta and a reproduction number of 6.3, the critical vaccination threshold is 96.7% of the total population.[21] No country has achieved this level of vaccination to provide an example, and due to contraindications, vaccine uptake, and no authorized vaccine for individuals four years old and under, achieving this vaccination threshold is impossible. A review of vaccine-driven COVID-19 exit strategies therefore concluded that vaccination targets should be set to levels whereby the resulting disease burden is manageable for a country's healthcare system in the setting of minimum public health measures.[7]

- No model can accurately predict how SARS-CoV-2 might mutate and the resulting impact on transmissibility and disease severity.[18] The possibility of recombination events between SARS-CoV-2 and other coronaviruses is another possibility that makes this prediction challenging as there is limited or no evidence to inform such a parameter. Such recombination events can also occur in animal reservoirs. The possibility of a variant with significant immune escape will persist when SARS-CoV-2 becomes endemic,[28] and could present as a novel pathogen, at least to population immunity.[7] Strong pandemic preparedness (e.g., public health incident response plans, domestic vaccine manufacturing) can reduce the risk in the transition from pandemic COVID-19 to endemic COVID-19 and its maintenance.

- Some infectious diseases, in particular respiratory infections, decreased in prevalence during the pandemic. This could be due to COVID-19-related public health measures, as well as under-diagnosis or under-reporting of infections. As a result, SARS-CoV-2 co-infections are not well understood and could increase the risk during the transition to endemicity, which will likely involve the lifting of public health measures,[18] which were preventing transmission of non-COVID-19 infections. The unusually high respiratory syncytial virus (RSV) cases in the US this past summer is an example of this scenario.[29] The potential complexity of COVID-19 co-infections and surges in other communicable diseases would put further strain on public health, the health system, and health care workers. Public health, health system, and health care worker recovery supports could ease the transition to endemic COVID-19 and ensure capacity to address further COVID-19 challenges.

References

1. Stoddard M, Sarkar S, Nolan RP, White DE, White L, Hochberg NS, et al. Beyond the new normal: assessing the feasibility of vaccine-based elimination of SARS-CoV-2. medRxiv 20240309 [Preprint]. 2021 Jan 29 [cited 2021 Dec 03]. Available from: https://doi.org/10.1101/2021.01.27.20240309

2. Mole B. More than 5 million people have died of COVID-19 worldwide. Ars Technica [Internet], 2021 Nov 01 [cited 2021 Nov 16]; Science. Available from: https://arstechnica.com/science/2021/11/more-than-5-million-people-have-died-of-covid-19-worldwide/

3. Ontario Agency for Health Protection and Promotion (Public Health Ontario). COVID-19 Delta: risk assessment and implications for practice (September 20, 2021 Update) [Internet]. Toronto, ON: Queen's Printer for Ontario; 2021 [cited 2021 Nov 19]. Available from: https://www.publichealthontario.ca/-/media/documents/ncov/voc/2021/10/covid-19-delta-variant-risk-assessment-update.pdf?sc_lang=en

4. Ontario Agency for Health Protection and Promotion (Public Health Ontario). SARS-CoV-2 whole genome sequencing in Ontario, October 12, 2021 [Internet]. Toronto, ON: Queen's Printer for Ontario; 2021 [cited 2021 Nov 19]. Available from: https://www.publichealthontario.ca/-/media/documents/ncov/epi/covid-19-sars-cov2-whole-genome-sequencing-epi-summary.pdf?sc_lang=en

5. US Centers for Disease Control and Prevention. Principles of epidemiology in public health practice, third edition: an introduction to applied epidemiology and biostatistics, Lesson 1: introduction to epidemiology [Internet]. Atlanta, GA: US Centers for Disease Control and Prevention; 2012 [cited 2021 Nov 19]. Available from: https://www.cdc.gov/csels/dsepd/ss1978/lesson1/section11.html

6. US Centers for Disease Control and Prevention. Principles of epidemiology in public health practice, third edition: an introduction to applied epidemiology and biostatistics, glossary [Internet]. Atlanta, GA: US Centers for Disease Control and Prevention; 2012 [cited 2021 Nov 19]. Available from: https://www.cdc.gov/csels/dsepd/ss1978/glossary.html

7. Wei WE, Tan WK, Cook AR, Hsu LY, Teo YY, Lee VJM. Living with COVID-19: the road ahead. Ann Acad Med Singapore. 2021;50(8):619-28. Available from: https://dx.doi.org/10.47102/annals-acadmedsg.2021244

8. Antia R, Halloran ME. Transition to endemicity: understanding COVID-19. Immunity. 2021;54(10):2172-6. Available from: https://dx.doi.org/10.1016/j.immuni.2021.09.019

9. Stieg C. Experts say Covid could become endemic — here's what that means for you. CNBC [Internet], 2021 Feb 27 [cited 2021 Nov 15]; Health and Wellness. Available from: https://www.cnbc.com/2021/02/27/what-if-covid-becomes-endemic.html

10. Phillips N. The coronavirus is here to stay — here's what that means. Nature [Internet], 2021 Feb 16 [cited 2021 Nov 16]; News Feature. Available from: https://www.nature.com/articles/d41586-021-00396-2

11. Phillips N. The coronavirus is here to stay - here's what that means. Nature. 2021;590(7846):382-4. Available from: https://dx.doi.org/10.1038/d41586-021-00396-2

12. World Health Organization. WHO Director-General's opening remarks at the media briefing on COVID-19 - 11 March 2020 [Internet]. Geneva: World Health Organization; 2021 [cited 2021 Nov 15]. Available from: https://www.who.int/director-general/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---11-march-2020

13. World Economic Forum. COVID-19 will likely shift from pandemic to endemic — but what does that mean? World Economic Forum [Internet], 2021 Sep 23 [cited 2021 Nov 16]. Available from: https://www.weforum.org/agenda/2021/09/covid-pandemic-epidemic-disease-coronavirus/

14. Zhang S. America has lost the plot on COVID. The Atlantic [Internet], 2021 Nov 01 [cited 2021 Nov 16]; Health. Available from: https://www.theatlantic.com/health/archive/2021/11/what-americas-covid-goal-now/620572/

15. Beams AB, Bateman R, Adler FR. Will SARS-CoV-2 become just another seasonal coronavirus? Viruses. 2021;13(5):07. Available from: https://dx.doi.org/10.3390/v13050854

16. Dagpunar J, Wu C. A prototype vaccination model for endemic Covid-19 under waning immunity and imperfect vaccine take-up. medRxiv 21266002 [Preprint]. 2021 Nov 11 [cited 2021 Nov 15]. Available from: https://doi.org/10.1101/2021.11.06.21266002

17. Krueger T, Gogolewski K, Bodych M. Assessing the risk of COVID-19 epidemic resurgence in relation to the delta variant and to vaccination passes. medRxiv 21256847 [Preprint]. 2021 Jul 18 [cited 2021 Dec 03]. Available from: https://doi.org/10.1101/2021.05.07.21256847

18. Telenti A, Arvin A, Corey L, Corti D, Diamond MS, Garcia-Sastre A, et al. After the pandemic: perspectives on the future trajectory of COVID-19. Nature. 2021;596(7873):495-504. Available from: https://dx.doi.org/10.1038/s41586-021-03792-w

19. Veldhoen M, Simas JP. Endemic SARS-CoV-2 will maintain post-pandemic immunity. Nature Rev Immunol. 2021;21(3):131-2. Available from: https://dx.doi.org/10.1038/s41577-020-00493-9

20. Keeling MJ, Thomas A, Hill EM, Thompson RN, Dyson L, Tildesley MJ, et al. Waning, boosting and a path to endemicity for SARS-CoV-2. medRxiv 21265977 [Preprint]. 2021 Nov 10 [cited 2021 Dec 03]. Available from: https://doi.org/10.1101/2021.11.05.21265977

21. Ontario Agency for Health Protection and Promotion (Public Health Ontario). PHMT updates on Delta and Lambda (presentation). Presented on July 12, 2021 (unpublished). In press.

22. Gweryina RI, Madubueze CE, Kaduna FS. Mathematical assessment of the role of denial on COVID-19 transmission with non-linear incidence and treatment functions. Sci Afr. 2021;12:e00811. Available from: https://doi.org/10.1016/j.sciaf.2021.e00811

23. Iuliano AD, Roguski KM, Chang HH, Muscatello DJ, Palekar R, Tempia S, et al. Estimates of global seasonal influenza-associated respiratory mortality: a modelling study. Lancet. 2018;391:1285-300. Available from: https://doi.org/10.1016/S0140-6736(17)33293-2

24. Nalbandian A, Sehgal K, Gupta A, Madhavan MV, McGroder C, Stevens JS, et al. Post-acute COVID-19 syndrome. Nat Med. 2021;27(4):601-15. Available from: http://doi.org/10.1038/s41591-021-01283-z

25. European Commission. European Health Union: green light for two new COVID-19 therapeutics [Internet]. Brussels: European Commission; 2021 [cited 2021 Nov 19]. Available from: https://ec.europa.eu/commission/presscorner/detail/en/IP_21_5901

26. Pfizer. Pfizer seeks emergency use authorization for novel COVID-19 oral antiviral candidate [Internet]. New York: Pfizer; 2021 [cited 2021 Nov 19]. Available from: https://www.pfizer.com/news/press-release/press-release-detail/pfizer-seeks-emergency-use-authorization-novel-covid-19

27. Balisacan J, Chyba M, Shanbrom C. Two new compartmental epidemiological models and their equilibria. medRxiv 21263050 [Preprint]. 2021 Sep 07 [cited 2021 Dec 03]. Available from: https://doi.org/10.1101/2021.09.03.21263050

28. US Centers for Disease Control and Prevention. SARS-CoV-2 variant classifications and definitions [Internet]. Atlanta, GA: US Centers for Disease Control and Prevention; 2021 [cited 2021 Nov 19]. Available from: https://www.cdc.gov/coronavirus/2019-ncov/variants/variant-info.html?CDC_AA_refVal=https%3A%2F%2Fwww.cdc.gov%2Fcoronavirus%2F2019-ncov%2Fcases-updates%2Fvariant-surveillance%2Fvariant-info.html

29. Agha R, AvJR. Delayed seasonal RSV surge observed during the COVID-19 pandemic. Pediatrics. 2021;148(3):e2021052089. Available from: https://doi.org/10.1542/peds.2021-052089

Citation

Ontario Agency for Health Protection and Promotion (Public Health Ontario). What does it mean for COVID-19 to be ‘endemic’ and when will we get there? Toronto, ON: Queen's Printer for Ontario; 2021.

Disclaimer

This document was developed by Public Health Ontario (PHO). PHO provides scientific and technical advice to Ontario’s government, public health organizations and health care providers. PHO’s work is guided by the current best available evidence at the time of publication. The application and use of this document is the responsibility of the user. PHO assumes no liability resulting from any such application or use. This document may be reproduced without permission for non-commercial purposes only and provided that appropriate credit is given to PHO. No changes and/or modifications may be made to this document without express written permission from PHO.

Public Health Ontario

Public Health Ontario is an agency of the Government of Ontario dedicated to protecting and promoting the health of all Ontarians and reducing inequities in health. Public Health Ontario links public health practitioners, front-line health workers and researchers to the best scientific intelligence and knowledge from around the world.

For more information about PHO, visit publichealthontario.ca.

Ontario