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Modelling the Future of COVID-19 in Ontario

CIA Pandemic Modelling Project Team[1]

Predicting future outcomes during the COVID-19 pandemic has been challenging due to ever-changing factors such as new variants, vaccines, seasonality, and dynamic government intervention measures. Further, we do not have a comprehensive understanding of the impact of these factors: we do not know exactly how infectious each variant is, nor do we know the level of vaccination required for herd immunity or how that level changes from summer through the fall.

To understand the COVID-19 pandemic in the face of these uncertain factors, the Canadian Institute of Actuaries (CIA) explored a variety of scenarios for Ontario where key assumptions are varied and the outcomes of the pandemic are analyzed. These scenarios show a range of possible future outcomes that may be realized over the coming year.

Most notably, our findings indicate that vaccination rates nearing 90% of total population may be required to prevent a fourth wave in late 2021 – driven by seasonality – depending on how infectious variants are and actual vaccine effectiveness against those variants. This implies that in order to mitigate a fourth wave, everyone who is currently eligible would need to get fully vaccinated. The knowledge that this potential future wave can be mitigated highlights the importance of setting higher targets for vaccination and continuing to ensure the public follows through on second doses through the summer and fall.

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The CIA's original research is published in *The Future of COVID-19 in Ontario: Variants, Vaccines, and Avoiding Future Waves.*[2] This insight statement highlights the key findings:

- Vaccinations are key, with public willingness to vaccinate being the most important factor in ending the pandemic.
- A fourth wave is almost certain unless we can achieve 90% full vaccination of the total population. Without 90% vaccination, it is only a question of how severe that fourth wave will be.
- The emergence of variants is a risk and a potential driver of future pandemic waves.
- Given the uncertainty of how effective vaccines will be against new variants and how the spread of new variants will change in the fall, it is prudent to set and follow through on aggressive vaccination targets.
- Increasing the population's willingness to vaccinate to 90% would effectively mitigate a wave in late 2021 in the majority of potential future scenarios.
- Even if vaccines aren't as effective against new variants, the pursuit of a 90% vaccination rate would still be most effective in slowing the spread of COVID-19.

Building our model

Our analyses were based on a model[3] for the spread of COVID-19 in Ontario originally developed by Drs. Ashleigh Tuite, David Fisman, and Amy Greer, "Mathematical modelling of COVID-19 transmission and mitigation strategies in the population of Ontario, Canada." It was developed using a modified "susceptible-exposed-infectious-recovered" framework with additional compartments to incorporate public health interventions, varying severities of clinical symptoms, and the risk of hospital admission. We incorporated additional factors that influence the spread of COVID-19, including, among other factors: seasonality, updated experience and assumptions from Ontario data, vaccination data, interventions, and the effect of new variants.

Given that the biology of the COVID-19 virus was evolving more quickly than we could update our model and capture and analyze the results, we decided to limit the collection of actual data to phase 1, which ended on April 1, 2021, with our model picking up from there for the following year.

Emergence of variants

At the beginning of 2021, vaccines were expected to slow down the spread of COVID-19 in Ontario. However, the emergence of variants appears to have changed the expectation. To understand the impact of variants, we modelled optimistic and pessimistic scenarios with varying transmissibility relative to the original strain. We assumed the vaccine effectiveness against the variants to be 70% of the 94% effectiveness assumed for the original strain (i.e., 66% effectiveness).

[2] www.cia-ica.ca/publications/publication-details/rp221087
[3] www.cmaj.ca/content/192/19/E497

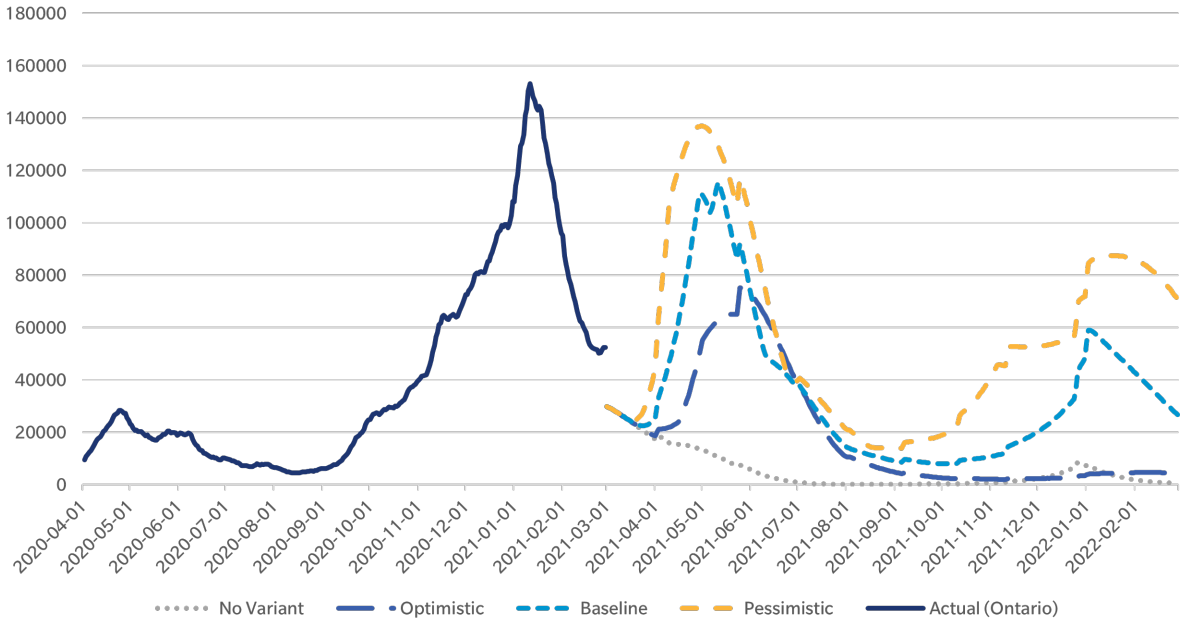
Table 1: New variant transmissibility by variant scenario

Variant scenario	Transmissibility relative to the original strain
No variants	100%
Optimistic	150%
Baseline	170%
Pessimistic	190%

Figure 1 shows the actual experience in Ontario from April 2, 2020, to February 28, 2021, followed by the model projection thereafter for one year. While the scenario with no variant seems unrealistic given the observed emergence of variants, the model output indicating the elimination of COVID-19 in the summer of 2021 is noteworthy. This emphasizes the significance of a successful rollout of a highly effective vaccine while taking advantage of the positive seasonality effects to manage this pandemic.

All variant scenarios analyzed show a third wave in the spring of 2021 (which we now know happened) as well as a potential fourth wave in late 2021. However, we do note from our model that the COVID-19 impact subsides in the summer months, primarily due to the seasonality effects.

Figure 1: Daily active infection cases of COVID-19



Vaccine success

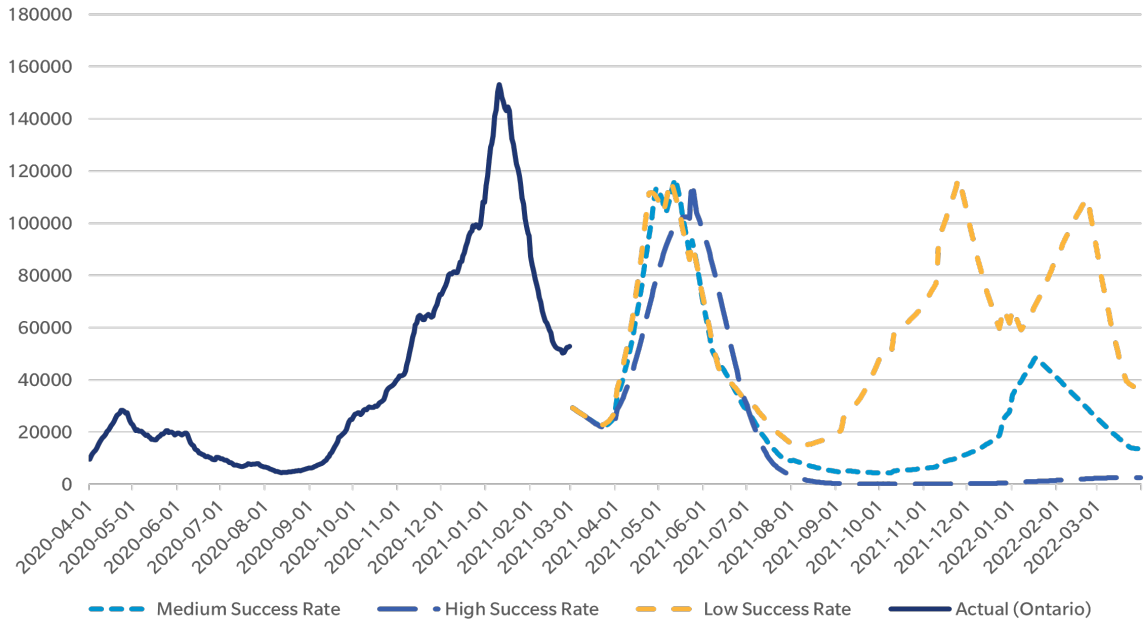
Variants present a high risk, and vaccines are the best long-term defense to mitigate future spread. To highlight the importance of vaccination on future outcomes, the following charts show active COVID-19 cases over time with varied vaccine success. The first graph (figure 2) shows that with our baseline expectation for variant transmissibility, a highly successful vaccine rollout would eliminate any risk of a fall wave. The second graph (figure 3) shows that even with pessimistic assumptions for variant transmissibility a highly successful vaccine rollout would still virtually eliminate a fall wave.

Table 2: Vaccine success by effectiveness for variants and population willingness to vaccinate

Vaccine success rate	Variant vaccine effectiveness	Willingness to vaccinate
Low	56%	70%
Medium	66%	80%
High	85%	90%

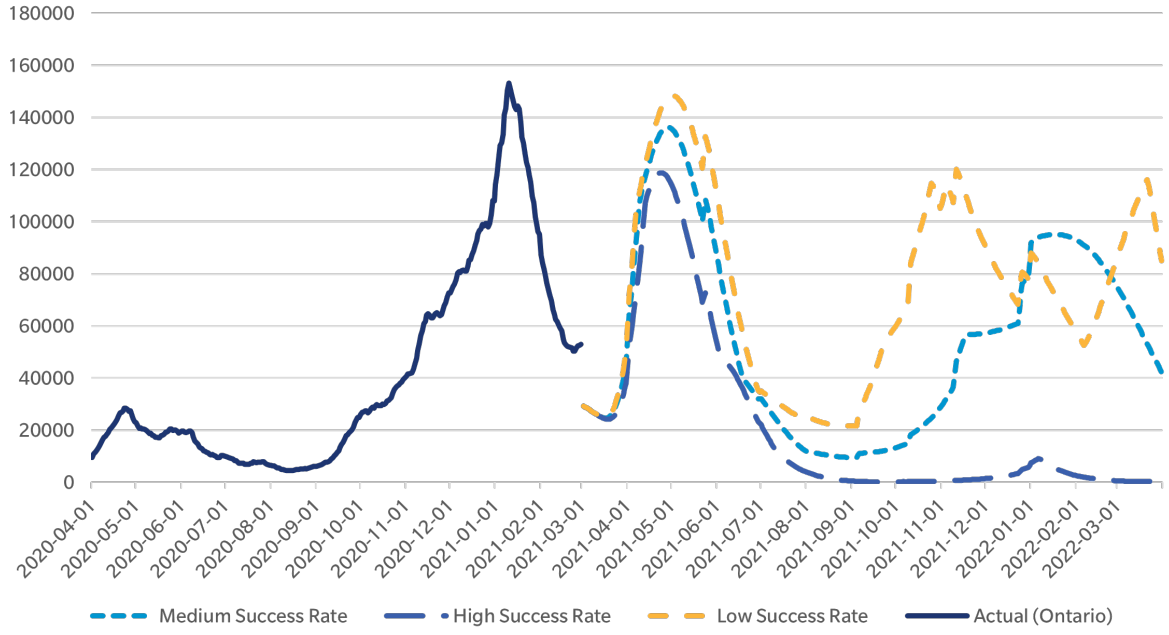
Figure 2 highlights forecasted infections over time with fixed expected variant infectiousness and varying vaccine success scenarios. Under the medium vaccine success scenario, we see decreasing infections over the summer but the risk of a fourth wave in late 2021. The low vaccine success scenario shows a high level of infections maintained throughout the summer of 2021 and resulting in a dual peak in late 2021 and early 2022. The high vaccine success scenario shows how we may be able to prevent a fourth wave this fall.

Figure 2: Baseline variant scenario's daily active infection cases of COVID-19



In a scenario with a pessimistic assumption for both COVID-19 transmissibility and vaccine outlook, we see the risk of an extreme fourth wave in the fall. However, even with pessimistic transmissibility assumptions, there is still potential to limit infections in the fall and winter through vaccine response.

Figure 3: Pessimistic variant scenario's daily active infection cases of COVID-19



We found that results were more sensitive to population willingness to vaccinate than to vaccine effectiveness. At 80% willingness and 80% effectiveness, our model showed that potential fourth wave ICU cases peak at about 120 cases in the winter of 2022. In comparison, at 90% willingness and 66% effectiveness, our model showed fourth wave ICU cases peak at about 50 cases in the spring of 2022. This is driven by two factors: higher willingness provides better protection for at-risk populations and vaccines are assumed to be highly effective against severe cases despite lower effectiveness against mild infections. In addition, willingness to vaccinate is easier to project and influence than vaccine effectiveness.

Key insights

1. The population's willingness to vaccinate is the key to managing the current pandemic. Vaccines can be developed but if left unadministered or administered to a low level, future waves of the pandemic cannot be mitigated. In the face of public complacency towards vaccines, governments must educate the public about the potential negative results of this inaction.
2. Even if vaccine effectiveness is lower than originally expected, safe vaccines with lower efficacy may be sufficient to combat a pandemic as long as the population has a high degree of willingness to vaccinate.
3. Set high targets for vaccinations of the population and follow through on the roll-out plan. Ensure the population gets the required number of doses.
4. In the absence of vaccines, government interventions are an effective way to manage the spread of COVID-19. However, once there has been significant spread in the population, a strategy to drastically reduce active cases that relies solely on government intervention would likely not be feasible. This is due both to the length of time required for the intervention and difficulties managing inter-border travel. While early, strict lockdowns have been effective in some jurisdictions at virtually eliminating COVID-19, this strategy has become much less practical as the pandemic has progressed. Atlantic Canada has experienced good results by controlling and limiting access to their border.
5. There is benefit to the approaches of scenario-testing and risk assessment provided in this paper to increase understanding of pandemics. Applying these actuarial principles to future work can provide additional insight beyond forecasting that is focused on predicting outcomes.

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