Scientific Advisory Group

COVID-19 Scientific Advisory Group Rapid Evidence Report

Population vaccination strategies for COVID-19: evidence around the role of exposure risk

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Alberta Health Services

Physical distancing works

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Lay Summary

BACKGROUND

- In Canada, provinces have generally prioritized people for COVID-19 vaccination based on their risk of severe outcomes such as ICU admission or death.
- The arrival of a third wave of COVID-19 in Alberta and other Canadian provinces, driven by more contagious COVID-19 Variants of Concern (VOCs) has shown we need to assess and adjust vaccination rollout to best reduce the rate of disease transmission
- There are hundreds of Albertan communities with very high rates of infection, in the highest 25% infection rates worldwide. There are currently 11 communities in Alberta with both the highest rates of active COVID-19 cases, and lowest rates of vaccination. These communities often have both a younger population that is not yet eligible for vaccination, and a local industry and work patterns that do not support working from home.
- This review summarizes the available evidence on whether vaccinating people based on how likely they are to catch or pass on COVID-19, rather than on their individual risk of dying may be helpful in pandemic control.

KEY FINDINGS

- Almost all of the evidence on this topic comes from modelling studies that have not been peer-reviewed. Most of these models assumed that vaccination campaigns were starting from scratch (ie. nobody is vaccinated yet) and that there is extremely high disease transmission – this is not the case in Alberta.
- Modelling from the Ontario Science Advisory Table, which has a situation similar to Alberta's, suggests that in Ontario an additional 10-15% of hospitalizations, ICU admissions, and deaths could be prevented by directing vaccines to areas with a high rate of COVID-19 transmission
- When all of the studies are considered together, the evidence suggests that once many people at high risk of severe outcomes have been vaccinated, shifting to vaccinating people who live or work in areas where disease transmission is high can reduce the overall number of infections and reduce severe outcomes like hospitalizations and ICU admissions. This also would protect the health care system capacity to provide care for all. This strategy could also help make sure that people who might have a hard time getting the vaccine have the same chance as everybody else.

RECOMMENDATIONS

- A strategy of directing more vaccine supply to areas with high levels of disease transmission for all ages eligible for the vaccine should be strongly considered.
- Vaccination campaigns should be resourced to make it as easy as possible for people to get their shot
- Outreach should be done to engage with those who are skeptical or hesitant about vaccines.
- Additional guidance: Although there are no COVID examples of this strategy, ring vaccination (where you vaccinate a case's contacts and the contact's contacts)

has been effective in the past to control some diseases including Smallpox and Ebola. This strategy could be evaluated/considered if public health resources are available and with rapid and complete contact tracing in place. The best use of this strategy is likely in areas with low transmission and new outbreaks, particularly in non B.1.1.7 VOC outbreaks to potentially help prevent VOC surges becoming established.

Authorship and Committee Members

Name	Contribution
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Topic: Population vaccination strategies for COVID-19: evidence around the role of exposure risk based strategies

1. **What transmission/exposure-risk vaccination strategies have been proposed or utilized to reduce transmission of COVID-19, alongside medical-risk prioritization strategies?**
2. **In the face of scarce vaccination supply, is there evidence to support the use of exposure-risk vaccination strategies alongside or instead of medical-risk strategies to reduce community COVID-19 transmission?**

Context

- Canadian vaccination recommendations have been developed by the National Advisory Committee on Immunization (NACI), a pan-Canadian, interdisciplinary group with expertise in pediatrics, infectious diseases, immunology, pharmacy, nursing, epidemiology, pharmacoeconomics, social science and public health. Their mandate is to provide evidence-based recommendations that consider economics, ethics, equity, feasibility, and acceptability.
  - COVID-19 vaccine rollout across Canadian provinces has been largely focused on protecting individuals at high risk of severe COVID-19 outcomes, with all provinces and one territory incorporating age based risk (a proxy for medical risk of severe outcomes) and prioritization of long-term care residents. In addition, healthcare workers who work in long term care or who directly care for COVID-19 patients have been prioritized in all provinces in keeping with NACI guidance.
- Otherwise, prioritization is heterogeneous:
  - 6 jurisdictions include various “frontline” or essential workers beyond healthcare workers
  - Beyond age based medical risk, several provinces have prioritized those with specific medical risks, a group which has been variably defined
  - There has been variable prioritizing of First Nations and Metis communities and remote communities
  - Essential worker groups have been prioritized in many provinces, but these groups have been variably defined (eg: those who travel for work, congregate housed workers, food plant workers, and teachers)
- The development of a “third wave” of COVID-19 with extremely high case rates in several provinces, particularly Alberta, has highlighted the importance of strategies to reduce case transmission, and optimal vaccine rollout strategies have been identified as important to achieve this goal
- Areas in Alberta with a high number of active COVID-19 cases often have lower vaccination rates that are insufficient to mitigate viral transmission. This may be due to a combination of factors such as vaccine eligibility, population distribution, age distribution, local industry, and variable rates of vaccine hesitancy in communities across Alberta.
- There are currently (as of April 27, 2021) 11 communities in Alberta with active case rates above 400/100 000 and vaccine coverage ≤ 20%; and 10 communities with active case rates above 600/100 000 and vaccine coverage

below 20%. More detailed information and high-level analysis is available in the appendix.

- Transmission/exposure-risk vaccination strategies prioritize populations or communities where individuals are at high risk of acquiring the virus and transmitting it to others (and thus contribute to incidence and total number of cases), but these individuals are not necessarily at the highest risk of severe outcomes. Some jurisdictions, such as Ontario, have recently adjusted their vaccine prioritization scheme to target neighborhoods and regions with high disease transmission.
- The current Alberta prioritization strategy, focusing on prevention of morbidity and mortality by prioritizing those vulnerable due to age and medical risk, was largely developed before the sharp increase in COVID-19 variants of concern (VOC), which are more easily transmissible. The current rates of infection in older age groups shows evidence of a protective effect from this vaccination strategy with much lower rates than in the second wave.
- Developing a strategy that balances maximal speed of immunization given availability of vaccines, complexity of operationalization, and the possible benefits of risk based strategies on overall infection rates is timely.
- Vaccination is expected to reduce community transmission by decreasing the number of susceptible people. Information on COVID-19 transmission following vaccination has been previously reviewed by the Scientific Advisory Group (SAG) and COVID-END, with current data suggesting that vaccination reduces transmission by reducing the number of active cases (including asymptomatic cases) and reducing the infectiousness of those infected. Preliminary data suggests that COVID-19 positive individuals who have been vaccinated may be less likely to transmit based on virologic parameters.

Key Messages from the Evidence Summary

- The majority of identified evidence about transmission/exposure risk vaccination strategies is in preprint manuscripts; the included articles are largely composed of modelling studies and grey literature.
- Many jurisdictions that are comparable to Alberta are moving towards prioritizing individuals with a high risk of COVID-19 transmission/exposure, suggesting that this is a feasible option. These jurisdictions include Ontario, New Zealand, China, Australia, Ireland, Hong Kong, Germany, Austria, Malta, Norway, Poland, and Spain.
- Potential strategies for targeting populations with high transmission/exposure in the literature can be designed according to:
    - Geographic "hotspot" identification: vaccines are allocated to geographic areas, communities or neighborhoods with high rates of infection
    - Occupational risk (essential workers): vaccines are allocated to individuals who have a high number of contacts due to the nature of their occupation and who cannot work from home, as well as the family members of these individuals

  - Age-targeting of the population at risk: vaccines are allocated to younger adults (typically aged 18-49), as this population tends to have a higher degree of social interaction than older adults
  - Overall number of social contacts: vaccines are allocated to individuals with a high number of social contacts, regardless of age
  - Housing situation: vaccines are allocated to individuals whose living arrangements increase their risk of exposure and transmission (such as those who are unstably housed, those living in multigenerational houses, or those with roommates or other shared accommodation)
  - Ring vaccination: following identification of a positive case, vaccines are administered to two generations of contacts (ie. the case's contacts, and the contact's contacts)
- Individuals at high risk of infection and consequent transmission should be considered in the broader context of prioritization and with attention to the ability for the groups to be identified and encouraged to vaccinate. Considerations include their place in the existing prioritization scheme; risk of viral transmission; which prioritization categories might intersect, and the logistical challenges of prioritizing these groups especially groups identified by occupation or network contact numbers,
- The most relevant models for Alberta are likely from the Ontario Science Table model (Mishra et al, 2021) and the model by Mulberry (preprint). These models use R_0 values less than 1.5) which would suggest that ongoing NPI (nonpharmaceutical interventions) are maintained as needed to control transmission during rollout, and use Canadian population data. The Ontario Science Table model assumes that 80% of those with age-based risk (ie. over 60 years old) are already vaccinated when allocation changes to prioritize hotspots. As such, when highly vulnerable populations have had good vaccine coverage, switching to a transmission reduction strategy may reduce overall case rates and also reduce morbidity and mortality.
- Evidence from Ontario has highlighted the equity imbalance associated with a strictly age-based (ie. medical-risk) vaccination strategy – Ontario neighborhoods where residents have the lowest risk of SARS-CoV-2 infections are 1.5 times more likely to have received at least one COVID-19 vaccine dose by April 5, 2021, as compared to residents of neighborhoods with the highest risk of SARS-CoV-2 infections. **Modelling vaccine redistribution to these high-risk areas suggests that at 70% vaccine coverage of adults (16-59), an additional 14% of hospitalizations and ICU admissions and 11% of deaths could be prevented compared to the current vaccination strategy.**
- One modelling study described vaccinating all front-line workers with AstraZeneca, while simultaneously distributing the mRNA vaccines (Pfizer/BioNTech & Moderna) by age/medical risk to the general population. This study suggested that this strategy could reduce overall mortality and healthcare utilization as front-line workers were assumed to be more willing to be vaccinated. This approach may have real or perceived ethical and equity issues that must be considered.

- True ring vaccination (as has been done to help eradicate Smallpox in the past) of succeeding generations of contacts was modelled in one COVID-19 modelling study, however, this strategy requires rapid complete contact tracing with rapid test results, and vaccination infrastructure to safely vaccinate contacts who should be quarantining to mitigate forward transmission and may not be feasible. In addition, ring vaccination is not usually prioritized in a high transmission setting, but can be considered in settings with very low transmission and new introduction of disease, or potentially in elimination phases.
- The specific results from modeling studies are highly dependent on the model inputs for population structure, existing natural immunity, vaccine coverage, vaccine efficacy, vaccination rate, transmission rate, public health measures, timing, and vaccine uptake. The robustness of existing data means that the general concepts can be applied to these research questions, but the magnitude of effect when applied to Alberta may differ.
- Many models assumed an unvaccinated population and a reproduction number ≥ 2 (as seen in early epidemics without public health measures in place), limiting applicability to Alberta where about 25% of the population (mostly those with age-based and medical risk) have been vaccinated.
- Vaccine hesitancy was incorporated into most, but not all models. For most models, population coverage was one of the model outputs and was assumed to be between 60-80% in most studies. In studies that assumed vaccine hesitancy, estimates of uptake were approximately 70%.
- The goals of the vaccine campaign – whether the focus is to minimize new cases, deaths, years of life lost, healthcare utilization, or to maximize value for money – will determine the optimal allocation strategy when vaccine supply is scarce.
- In most models (where at baseline, the population was unvaccinated), vaccination based on transmission/exposure risk is the most effective strategy for reducing incidence and maximizing value for money, while vaccinating based on medical risk is the most effective for reducing overall mortality and healthcare utilization. In the current context given good vaccine coverage of those at higher risk in Alberta, switching to a rapid strategic transmission risk model may be an effective strategy to help contain Wave 3 and potentially slow the spread of COVID-19 VOC.
- An ethical analysis of vaccine allocation supported that transmission risk models may be supported in the context of maximizing societal benefit in resource scarcity. In the case of COVID-19 vaccines, maximum benefit could potentially be achieved by prioritizing children and young people based on an assumption that they tend to get infected more frequently, to remain infected for longer, and can therefore be significant vectors of disease transmission to the elderly and other vulnerable groups. This is slightly less relevant when looking at hybrid models where medically vulnerable individuals have already been vaccinated.
- Multiple models support that vaccinating younger adults (i.e. of working age) or allocating vaccines to geographically identified hotspots can effectively mitigate disease incidence.
- The two main risk prioritization strategies to consider therefore are:

1) Prioritizing vaccines for essential workers, who are generally 18-59 years old, may be an effective way to reduce mortality, minimize years of life lost (YLL), and minimize infections, but does not have a substantial effect on severe complications from COVID-19. This strategy is less costly and more effective than vaccinating all adults randomly. Operationalizing this strategy may be complex (defining target groups, outreach) which could potentially result in an overall slower vaccine rollout with more communication challenges.
2) Targeting geographic hotspots has been shown to reduce disease transmission and improve the equitable distribution of vaccine. In many regions this may also encompass important essential worker groups. Further models from the Philippines and theoretical modeling suggest that allocating vaccines based on disease transmission rate can reduce deaths and substantially reduce infections.

Committee Discussion

A robust discussion was held on several topics identified in this review.

The need to balance speed (if vaccine supplies are as projected, vaccination rates may be able to be maintained at a high level) versus strategy (which strategies are relatively straightforward to implement but can reduce transmission more quickly than blanket immunization?) was recognized.

Ring vaccination was discussed at length, with some disagreement relating to its feasibility. In one perspective, the incubation time and pre-symptomatic phase of smallpox has clear similarities to COVID-19 and ring vaccination was effective for controlling smallpox outbreaks. In the other perspective, ring vaccination requires extensive contact tracing infrastructure (ideally two generations of contacts identified both forwards and backwards), and the availability of outreach personnel or vaccination centres to accommodate individuals who would be quarantining as high risk contacts. Alberta Precision Laboratories has stated that they will decrease broad screening for VOCs soon, which will limit extensive contact tracing on all but high-risk outbreaks and hospitalized/emergency department patients. Although ring vaccination was seen as a potentially useful consideration after the current caseload is reduced, the majority of members agreed that it currently does not have enough COVID-19 data to be a full recommendation and given current conditions is not likely currently feasible. One member did not agree with this, suggesting that a laboratory testing strategy was not an absolute pre-requisite, and that we should make a recommendation for ring vaccination.

There was some discussion on how additional provincial data might support the evolution of the vaccination strategy in Alberta. Information regarding previous infection rates, age structure of each local geographic area (LGA), vaccine intention, and degree of immunization across eligible groups can help identify where variations in vaccine uptake might be attributed to population structure or access barriers rather than hesitancy.

The committee also discussed how changes in supply would affect the vaccination strategy. As we are expected to receive large shipments of Pfizer/BioNTech, Moderna, and Janssen in the coming weeks, there was concern from some committee members that targeting doses to specific populations or LGAs and maintaining eligibility criteria may slow down the vaccine rollout. Instead, the committee suggested that focusing attention on those with high-exposure risk and improving access to vaccines would balance need with efficiency to get the highest vaccine coverage in the shortest amount of time.

Recommendations

1. "Hotspot" Vaccination with Phase 3: As new vaccine supply becomes available, weighting the supply to areas of high incidence and active case rates as accessible to all eligible individuals in those areas could lower provincial hospitalization rates ICU utilization, and deaths.
   Rationale: The modelling evidence suggests that after a certain proportion of medically vulnerable people have been vaccinated, an exposure risk targeted strategy by geography ("hotspot" strategy) can reduce hospitalizations and ICU admissions in situations of limited supply, and offer practical advantages over essential worker or network-exposure targeted strategies, with potentially greater equity. However, with supply expected to significantly increase over the coming weeks, there is a need to balance the risk that an operationally complex targeted exposure-risk strategy could inadvertently slow the overall vaccination rates by limiting eligibility.

2. Vaccine uptake in hotspot areas should be optimized by outreach and continued engagement with local community leaders and health care workers, to address local barriers to vaccination as appropriate. A variety of strategies could be considered, including neighbourhood and community pop-up clinics, mobile clinics, and/or workplace-based clinics in high risk workplaces as is feasible.
   Rationale: In general, the modelling studies required 60-80% vaccine uptake to achieve herd immunity. Tools and resources to address vaccine hesitancy and mitigate the barriers to vaccination such as financial or employment barriers, travel requirements, or mistrust of healthcare institutions will be critical to reaching the necessary level of population coverage to achieve low endemic rather than pandemic COVID-19 in Alberta. The effectiveness of different types of strategies to increase vaccine uptake should be tracked to guide rollout.

Practical Considerations

- Ring Vaccination: evidence for this strategy in COVID-19 is not currently at a level to support a recommendation. As public health contact tracing capacity and vaccine supply permits, ring vaccination of contacts can be evaluated for feasibility in low transmission areas, particularly in non-B.1.1.7. VOC cases where public health support is enhanced.
  Rationale: Ring vaccination was effectively used to help eradicate Smallpox and control the recent Ebola outbreaks in West Africa. Although the capacity for forwards and backwards contact tracing is not available for the current COVID-19 active caseload, the concept of "taking the vaccine to the people that need it" could be a useful way to quickly control outbreaks in low incidence settings as they arise through 2021 and into the future. A communication strategy to promote vaccination among individuals who have been identified as a contact of a COVID-19 case (or

contacts of contacts) has the potential to function in a similar way to ring vaccination in the absence of capacity to formally trace and vaccinate several generations of contacts, but would require the ability for contacts to be quickly and safely vaccinated (currently contacts are quarantined and attendance at vaccine clinics is not encouraged).

An epidemiologist from LSTMH who modelled ring vaccination for Ebola, Adam Kucharksi, was contacted to see if they had modeled ring vaccination for COVID-19. He noted they had considered it but not done it with the following comments: "As noted in our EID paper on Ebola, ring vaccination works best when you have a system that can contact trace effectively (because vaccination essentially supplements the role of quarantine in getting ahead of the outbreak). For infections with a short interval (e.g. 5-6 days for SARS-CoV-2 vs about 2 weeks for Ebola) and presymptomatic transmission, contact tracing - and hence any ring vaccination that piggy backs on the same protocol - will often struggle. In recent Ebola (and earlier smallpox) outbreaks, the net of 'contacts-of-contacts' to be vaccinated in the ring has sometimes been cast quite wide (e.g. a whole community) to reduce the risk of a missed contact undermining control. Vietnam's contacts-of-contacts-of-contacts tracing for COVID is probably in practice quite similar to this sort of concept - effectively targeting communities rather than individual contact links. If there is substantial variation in where infections are happening (e.g. very local clustering) there could be an argument to targeting 'rings' around these areas as a priority if logistics are feasible. Although if transmission is widespread, and tracking infection difficult, that may leave at-risk groups in non-ring areas vulnerable" (personal communication). This comment would support that geographic hotspot strategies if focused could be functionally similar to ring vaccination if done at the level of postal code as case numbers decrease.

- A hybrid model of vaccine allocation may offer greatest transmission control for the entire population, after highly medically vulnerable populations (such as the elderly) have attained good vaccine coverage, with a switch to an exposure-risk prioritization strategy for eligible individuals in areas with high transmission.
- There may be substantial overlap between essential worker populations and current hotspot communities. Current hotspots in Alberta correspond to areas where the primary industry requires a high number of social contacts (such as the hospitality industry in Banff, or oil & gas work camps in Northern Alberta).
- "Hotspots" can be assessed by incidence and active case rate /100,000). The definition of what would be considered a hotspot could be based on the highest transmission areas with the threshold guided by the amount of available vaccine for allocated for exposure risk campaigns. It is noted for example that currently 75% of Albertans reside in areas with >300/100,000 case rates so that level would not offer discrimination (see Table 1). The proportion of currently vaccine ineligible adults age 19-40 is 70% in the highest case rate areas.

Table 1. Total population in potential “hotspot” areas by threshold

Active case rate /100 000	Total population in affected areas	Population aged 19-40 in affected areas (%)
>350	3,150,474	1,225,903 (38.9)
>400	2,433,472	1,135,029 (46.6%)
>500	1,551,963	782,643 (50.4%)
>600	754,541	525652 (69.7%)

These data were accessed May 5, 2021 from the AHS immunization dashboard.

- As the “third wave” subsides in Alberta, an opportunity to surveil for community incidence increases could be identified by a more comprehensive wastewater monitoring program, which can provide a forecast of expected cases in the coming weeks, potentially before cases come to medical attention. The feasibility of this would require assessment.
- Non-pharmaceutical interventions that reduce physical contacts (ie. business restrictions, gathering restrictions, and social distancing requirements) remain critical to control disease transmission during vaccine roll-out.
- Vaccines that require a single dose (such as that developed by Janssen) and may be in lower supply should be allocated to individuals who may be at risk for missing second doses (such as transient or hard-to-track populations).

Research Gaps

- There are no comparative or retrospective observational studies to support the findings of the modelling studies.
- There is a relative lack of qualitative evidence to address the ethical perspectives, equity concerns, and perspectives of populations who might be affected by a vaccine distribution plan based on transmission/exposure risk.
- Existing models have varied assumptions that may need to be adjusted based on vaccine rollout experience in various jurisdictions.
- Additional research evaluating the impact of ring vaccination would help clarify the optimal way to integrate this strategy with geographic hotspot vaccination or other approaches.

Strength of Evidence

Although the body of evidence for this review is reasonably substantial for such a rapidly evolving topic, it is weak overall. The majority of included articles are modelling studies and preprints, and given the nature of the pandemic and vaccine availability only since the start of 2021, there is limited real-world (retrospective) evidence to support the findings of the extensive modelling studies that were identified. These models may be built with real data, but the outputs are extremely specific to the assumed model parameters. Therefore, the concepts and general findings from the models are likely applicable to the research questions but the magnitude of the effect may be different when the Alberta context is considered.

The grey literature comes from reputable sources and can be used to confirm that other jurisdictions are considering or using transmission risk as criteria for prioritizing vaccination. No evidence was identified from Alberta; however, there were five articles that were from Canadian research groups and produced a model or study results based on Canadian data and preferences. It is notable that the evidence included in this review is remarkably consistent, lending support to the concept of transmission/exposure risk.

Limitations of this review

This review is subject to several limitations that may affect the findings. First and foremost, the body of evidence is heavily based on modelling studies rather than retrospective experience. Further, most of the included studies have not yet been peer reviewed. This is intended to be a rapid review, so the database search was thorough but not systematic and only articles in English were included. It is possible that relevant studies have not been included. Finally, the short turnaround for this review and rapid evolution of vaccine strategy evidence makes it difficult to conduct an in-depth assessment of each study for quality and relevance.

Summary of Evidence

There was very limited peer-reviewed evidence of implementation of exposure-based or transmission-based vaccination allocation strategies. Of 160 relevant articles identified from database searching and *ad hoc* additions, 36 pieces of primary literature and five pieces of grey literature were included in the final synthesis. 30 of these were modelling studies (20 preprints), and six studies using other methodologies (two preprint). The breakdown of the included literature is shown in Table 2 below. The evidence extracted from the peer-reviewed and preprint articles is included in Table 4 in the appendix.

Table 2. Distribution of included preprint and peer-reviewed literature by methodology.

	Preprint Literature	**Peer-reviewed Literature**
Modelling & Simulation	Adibi et al. (Canada) Babus et al. (US) Buhat et al. (Philippines) Buckner, Chowell & Springborn (US) Chapman et al. (US) Chen et al. (US) Goldenbogen et al. (Germany) Herings et al. (Netherlands) Hoertel et al. (France) Hunziker et al. (Switzerland) Ives & Bozzuto (US) MacIntyre, Costantino & Trent (Australia) Matrajt et al. (US) Meehan et al. (Australia) Mulberry et al. (Canada) Rodríguez, Patón & Acuña (Spain) Shayak et al. (US) Tatapudi, Das & Das (United States) Tran et al. (US) Wang, Wu & Tang (China) Yu et al. (China)	Bubar et al. (US) Cook et al. (UK) Foy et al. (India) Grauer, Lowen & Liebchen (Germany) Hogan et al. (UK) Jentsh, Anand & Bauch (Canada) Kohli et al. (US) Rosen, Waitzberg & Israeli (Israel) Shim (Korea) Sjödin, Rocklöv, & Britton (Sweden)
Other	Saraswat, Ansumali & Prakash (India) Zhao, Ismail & Tunis (Canada)	Dooling et al. (MMWR) (US) Guibliani, Savulescu & Wilkinson (UK) Hasan et al. (Australia) Jain et al. (United States)

Grey Literature	ECDC (Europe) Health Information and Quality Authority (Ireland) Mishra et al. (Canada) Ontario Ministry of Health (Canada) COVID-END (Canada)

What exposure-risk vaccination strategies have been proposed or utilized to reduce transmission of COVID-19, alongside medical-risk prioritization strategies?

Note: In this section, the strategies in the literature will be discussed in broad terms. The details and findings of the modelling studies testing different strategies is addressed in the next section under question 2.

Evidence from secondary and grey literature

The COVID-END evidence network maintains a living profile of evidence related to the COVID-19 vaccine rollout. In the most recent update (April 6, 2021), the authors identified three pieces of grey literature demonstrating that transmission/exposure –based vaccine allocation is under consideration or underway in other jurisdictions (COVID-END, 2021). This is a relatively new development – these allocation plans were not available in the previous iterations (COVID-END, 2021). Jurisdictions that have expanded vaccine priorities to those at high risk of disease transmission include: Ontario (geographic hotspots), New Zealand (border workers, essential workers), China (essential services), Australia (essential workers), Hong Kong (essential workers), Ireland (living and working in crowded conditions) and Germany (education workers) (COVID-END, 2021).

A technical report from the European Centre for Disease Control (ECDC) reports that six European countries (Austria, Germany, Malta, Norway, Poland, Spain) have adapted their vaccine prioritization schemes in response to the rise of COVID-19 variants of concern (ECDC, 2021). These adaptations include included providing more vaccine doses to areas of high incidence or a redefinition of the priority groups based on the epidemiological situation (ECDC, 2021).

Detailed example 1: Ireland

The Irish Health Information and Quality Authority recently conducted a rapid review and analysis of the risk of infection and severe outcomes for people aged 18-64 who are at high risk of COVID-19 exposure and transmission due to occupation or housing status. In this study, 12 at-risk groups were identified: Travellers (a nomadic ethnic group), Roma community (a nomadic ethnic group), residents and staff of refugee assistance centres, prisoners and prison staff, people who are experiencing homelessness and staff in homeless-serving facilities, addiction service users and staff in these services, people working in food processing plants, residents and staff of women's refuges, undocumented migrants, sex workers, and seasonal harvest workers (Health Information and Quality Authority, 2021).

In this study, Travellers, refugees, and meatpacking plant workers were all at significantly increased crude risk of infection compared to general population, but not necessarily at risk of severe outcomes (Health Information and Quality Authority, 2021).

This review identified vaccine allocation frameworks from John Hopkins Bloomberg School of Public Health and National Academies of Sciences, Engineering, and Medicine that include priority for people whose living or working conditions give them an elevated risk of infection, even if they have a lesser or unknown risk of severe illness and death (Health Information and Quality Authority, 2021). No recommendations are made in this review, but the conclusions suggest that vaccine distribution to these groups should be considered in the context of existing prioritization schemes, risk of transmission, where eligibility might intersect, and the logistical challenges of prioritizing these groups (Health Information and Quality Authority, 2021).

Detailed example 2: Ontario

Ontario has recently announced a change to their “Phase 2” vaccine rollout to prioritize communities with a high incidence of COVID-19 (Ontario Ministry of Health, 2021). Residents of neighborhoods with the lowest risk of SARS-CoV-2 infections were 1.5 times more likely to have received at least one COVID-19 vaccine dose by April 5, 2021, as compared to residents of neighborhoods with the highest risk of SARS-CoV-2 infections. However, the average incidence of SARS-CoV-2 infections between March 7 and April 3, 2021 was 9 times lower in neighborhoods with the lowest risk of SARS-CoV-2 infections (Mishra et al., 2021). Neighborhoods with low vaccination rates relative to incidence tend to be younger, may have higher concentrations of Black or racialized populations, lower income, and materially deprived populations (Mishra et al., 2021; Ontario Ministry of Health, 2021). Other risk factors include multigenerational households, high-density housing, precarious employment and lack of paid sick leave (Mishra et al., 2021).

In the new scheme, vaccines are allocated to adults aged 50+ in COVID-19 Hot Spot Communities, starting with older individuals and decreasing in age, followed by essential workers who cannot work from home (Ontario Ministry of Health, 2021). These changes were made based on modelling from the Ontario Science Advisory Table, showing substantial overlap between neighborhoods with high incident COVID-19 rates and proportion of essential workers. In this model, the potential effect of a hotspot vaccination strategy to complement the existing medical risk-based strategy is demonstrated. In the model, 50% of the vaccine shipments to Ontario were allocated to 74 hotspot communities and distributed to all individuals over age 16; the remaining 50% of the shipment was distributed according to the existing paradigm based on age and medical risk (Mishra et al., 2021). The authors assumed a vaccine efficacy of 60% for preventing infection; that 80% of adults over 60 were vaccinated prior to redirecting vaccines to hotspots; and that they would achieve 70% coverage in those aged 16-59 in hotspot communities. Modelling vaccine distribution to COVID-19 hotspots showed that an additional 14% of hospitalizations and ICU admissions and 11% of deaths could be prevented compared to the current vaccination strategy of continuing with age/medical risk prioritization (Mishra et al., 2021).

Evidence from the primary literature

There was limited documentation of vaccine allocation to populations at high risk of COVID-19 exposure/transmission.

Israel and US approaches:

The Israeli vaccine advisory committee considered scenarios to prioritize those with medical risk versus prioritizing those with transmission risk and ultimately chose allocation based on medical risk (Rosen, Waitzberg & Israeli, 2021). Notably, in 2021 Israel was able to add younger adults and some essential workers (such as teachers) to their immunization campaigns to increase the population coverage and reduce disease transmission (Rosen, Waitzberg & Israeli, 2021).

In the United States, there is a high degree of variability between states regarding how essential workers are prioritized. All states have prioritized frontline healthcare workers according to federal guidance; although this guidance has classified first responders into a single high-priority group, they are often prioritized lower (Jain et al., 2021). The United States Centers for Disease Control and Prevention (CDC) Advisory Committee recommend that non-healthcare essential workers are vaccinated after those in long-term care, but before those with medical risk (Dooling et al., 2021). In general, vaccine allocation across the United States is based on medical risk rather than transmission/exposure risk and contradicts the recommendations of the CDC (Jain et al., 2021). Of note, these studies report on the content of existing policies rather than the impact – this is a key shortcoming of these articles.

Public health expert and stakeholder options:
A Canadian survey of 156 public health experts and stakeholders revealed that across five pandemic scenarios, protecting the medically vulnerable was generally the highest priority for vaccine allocation, followed in descending order by protecting healthcare capacity, minimizing transmission, and protecting critical infrastructure (Zhao, Ismail & Tunis, preprint). This priority list mirrors Canadian public opinion on vaccine allocation (Zhao, Ismail & Tunis, preprint).

Modelling studies:
Modelling studies used six different ways to identify and prioritize populations with high transmission/exposure risk. Each modelling study proposed a slightly different prioritization scheme, rollout plan, and comparator, but they can broadly be grouped into the categories listed in Table 3 below. No secondary literature was identified to synthesize the evidence available from modelling studies.

Table 3. COVID-19 Transmission/exposure risk classification in modelling studies

Source of risk	**Citation**
Occupation	Adibi et al., preprint Chapman et al., preprint Cook et al., 2021 Kohli et al., 2021 Mulberry et al., preprint Shayak et al., preprint Tatapudi, Das & Das, preprint
Occupation + age	Babus et al., preprint Herings et al., preprint Hoertel et al., preprint
Age (prioritizing younger adults due to higher transmission risk)	Bubar et al., preprint Buckner, Cowell & Springborn, preprint Hunziker et al., preprint

	MacIntyre, Costantino & Trent, preprint Matrajt et al., preprint Meehan et al., preprint Rodríguez, Patón & Acuña, preprint Shim, 2021 Sjödin, Rocklöv, & Britton, 2021 Tran et al., preprint Wang, Wu & Tang, preprint
Geographic incidence	Buhat et al., preprint Grauer, Lowen & Liebchen, 2020 Ives & Bozzuto, preprint Yu et al., preprint
Number of social contacts	Chen et al., preprint Foy et al., 2021 Goldenbogen et al., preprint Hogan et al., 2020 Jentsh, Anand & Bauch, 2021
Multigenerational housing	Saraswat, Ansumali & Prakash, preprint

Adibi et al. (preprint) uses data from British Columbia (BC) to show how existing vaccine supply can be used for populations with medical risk in addition to essential workers (“front-line workers”). This model is predicated on the AstraZeneca (AZ) vaccine and the delay in rollout due to concerns of VIPIT (Adibi et al., preprint). In this model, all 246700 doses of the AZ vaccine are allocated to front-line workers (unspecified) despite VIPIT risk, while mRNA vaccines (such as Pfizer/BioNTech and Moderna) are offered to individuals over 60 years old (scenario A), versus delaying front-line vaccination until after those with medical risk are offered the mRNA vaccines (scenario B) (Adibi et al., preprint). Compared to scenario B, scenario A resulted in 27175 fewer COVID-19 cases, 506 fewer hospitalizations, 87 fewer deaths, and 1462 fewer cases of Long COVID (Adibi et al., preprint). In this scenario, the expected number of deaths due to VIPIT after second doses are administered is less than 1 (0.676 [95% CI 0.413-0.995]) with a 49% probability of observing at least one death due to VIPIT by the end of the summer (Adibi et al., preprint).

MacIntyre, Costantino & Trent (preprint) model a ring vaccination strategy, with the assumption that existing COVID-19 vaccines will have at least 45% efficacy when administered as post-exposure prophylaxis (not based on data). In this strategy, all contacts of a confirmed case are vaccinated and the contacts of the contacts are vaccinated in turn (MacIntyre, Costantino & Trent, preprint). This strategy is the most efficient way to deliver vaccine doses compared to age-based vaccination when supply is limited, although it would require robust public health infrastructure to ensure that at least 90% of contacts are identified, traced, and vaccinated (MacIntyre, Costantino & Trent, preprint).

Synthesis of the Information Relating to Question 1

Taken together, the grey literature and primary literature presented here show that there are several ways to identify and prioritize populations at high risk of COVID-19 transmission/exposure. Modelling studies show that transmission/exposure risk can be considered in several different ways, not just by geography or by occupation. Age, housing situation, and number of social contacts can all be used to prioritize vaccination to influence disease transmission. The modelling studies by Adibi et al. (preprint) and MacIntyre, Costantino & Trent (preprint) show that simultaneous complementary vaccination strategies are possible, and may have a substantial effect on health resources.

It appears that vaccination strategies to minimize transmission are growing in popularity - Ontario, New Zealand, China, Australia, Hong Kong, Austria, Malta, Norway, Poland, Spain, and Germany have all prioritized vaccinations for populations at high risk of transmission, or have adapted their existing plans to include these groups. Many of these jurisdictions are good comparators for Alberta and show that transmission-based vaccination strategies are possible.

In the face of scarce vaccination supply, is there evidence to support the use of exposure-risk vaccination strategies alongside medical-risk strategies to reduce community COVID-19 transmission?

Evidence from the primary literature

Only modelling evidence is available to demonstrate the potential effects of a vaccination strategy based on exposure/transmission risk. An optimal vaccine allocation plan is not static; rather, it depends on the priorities of those implementing the vaccination campaign. The strategy for minimizing overall deaths may be different from the strategy to minimize total years of life lost, minimizing disease transmission, minimizing hospitalizations & ICU admissions, or maximizing value for money. In addition, the specific outputs from each model depend on the data used to build it and the assumptions made regarding vaccine efficacy, assumed population coverage; rate of vaccination, reproduction number, non-pharmaceutical interventions (eg. public health recommendations & restrictions), timing, and vaccine uptake. The general findings of the modelling studies are presented here for the sake of brevity.

The models almost universally showed that when vaccine supply is scarce (resulting in low population coverage), vaccinating working-age people with a high number of social interactions (whether due to geographic location, occupation, education, or other cause) is an effective way to mitigate COVID-19 incidence (Bubar et al., 2021; Buckner, Chowell & Springborn, preprint; Buhat et al., preprint; Chapman et al., preprint; Chen et al., preprint; Goldenbogen et al., preprint; Grauer, Lowen & Liebchen, 2020; Hoertel et al., preprint; Hunziker et al., preprint; Hogan et al., 2020; Ives & Bozzuto, preprint; Jentsh, Anand & Bauch, 2021; Kohli et al., 2021; MacIntyre, Costantino & Trent, preprint; Matrajt et al., preprint; Meehan et al., preprint, Mulberry et al., preprint; Rodríguez, Patón & Acuña, preprint; Saraswat, Ansumali & Prakash, preprint; Shayak et al., preprint; Shim, 2021; Sjödin, Rocklöv, & Britton, 2021; Tran et al, preprint; Wang, Wu & Tang, preprint; Yu et al., preprint). When the goal is to reduce mortality and healthcare utilization (hospitalizations and ICU admissions), vaccinating older people (aged 60+) and other populations with medical risk is still the best option (Bubar et al., 2021; Buckner, Chowell & Springborn; preprint; Chapman et al., preprint; Cook et al., 2021; Foy et al., 2021; Goldenbogen et al., preprint; Herings et al., preprint; Hogan et al., 2020; Jentsh, Anand & Bauch, 2021; MacIntyre, Costantino & Trent, preprint; Matrajt et al., preprint; Meehan et al., preprint; Mulberry et al., preprint; Shim, 2021; Sjödin, Rocklöv, & Britton, 2021; Tran et al., preprint; Wang, Wu & Tang, preprint; Yu et al., preprint). Of note, these models assumed that the vaccination campaigns were starting from scratch (ie. nobody was vaccinated) and that severe outcomes would arise from people with high medical risk waiting for their vaccine. This contrasts with the results from the Ontario Science Table, who assumed that 80% of the medical risk population was already vaccinated at the start of the model and the allocation was changing to prioritize hotspots (Mishra et al., 2021).

Occupation-based vaccination strategies in cases of scarce supply have been modeled in several studies. Babus et al. (preprint) suggests that in a scenario where the vaccine is 50% effective at preventing infection and a targeted stay-at-home order is in place and some individuals can work from home, optimal vaccine allocation is to vaccinate all individuals who must be present in the workplace regardless of age. Targeting essential workers has the potential to minimize deaths (when starting with older essential workers), minimize YLL (when starting with younger essential workers) and minimize infections (when starting with essential workers in general) each by 17-18% (Buckner, Chowell & Springborn, preprint). Chapman (preprint) showed using California data that targeting essential workers could avert over 101,000 COVID-19 cases and 4600 deaths. Modelling using the existing prioritization in the UK (where healthcare workers are prioritized along with those over 80 years) showed that health and social care workers accounted for 625 additional deaths, 5380 hospitalizations and 662 ICU admissions compared to age-based vaccination only (Cook et al., 2021).

Similarly, vaccinating by transmission/exposure risk is not ideal for reducing severe complications. Herings (preprint) shows that 67.5% of the working age population must be vaccinated to achieve a 50% reduction in the risk of severe outcomes. Vaccinating essential workers ahead of those with medical risk is cost effective –resulting in cost savings in populations over 65 years but overall associated with a cost of QALY of $20,000 for essential workers (well below the standard government willingness to pay of $50000 per QALY) (Kohli et al., 2021). Canadian modelling shows that vaccinating essential workers earlier can reduce infections, hospitalizations, deaths, and instances of Long COVID across a range of scenarios and data inputs (Mulberry et al., preprint).

Targeting geographic hotspots has been shown to reduce disease transmission and improve vaccination equity among communities that might be racialized or have a higher proportion of those with lower socioeconomic status. Modeling from the Philippines suggested that as vaccine supply increases after the initial distribution by population, extra doses should be allocated to Manila (where cases rates were highest) as allocating based on the number of infections generated the lowest death projections, while allocating vaccines based on population size resulted in the highest number of death projections (Buhat et al., preprint). A more theoretical modelling study showed that at a high reproductive number (R_0) (2.5-3) and vaccination rate of 1%/day, allocating vaccines based on infection rate can reduce the epidemic peak and limit deaths compared to demographic distribution (Grauer, Lowen & Liebchen, 2020). Models based on Chinese data found that adopting a dynamic prioritization scheme to maintain R_0 around 1.5 highlighted that vaccinating younger individuals (age 15-39) could reduce infections by 88-89%, while an age-based strategy was more useful for minimizing deaths and ICU admissions (Yu et al., preprint).

An ethical analysis of vaccine allocation suggested that to maximize expected benefits, scarce health resources should not necessarily be allocated purely based on individual need (ie. allocated to those with the most medical risk) (Giubilini, Savulescu & Wilkinson, 2020). In the case of COVID-19 vaccines, the authors extrapolate from influenza evidence and argue that maximum benefit can be achieved by prioritizing children and young people because they tend to get infected more frequently, to remain infected for longer, and therefore may transmit the disease to the elderly (Giubilini, Savulescu & Wilkinson, 2020). In this scenario, those with a high degree of medical risk are protected by the indirect immunity that comes from vaccinating young people with a high number of social interactions, rather than the direct immunity of the vaccine (Giubilini, Savulescu & Wilkinson, 2020). The authors argue that when vaccine supply is limited, the societal benefits of protecting the vulnerable and limiting social distancing restrictions outweigh the potential ethical problems of mandating children and young people to be vaccinated (even though this may not be viewed as a hardship) (Giubilini, Savulescu & Wilkinson, 2020).

The concept of justice is noted by some of the authors of the models. In Hunziker (preprint) the scenario where 'younger people receive a quarter dose vaccination, leaving the elderly aside until 80% of the younger are vaccinated, then vaccinating the elderly at full dose' had the lowest deaths in 100 days, the fastest time to <100k cases/day, and the fastest time to <1000 deaths. However, the authors state that this may be perceived as an unjust prioritization model as many believe that the elderly should be first in line for vaccination due to their risk (Hunziker et al. preprint). Ives & Bozzuto (preprint) propose a geographic hotspot allocation strategy where vaccines are distributed to US counties based on transmission rate (reproductive number) instead of population size. In this model, herd immunity reached earlier and with fewer vaccines and has the advantage of increasing vaccine equity for Black populations, who currently lag behind counties that are primarily Caucasian counties by about four days (Ives & Bozzuto, preprint).

Synthesis of the Information Relating to Question 2

Taken together, the evidence suggests that optimal vaccine allocation in the face of scarce resources should be based on the overarching goals of the vaccination program. The strategies to minimize disease transmission are different from the strategies required to minimize mortality. Vaccination strategies to minimize mortality are most effective when the elderly and those with medical risk of severe COVID-19 are vaccinated first, while strategies to mitigate disease transmission are most effective when individuals at high risk of disease exposure or transmission are given priority.

The modelling studies commonly assumed that vaccination campaigns were starting from scratch (ie. only natural immunity in the population), with a reproduction number ≥ 2. This limits the applicability to Alberta where nearly 80% of high risk patients are already vaccinated. The most relevant models for Alberta are likely the Ontario Science Table model (Mishra et al, 2021) and the model by Mulberry (preprint). These models use low R_0 values (less than 1.5), use Canadian population data, and the Ontario

Science Table assumes that 80% of those with age-based risk (ie. over 60 years old) is already vaccinated when allocation changes to prioritize hotspots. As such, when highly vulnerable populations have had good vaccine coverage, switching to a transmission reduction strategy may reduce overall case rates and also reduce morbidity and mortality.

In addition, the social justice and equity concerns of vaccine allocation may be somewhat allayed by prioritizing essential workers and geographic hotspots. These populations/communities may be younger, racialized, with lower income, and have more disadvantageous social determinants of health than the populations who are prioritized by age-based / medical-risk based strategies.

Evolving Evidence

Research on SARS-CoV-2 is continually evolving and as such the evidence will continue to be assessed as new information is provided. As more jurisdictions roll out their vaccine programs, more data will be available to determine the effect of the vaccination prioritization strategies. In addition, most of the evidence gathered for this review were preprints – as these studies undergo peer review, the findings and quality of the studies may change.

Appendix

List of Abbreviations

AHS: Alberta Health Services
AZ: AstraZeneca
BC: British Columba
CDC: United States Centres for Disease Control and Prevention
COVID-19: Coronavirus Disease 2019
COVID-END: COVID-19 Evidence Network to support Decision-making
DALY: Disability-adjusted life years
ECDC: European Centre for Disease Control
HCW: Healthcare worker
HIC: High income country
ICU: Intensive Care Unit
LIC: Low income country
LMIC: Lower-middle income countries
LTC: Long-term care
MIC: middle income country
NPI: Non-pharmaceutical intervention
PEP: Post-exposure prophylaxis
QALY: Quality-adjusted Life Year
R_0: Reproductive Number
SAG: Scientific Advisory Group
UK: United Kingdom
UMIC: Upper-middle income countries
US: United States
VE: Vaccine effectiveness
VIPIT: Vaccine-Induced Prothrombotic Immune Thrombocytopenia
YLL: Years of Life Lost

Evidence Extraction Table

Table 4. Evidence extracted from primary literature. 36 pieces of primary literature were included in this review.

Reference	Study Type	Targeted Population	Vaccination Strategy / Modelling Assumptions	Effects of Vaccination Strategy / Optimal Vaccination Strategy	Notes
Adibi et al, preprint Canada (BC)	Modelling	"Front-line workers" (occupation unspecified)	- Allocating all doses of AstraZeneca vaccine (246700) to front-line workers, despite VIPIT risk, and offering mRNA vaccines to this population after those over 60 years old are fully vaccinated - Assumptions: first vaccine dose is 80% effective against illness and 75% effective against transmission; optimal uptake by front-line workers - Scenarios: A: Immediately prioritize front-line workers for AZ vaccine B: Delay front-line vaccination until after those with age-related risk, then offering mRNA vaccine to front-line workers	Compared to scenario B, scenario A led to: - 27175 fewer COVID-19 cases - 506 fewer hospitalizations - 87 fewer deaths - 1462 fewer cases of Long COVID - Expected number of deaths due to risk of VIPIT from the first AZ dose is 0.337 [95% CI 0.206-0.496] - probability of observing at least one VIPIT-related death in the same period is 28.6%. - Expected number of deaths due to VIPIT risk after second dose is 0.676 [95% CI 0.413-0.995]. - The probability of observing at least one VIPIT-related death by the end of the summer will be 48.9%. - The ethics of this approach were not considered here	- Preprint manuscript written late March 2021; risks of VIPIT may have changed at time of synthesis - VIPIT modeling based on risk estimates from European Medicines Agency
Babus et al., preprint United States	Modelling	Occupation and age	- Age groups: 16-19, 20-29, 30-39, …, 80+ - 454 eligible occupations - Infection rate inferred based on UK coronavirus-related deaths between 9 March – 25 May 2020 - Infection rate for US imputed by relating death rate to physical proximity score for each occupation - vaccine is 50% effective - Assumption: Exposure to virus depends on occupation but infection fatality rate depends on age - Does not account for non-occupational exposure - Scenarios: A: Optimal distribution without a stay-at-home order B: Optimal distribution when a targeted stay-at-home order is implemented and that the individuals who are unable to return to work produce no output	Optimal vaccine allocation with scarce supply: **Scenario A:** All employed people above age 60 receive the vaccine. Most essential occupations are eligible for vaccination at age 50, while high risk essential individuals (such as nursing) are eligible at age 40 **Scenario B**: Employees who are 80+ and some 70-80 years are mandated to stay at home but cannot work. Vaccines are allocated to essential workers over 50 years, and nurses over 40 years **Scenario C**: Vaccines can be distributed to all individuals who must be present in the workplace, regardless of age 50% effective vaccine:1.37% of the employed workforce will still get the virus over the two months until the vaccine becomes widely available. Work from home decreases this to 0.53% 70% effective vaccine: reduces the fraction of infected people close to 1.27% (exercise 1 and 2) or to 0.41% - Increased vaccine supply decreases the fraction of infected people	

Reference	Study Type	Targeted Population	Vaccination Strategy / Modelling Assumptions	Effects of Vaccination Strategy / Optimal Vaccination Strategy	Notes
			C: Optimal distribution when a targeted stay-at-home order is implemented but some individuals can work from home		
Bubar et al., 2021 United States	Modelling	Age – assumption that younger people have a higher risk of transmitting virus	- Strategies for prioritization: (i) children and teenagers (ii) adults between ages 20 and 49 years (iii) adults 20 years or older (iv) adults 60 years or older (v) all individuals - In all strategies, once the prioritized population was vaccinated, vaccines were allocated irrespective of age—that is, in proportion to their numbers in the population. - Reproduction number between 1.1 and 2.0 - Vaccine efficacy of 90% - Scenario 1: vaccines were administered to 0.2% of the population per day until supply was exhausted, with basic reproduction number (R0) = 1.15 - Scenario 2: vaccines were administered to 0.2% of the population per day until supply was exhausted, but with R0 = 1.5	- Direct vaccination of adults older than 60 years of age (60+) always reduced mortality and years of life lost (YLL) more than the alternative strategies when transmission was high [R0 = 1.5, scenario 2] - For lower transmission (R0 = 1.15, scenario 1), vaccination of adults aged 20 to 49 years reduced mortality and YLL more than the alternative strategies, but differences between prioritization of adults aged 20 to 49 years, 20+ years, and 60+ years were small for vaccine supplies above 25% - Prioritizing adults aged 20 to 49 years minimized cumulative incidence in both scenarios for all vaccine efficacies and alternative rollout speeds - Prioritizing adults aged 60+ years was the best way to reduce mortality and YLL for R0 ≥ 1.3 - Prioritizing adults aged 20 to 49 years was superior for R0 ≤ 1.2. - Prioritizing adults aged 20 to 49 years minimized infections for all values of R0 investigated	
Buckner, Chowell & Springborn, preprint United States	Modelling	Age – assumption that younger people have a higher risk of transmitting virus	- Three alternative policy objectives: minimizing expected cases, years of life lost, or deaths. - Six age groups: 0-4, 5-19, 20-39, 40-59, 60-74, 75+ - Two occupation groups: nonessential workers (20-39, 40-59) and essential workers (49% of population, ages 20-39*, 40-59*) - Social distancing and contact rates included in model - R0 = 2.5 - Vaccine efficacy = 65%; doses for 60% of population	- **Minimizing deaths:** targeting progresses from older essential workers (40-59*), to the oldest (75+), to younger seniors (60-74), and then younger essential workers (20-39*) **- Minimizing YLL**: younger essential workers and younger seniors are targeted earlier (given their longer average years of life remaining - **Minimizing infections**: younger essential workers take top priority, followed by older essential workers and school-age children (5-19) - Each key outcome is reduced by 17-18% in the respective scenarios - Opportunity cost for minimizing deaths is high with respect to reducing infections; minimizing YLL is the best option for reducing deaths AND infections	

Reference	Study Type	Targeted Population	Vaccination Strategy / Modelling Assumptions	Effects of Vaccination Strategy / Optimal Vaccination Strategy	Notes
Buhat et al.,preprint Philippines	Modelling	Hotspots (cities) after frontline workers and those with medical risk	- Maximum R0 = 4 - Population size and density of each city taken from 2015 government statistics - Priority groups for vaccination: frontline health workers and uniformed personnel, senior citizens, and indigent population - the total number of vaccines for allocation is equal to 50% of the total population, and that the effectiveness rate of the vaccine is 90% - Vaccine costs considered as a resource constraint	- If budget is considered: 30,361,078 complete vaccines with 17,053 deaths; 562 deaths per million vaccines - If budget is not considered: 54,973,950 complete vaccines with 6,795 deaths; 123 deaths per million vaccines - If additional vaccines will be acquired, the best option for every unit of increase in supply should be to allocate it to Manila since for every 1000 additional vaccine allocations in Manila, projected deaths will decrease by around 5 - As population coverage of the vaccine increases, the number of cases decrease even if vaccine effectiveness is suboptimal - Allocating vaccines based on population size resulted in the highest number of death projections, while allocating based on the number of infections generated the lowest death projections	- Unclear if “vaccine” refers to one or two doses
Chapman et al., preprint United States	Modelling	Essential workers	- Population risks and values based on California data to December 2020 - Study outcomes: infections, clinical cases, deaths, disability-adjusted life years (DALYs) - Scenarios: (i) random allocation in individuals ≥20 years (ii) special population targeting (incarcerated adults, then education workers, and then persons experiencing homelessness) (iii) age-based targeting (oldest age group (≥80 years) to the youngest (20-to-29-year-olds) in 10-year increments) (iv) essential worker targeting (first allocated to frontline essential workers due to their higher infection risk, and then to non-frontline essential workers; CDC occupation classification) (v) comorbidity targeting (individuals with any comorbidities were prioritized over those with no comorbidities) - All healthcare workers & LTC residents vaccinated first	Base case: 5 million vaccinations - **Averted DALYs**: age-targeting performed the best of the strategies targeting by a single risk factor, followed by comorbidity targeting, then special population targeting and essential worker targeting - **Averted deaths:** Age targeting averted 9,100 deaths (95% CI 8,900-9,300; 65% of total deaths). Comorbidity-targeting, special population-targeting and essential worker-targeting averted 5,500 deaths (95% CI 5,300-5,700; 39% of total), 4,900 deaths (95% CI 4,700-5,100; 35% of total) and 4,600 deaths (95% CI 4,500-4,700; 33% of total), respectively - **Averted Clinical Cases:** Essential-worker-targeting averted 101,000 cases (95% CI 87,000-115,000, 17% of total). Comorbidity-targeting and special-population-targeting averted 99,000 cases (95% CI 88,000-115,000; 16% of total cases) and 94,000 cases (95% CI 82,000-108,000; 15% of total) respectively. Age-targeting averted 75,000 cases (95% CI 67,000-84,000; 12% of total), fewer even than random allocation (94,000, 95% CI 82,000-108,000; 15% of total).	- Unclear if “vaccination” refers to one or two doses - Does not state the R0 value used in the model

Reference	Study Type	Targeted Population	Vaccination Strategy / Modelling Assumptions	Effects of Vaccination Strategy / Optimal Vaccination Strategy	Notes
			- Vaccine 95% effective at preventing clinical disease but no impact on transmission - Vaccine availability corresponding to 5%, 13%, and 26% of the California population	- Orders of prioritization are robust across different vaccine availabilities and efficacy	
Chen et al., preprint United States	Modelling	Number of social contacts	- Health status based on data from Virginia through December 19, 2020 - Non-pharmaceutical interventions (NPIs) Masks, handwashing, social distancing, virtual learning, and isolation of symptomatic individuals included in model, and these behaviors relax as vaccination proceeds - Vaccine assumed to be 90% efficacious against infection, 50% efficacious against severe illness, and have no effect on transmission - Prioritization schemes: (i) No priority. Everyone 18+ years old is vaccinated with the same probability. (baseline) (ii) Essential workers. This strategy targets those who work for medical, care facilitation, retail, education, military, and government. (iii) Older people. This strategy prioritizes those who are at least 50 years old. (iv) High degree. Degree of an individual is the number of contacts per day. This strategy targets those in the top quartile among all 18+ years old in terms of degree. (v) Long total contact. Weighted degree of an individual is the total contact time this individual has with other people in a day. This strategy targets those in the top quartile among all 18+ years old in terms of weighted degree	- Assuming that the current non-pharmaceutical interventions remain at the same level over the next few months, by the end of March 2021, degree-based schemes can result in 56–110k fewer infections, 3.2–5.4k fewer hospitalizations, and 700–900 fewer deaths in the state of Virginia, compared to age-based schemes - All degree-based strategies can reduce infections by over 20% while all other strategies can reduce infections by at most 20% - Prioritizing people with high weighted degree (total contact durations) is even more effective than prioritizing those with high degree (with no NPI relaxation, targeting people of high weighted degree can reduce infections by about 23-30%, compared to targeting high degree people, which can reduce infections by about 21-26%) - Even with 50% vaccine efficacy, the degree- based strategy can reduce infections by 202K, hospitalizations by 13.7K, and mortality by 3.4K, by the end of March 2021 - All strategies targeting either essential workers or high degree people outperform the no-priority distribution. The degree-based strategies reduce incidence more than any other strategy	
Cook et al., 2021 UK	Modelling	Occupational risk	- Data from existing COVID-19 patient databases to estimate mortality, ICU admissions, and hospitalizations based on age and medical risk - Model 1: based only on age bands and ignored adjustments for health and social care workers (group 2), the extremely clinically vulnerable	- Health and social care workers estimated to account for 625 additional deaths, 5380 hospital admissions and 662 ICU admissions when not prioritized for vaccination - 2-4% improved reduction in hospitalizations in ICU admissions and hospitalizations when health and social care workers prioritized for vaccination	- Very challenging article to interpret and read

Reference	Study Type	Targeted Population	Vaccination Strategy / Modelling Assumptions	Effects of Vaccination Strategy / Optimal Vaccination Strategy	Notes
			aged < 70 years (group 4) and those at risk aged < 65 years (group 5) - Model 2: Prioritization for health & social care workers - Model 3: Prioritization for health & social care workers, extremely clinically vulnerable and at-risk	- vaccinating through adults age 60-69, with or without clinical risk has a substantial impact on all three metrics including reducing hospital admissions by > 80% and ICU admissions by almost 70% - Prioritization effect on deaths plateaus after those over age 60 are vaccinated, but reductions in hospitalizations and ICU admissions continue as younger adults are vaccinated (ages 18-59)	
Dooling et al., 2021 United States	CDC Advisory Committee recommendations	Non-healthcare essential workers with high workplace exposure	- Individuals in Phase 1b are offered the vaccine AFTER LTC residents and healthcare workers, but BEFORE persons aged 65–74 years, persons aged 16–64 years with high-risk medical conditions, and essential workers not already recommended for vaccination - This strategy incorporates exposure risk with equity concerns, as many essential workers in critical infrastructure belong to racial and ethnic minority groups		- CDC recommendation only, no data to show effect on transmission
Foy et al., 2021 India	Modelling	Exposure / transmission risk from number of social contacts based on age	- Two vaccine scenarios: sterilizing immunity & non-sterilizing immunity - Vaccination prioritization: (1) vaccines are distributed evenly across the entire population (2) 20–40 years (3) 40–60 years (4) ≥60 years - 2-15% dose availability - R0= 2.4	- In both sterilizing and non-sterilizing immunity, the greatest reduction in deaths is conferred by when those ≥60 years are prioritized first (ie. by medical risk) - All prioritization strategies result in extremely similar reductions in symptomatic infection rates, with the optimal strategy being dependent on the specific implementation and vaccine - The relative benefit of prioritizing vaccine allocation among older adults compared to other strategies is highest under slower rollout speeds, while overall benefit is greatest the faster the rollout speed	- Does not model disease incidence for each prioritization strategy
Giubilini, Savulescu & Wilkinson, 2020 UK	Ethical analysis	Young people (children) – high number of social interactions	- Scarce health resources are not and should not necessarily be allocated purely according to need in order to maximize their expected benefits - Children are less likely to experience severe consequences and to die of flu, they tend to get infected more frequently, to remain infected for longer, and therefore to become vectors for the contagion of the elderly, who are not adequately protected by the vaccine. It is hypothesized that this is also the case for COVID-19 - Indirect immunity might well confer more protection to the elderly and the other vulnerable population groups than direct vaccination - The greatest benefit of vaccinating children en masse will accrue to the vulnerable ones through indirect protection, rather than to the vaccinated children themselves. - Children and young people, and society more broadly, are paying a high cost for the sake of protecting the vulnerable. It may be that the sacrifices of being vaccinated for a child are smaller than the sacrifices of lockdown.		- Ethical analysis only; does not include real-world data

Reference	Study Type	Targeted Population	Vaccination Strategy / Modelling Assumptions	Effects of Vaccination Strategy / Optimal Vaccination Strategy	Notes
Goldenbogen et al., preprint Germany	Modelling	High levels of human-human interaction	- To evaluate the effect of NPIs (eg. lockdown) we simulated a baseline scenario representing an uncontrolled outbreak - Analysis of age-specific interaction patterns reveals strong interactions within households, indicated by overrepresentation of interactions within and between adjacent age cohorts (partnerships) and parent-child related age-cohorts. Underaged individuals, as well as the working population, show stronger interaction with members of the same group, as apparent from rectangular interaction patterns representing school and workplaces. - 70% of infections originate from only 20% of the infected population and that 70% do not spread the infection further - Model assumes ICU capacity is not exceeded and there is no additional mortality due to lack of health system capacity	- To reduce number of infections: it is most effective to vaccinate the most interactive individuals first, as it reduces the probability for an emerging infection wave, and thus increases systemic robustness. - To reduce fatalities: the age-sorted strategy is very effective at low vaccination levels and outperforms all other strategies significantly. However, for the high vaccination levels at which other strategies display population level immunity, those other strategies surpass vaccination by age - To reduce ICU occupancy: vaccination by age performs best at less than ~58% but vaccination by interactivity is best above this level. However, below 63% vaccination, none of these strategies is able to prevent overload of ICU capacity, without additional non-pharmaceutical interventions. - The “combined” strategy integrates the two strategies that either best reduce infections (i.e. by interaction) or death toll (by age), however it outperforms neither	- Does not note assumed R0 or vaccine efficacy
Grauer, Lowen & Liebchen, 2020 Germany	Modelling	Geographic hotspots	- R0= 2.5 – 3 - Social distancing included in models - 1% vaccinated per day Vaccination strategies: (i): infection-weighted strategy: available vaccine is distributed proportionally to the calculated bi-linear incidence rate (ii) focusing strategy: sequentially prioritizing the regions (cities) with the highest bi-linear incidence rate, and correspondingly the highest number of new infections in a certain time frame (iii) demographic strategy: vaccines distributed proportionally to population density	- The fraction of deaths, counted once the disease is gone, is generally highest for the demographic strategy, followed by the infection-weighted strategy, and lowest for the focusing strategy - In cities of different sizes, the focusing strategy and the infection weighted-strategy halve the number of deaths compared to the demographic strategy **Infection-weighted strategy** - Number of infections peaks when only 11% of the population has received vaccines and only 1% is infected (approx. day 14) **Focusing strategy** - Number of infections peak further shifts to earlier times (golden curve in panel a) and occurs when only 0.6% of the population is infected (approx. day 14) - When R0 = 1, deaths are reduced by 35% **Demographic strategy** - infection maximum occurs about 30 days (two infection cycles) after the onset of vaccine production, i.e. when	- Authors do not describe the assumed vaccine effectiveness

Reference	Study Type	Targeted Population	Vaccination Strategy / Modelling Assumptions	Effects of Vaccination Strategy / Optimal Vaccination Strategy	Notes
				about 22% of the population have received vaccines and 2% of the population is infected (approx. day 30)	
Hasan et al., 2021 Australia	Rapid systematic review of mass vaccination strategies	N/a	- Six countries simultaneously prioritized both health care workers (HCW) at risk of exposure to the virus, as well as elderly individuals in care facilities - Three countries prioritized frontline HCWs over elderly individuals in facilities and three prioritized the elderly in facilities over frontline HCWs - Three national policy documents discussed the prioritization of those in institutional care, or younger people with chronic conditions		- Prioritizing individuals at risk of transmission (ie. non-healthcare essential workers) is not common in English-speaking countries that are comparable to Canada
Herings et al., preprint Netherlands	Modelling based on cohort data	Working age people compared to medical risk	- Vaccination strategy based on predictive model of severe COVID-19 complications (sCOVID), built based on characteristics of 6074 Dutch COVID-19 patients - For each vaccination strategy the amount of vaccinations needed to reach a 50% reduction of severe complications was calculated. - Six different population vaccination scenarios were explored: 1) random (naive) 2) random for persons above 60 years (60plus) 3) oldest patients first in age bands of five years (oldest first) 4) target population of the annual influenza vaccination program (influenza) 5) those 25-65 years of age first (worker) 6) risk-based using the prediction algorithm (sCOVID).	- Vaccination coverage needed for 50% risk reduction: 1) random (naïve): 50% 2) 60plus: 18.1% 3) Oldest first: 10% 4) Influenza: 26.1% 5) Worker: 67.5% 6) sCOVID: 8.4%	- Model does not discuss effect on transmission - Model does not state assumed R0 or vaccine efficacy
Hoertel et al., preprint France	Modelling	Population of working age	- Vaccine efficacy: 95.6% in 16-55 year olds (Pfizer), 93.7% in 65-75 years (Pfizer) - Modeled scenarios: (i) no vaccination (ii) vaccination of the full population (iii) vaccination of adults aged less than 65 years (iv) vaccination of adults aged more than 45 years	- All scenarios except (v) and (vi), would allow lifting of NPIs, if they were applied immediately, based on a cumulative mortality rate lower than 17 per 100,000 and a cumulative hospital admission rate lower than 240 per 100,000 - Immediate vaccination of the full adult non-immunized population would result in a 97.5% [95% interval: 97.0; 97.9] decrease in cumulative incidence, a 95.4% [95%	- risk of transmission in people of working age is implied

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			(v) vaccination of adults aged less than 35 years or more than 65 years (vi) vaccination of adults aged more than 65 years (vii) vaccination of adults aged more than 55 years with mandatory vaccination of adults aged more than 65 years (assuming that it would lead to a 90% vaccination rate in this population) (viii) vaccination of individuals at higher risk for severe SARS-CoV-2 infection - Model includes NPIs	interval: 94.4; 96.5] decrease in mortality, and a 97.4% [95% interval: 96.8; 98.0] decrease in cumulative hospital-bed occupancy - Vaccinating only adults aged over 45 years, or only adults aged more than 55 years with mandatory vaccination of those aged over 65 years, would also enable lifting all NPIs - Model is robust in ± 20% sensitivity analysis	
Hunziker et al., preprint Switzerland	Modelling	Younger age (higher social interaction)	- Personalized dose vaccination strategy: older people with medical risk receive a full (standard) dose of vaccine, while younger people receive a quarter dose to increase vaccine coverage - Modeled using the efficacy and immunogenicity data from the Moderna vaccine - Vaccine efficacy set to 86.2% for both elderly full dose and younger quarter dose - Scenarios: “elderly first”: starting with regular dose vaccination until 80% of the elderly are covered, then vaccinating the younger at regular dose. “younger first”: starting with regular dose vaccination in the younger, leaving the elderly aside during the first 100 days “personalized-dose”: in parallel, using half of the stock for each, vaccinate the elderly at full dose and the younger at quarter dose “personalized-dose, the younger first”: starting with quarter dose vaccination in the younger, leaving the elderly aside until 80% of the younger are vaccinated, then vaccinating the elderly at full dose	- “elderly first”: a cumulative death count of 153’000 over 100 days. Case numbers fall below 100’000/day on day 64 and the daily deaths fall below 1’000/day on day 55 - “younger first”: Overall death count of 184’000, with case rates falling below 100’000/day on day 42 and death rates falling below 1000/day on day 70 - “personalized-dose”: Cumulative deaths of 128’000 in 100 days. The milestones of <100’000 deaths/day are reached on day 30, and of <1000 deaths/day on day 49 - “personalized-dose, younger first”: Overall deaths of 121’000 in 100 days; <100’000 cases/day in 22 days and <1000 death/day in 45 days; however, likely to be perceived as unjust	- This model requires a stock of Moderna vaccine - Authors do not state the assumed R0
Hogan et al, 2020 UK	Modelling	High number of contacts (elderly vs. working age individuals)	- “Efficiency” for the vaccine is to maximize the number of averted deaths - Vaccine efficacy assumed at 70%	- In all settings, if doses are limited, the most efficient approach is to vaccinate the most vulnerable elderly population, starting at the oldest age group and working downwards	- Model tested prior to vaccine development (September 2020)

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			- NPIs included (facemasks, working from home and test/trace/isolate) - R0 = 2.5 - We compare this optimal strategy to two age-targeted approaches. In the first we sequentially allocate from the oldest age group downwards (i.e. 80+, 75+, 70+ etc.). In the second we target the working-age population first starting with the highest risk group (i.e. 60–64) and working downwards by age, and then sequentially add in the younger and older age groups either side of the working age population until the whole population is covered	- In high-income countries (HIC), upper-middle-income countries (UMIC), and lower-middle-income countries (LMIC) the optimal allocation strategy is of "herd impact' when there are sufficient doses for 20-40% of the population. Vaccine is allocated to younger populations (including children and adults) so that transmission is reduced in the wider community and this indirectly reduces the risk to the vulnerable elderly population to a greater extent than is afforded by direct protection - in the UMIC and LMIC settings we obtain a "mixed" approach at these intermediate dose availability levels, with both the highest risk elderly and younger populations included. This is due to greater mixing between the older and general populations in these settings, as well as the size of the high-risk older populations, which are generally smaller than in HIC and middle-income countries (MIC)	- Does not model health system capacity or disease incidence
Ives & Bozzuto, preprint United States	Modelling	Geographic hotspots	- Vaccine allocation to US counties based on transmission rate (R0) instead of population size - Counties with higher R0 values require higher levels of vaccination to achieve herd immunity (1 − 1/R0). - Assumptions: (i) the vaccination rate (the first dose of the Pfizer-BioNTech and Moderna vaccines, or the single-shot Johnson & Johnson vaccine) is 1.58 million doses per day, starting from March 15, 2021 (day 0 on the x-axis in Fig. 1) when 71.1 million people had already been vaccinated with at least a single dose (ii) vaccines are 90% effective (iii) vaccinated individuals cannot spread COVID-19	- At the current rate of vaccine distribution, universal herd immunity in the US could be reached in roughly 130 days with the current population size-based distribution strategy - distributing vaccines according to R0 would mean that herd immunity is reached in all counties at the same time, about 51 days earlier than the last county under the current distribution. - 39% fewer vaccine doses would be required to achieve universal herd immunity if vaccines were distributed according to R0. - High-density counties have relatively large African American populations and the current distribution plan leads to a lag of about 4 days behind whites in reaching herd immunity	
Jain et al., 2021 United States	Jurisdictional scan	"Essential workers"	- all U.S. States prioritized frontline healthcare workers and those in long-term care facilities for vaccination as per Federal guidance - First responders were one single group in Federal guidance, including health (e.g., paramedic) and non-health (e.g., police/fire) workers. In State guidance, these groups were often prioritized differently		- High variability between the US Federal recommendations and State

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			- Of the 37 States including frontline essential workers, 12 assigned them to a lower priority than recommended in Federal guidance - Other essential workers (placed in the third phase of Federal recommendations) were included on only 22 State priority lists, although at the recommended Federal position in the majority of cases where present.		prioritization lists; in general, vaccines are allocated based on medical risk
Jentsh, Anand & Bauch, 2021 Canada (Ontario)	Modelling	High number of contacts	- Transmission occurs through an age-specific contact matrix - susceptibility to infection is age-specific - NPIs included in model (closed schools and workplaces) - Vaccine is 75% efficacious against infection and transmission - Scenarios: (i): Oldest-first strategy: the vaccine is administered to individuals aged 60 years or older first. After all individuals in this group are vaccinated, the vaccine is administered uniformly to individuals of other ages (ii): Youngest-first strategy: the vaccine is administered to individuals younger than 20 years of age first. (iii): Uniform strategy: the vaccine is administered to all age groups uniformly from the very start (iv): Contact-based strategy: vaccine allocated according to the relative role played by different age groups in transmission. This strategy tends to prioritize ages 15–19 year first, 20–59 year second, and gives least priority to older or younger ages	- vaccinating people aged 60 years or older first prevents the most deaths out of all four strategies if vaccination begins on Jan 1, 2021 - the uniform or contact-based strategies prevent the most deaths if vaccination begins on Sept 1, 2021, and the vaccination rate ranges from 1% to 2·5% of the population per week. - **Regime 1:** Vaccination starts on Jan 1, 2021, and the vaccination rate is relatively high (≥1·0% of the population per week). A third wave in the autumn of 2021 or winter of 2022 is thereby prevented. In this regime, enough people are vaccinated sufficiently far in advance to prevent a third wave, but the oldest-first strategy prevents more deaths than the other strategies - **Regime 2**: either vaccination starts early (Jan 1, 2021) but the vaccination rate is low (≤0·5% of the population per week), or vaccination starts late (Sept 1, 2021) but the vaccination rate is high (≥1·5% of the population per week. A sufficient proportion of the population is vaccinated for indirect protection from the vaccine to become important during the third wave, but not enough individuals are vaccinated to completely prevent it. As a result, the uniform and contact-based strategies are more effective than the oldest-first strategy, but the youngest-first strategy does worst of all **Regime 3:** vaccination starts late (Sept 1, 2021) and the vaccination rate is relatively low (≤1·0% of the population per week). This scenario does not allow enough time for indirect protection from vaccination to become strong. As a result, the oldest-first strategy prevents more deaths than the other three strategies. Overall mortality is higher for all strategies compared with the other two regimes on account of the delayed rollout of the vaccine	

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Kohli et al., 2021 United States	Economic modelling	Occupation	- Three prioritization strategies based on: (i) age (vaccinated sequentially from oldest to youngest) (ii) risk and age (vaccinated by medical risk followed by age tiers) (iii) occupation and age (essential workers, followed by age tiers) - Three supply scenarios: (i) “high supply”: four vaccines are successfully launched and supply is fulfilled as estimated in these disclosures. (ii) “medium supply”: manufacturers’ estimated final supply is delayed by one quarter (iii) “low supply”: final supply is delayed by two quarters - Vaccine efficacy assumed to be 60% - Base case: no vaccine - Assumes standard willingness to pay threshold of $50000 US	- For the age-based and risk-based prioritization schemes, vaccination is less costly and more effective than no vaccination for the highest risk individuals. - For both schemes, the incremental cost per QALY gained increases for Tiers that included individuals with lower risk of hospitalization and death due to COVID-19. - For the occupation-based scheme, the incremental cost per QALY gained for Tier 1 (priority and critical occupations) is $20,000, while vaccination is cost-saving for Tier 2 (age 65 years and above) - The difference between the prioritization schemes narrows as the vaccine supply increases - In all vaccine supply scenarios, the occupational prioritization scheme prevents fewer COVID-19-related outcomes than the age-based or risk-based scheme because of the younger ages reflected in the Tier 1 critical occupations target group in the model - Economic models do not consider the ethics of vaccine allocation	
MacIntyre, Costantino &Trent, preprint Australia (Victoria)	Modelling	Age (high transmission)	- R0 = 2.5 - Vaccine efficacy: 90% - Strategies: 1. Limited vaccine supply (1 million doses) given to targeted age groups a) Vaccine delivered in 8 days to 1 million young people (age group 10-29) b) Vaccine delivered in 8 days (first dose) to 1 million older people (age group 65+) c) Vaccinate 125,000 HCWs with first dose and over the following 7 days 875,000 people aged 10-29 2. Limited vaccine supply, ring vaccination (contact tracing and vaccination of contacts) 3. Unlimited supply and mass vaccination assuming enough doses to vaccinate the entire NSW population	**- If supply is restricted (1 million doses),** targeting the younger age group will have more impact on reducing the number of cases, whilst vaccinating people 65+ will have more impact on deaths, as this age group is at much higher risk of death - **with a limited vaccine stockpile** the most efficient way to delivery vaccine doses will be ring vaccination, assuming a 45% efficacy when used as PEP, and at least 90% of contacts per case traced and vaccinated. Ring vaccination with at least 90% of contacts traced can rapidly reduce disease incidence, cumulative cases, and deaths. - **With unlimited vaccine supply**, mass vaccination with a high efficacy vaccine and rapid uptake (at least 75,000 people vaccinated per day) will be the only strategy able to achieve herd immunity and prevent community transmission	

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Matrajt et al., preprint United States (Washington State)	Modelling	Younger age (high transmission)	- Five vaccination groups: (i) children (aged 0–19) (ii) adults between 20 and 49 years old (iii) adults between 50 and 64 years old (iv) adults between 65 and 74 years old (v) 75 and older. - Assumes that front-line health care workers and other essential personnel (e.g. firefighters, police) who should obviously be prioritized, have already been vaccinated. - Vaccine effectiveness (VE) = 10-100% - Vaccine coverage 10-100% - R0 = 3	- The epidemic can be substantially slowed with any vaccine with a VE ≥ 50% as long as a majority of the population is vaccinated - The models below do not change when considering existing population immunity to SARS-CoV-2 - For minimizing deaths and ICU peak hospitalizations, when R0 = 1.5, the optimal allocation strategy favors vaccinating children for low VE but is more equally distributed if VE = 60% and favors vaccinating the older age groups for higher VE **When VE= 10-50% and vaccine is scarce (<30% coverage)**: - Priority is given to the highest risk group (over 75 years old) to minimize deaths, followed by younger age groups as vaccine is available **When VE ≥60% and vaccine is scarce:** **-** Priority is given to high risk groups to minimize deaths - When enough vaccine is available for roughly half the population, prioritization changes to younger people to limit transmission **When VE=60% and vaccine is scarce (<30% coverage)**: - Priority is given to younger vaccination groups to minimize symptomatic infections and hospitalizations - Older adults (medical risk) are prioritized to minimize severe complications (ICU admissions) and deaths	
Meehan et al., preprint Australia (Victoria)	Modelling	Younger age (high transmission rates)	- Optimal allocation for limiting SARS-CoV-2 mortality, morbidity & transmission by: (i) minimizing the effective reproduction number, R_{eff}, for a fixed number of available vaccine doses (ii) minimizing the number of individuals that require hospitalization as a result of infection during the course of the epidemic (iii) minimizing deaths (iv) minimizing the number of doses required to suppress transmission and achieve elimination ($R_{eff} < 1$)	- Targeted vaccination dramatically reduces the transmission rate (R_{eff}) and cumulative number of hospitalizations and deaths relative to vaccination programs that uniformly distribute doses across the population - Differences between the uniform and targeted strategies are greatest at intermediate levels of population-level coverage (e.g., 40-60%) as results under the two strategies converge when coverage approaches 0 or 100%. - Countries with contacts concentrated among a limited number of age groups (e.g., China) exhibit greater	

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			- Vaccine effectiveness = 90% - Two separate vaccine modes: vaccines that protect against symptomatic disease OR vaccines that reduce susceptibility to transmission - Individuals divided into 10-year age bands from 0−9 up to 70+ years of age.	reductions in each of the three optimization targets (Reff, hospitalizations & deaths) when doses are allocated to priority age groups, as do countries with higher median ages (eg. the UK - Vaccinating individuals between 30 and 49 years of age is the most efficient way to minimize transmission - when doses are limited (e.g., 20% population-level coverage), targeting older individuals (60+ years of age) is the most efficient way to minimize hospitalizations and deaths - for disease-preventing vaccines (which typically fail ever to achieve herd immunity) older age groups consistently receive top priority for reducing hospitalizations and deaths, whereas the results for transmission are equivalent to those for infection-preventing vaccines	
Mishra et al., 2021 Canada (Ontario)	Modelling	Hotspots	- Vaccine efficacy = 60% (reducing infection) - 80% of the population aged 60 years and above would be vaccinated by April 28, 2021 - allocate 50% of COVID -19 vaccines to the 74 COVID-19 hotspots ranked in the top 20% of cumulative SARSCoV-2 incidence among all Ontario neighbourhoods (distributed to 16-59 year olds) and the remaining 50% of vaccines would be equally distributed across the province (including hotspots) - 3 million doses of COVID-19 vaccine are administered over 30 days (100,000 doses per day starting on April 9, 2021) - Assumes 70% coverage in 16-59 y.o. in hotspot communities - Vaccine strategies: (i) Ontario’s initial COVID-19 vaccination strategy (medical risk only) (ii) Strategy that accelerates the vaccination of essential workers, their families and other residents living in COVID-19 hotspots	- the hotspot-accelerated vaccination strategy is projected to prevent an additional 14% of COVID-19 hospitalizations, 14% of COVID-19 ICU admissions and 11% of COVID-19 deaths in Ontario’s population aged 16 years and older compared to age-based strategy - With 3 million doses available over 30 days, the number of vaccinations needed to prevent 1 confirmed SARS-CoV-2 infection is 37 with the initial strategy and 22 with the hotspot-accelerated strategy	- Grey literature
Mulberry et al., preprint	Modelling	Essential workers	- Extension of Bubar et al. using BC data	- vaccinating essential workers earlier gives large reductions in infections, hospitalizations, deaths, and	

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Canada (BC)			- 15 vaccination groups: {0− 9, 10− 19, 20 −29, …, 70 −79, 80+, 20−29e, 30−39e, …, 70−79e}, where the e superscript denotes an "essential worker" group - approximately 13% of the population of BC are considered to be "essential" - R0= 1.05 – 1.5 as model progresses - Includes distancing measures - Vaccine effectiveness = 90%, then vary the effectiveness in preventing infection from 0.6 to 0.9 - Five vaccination scenarios: In all scenarios the 80+ age group is vaccinated first. (i) Scenario A: available vaccines are distributed to age groups in order of decreasing age. (ii) Scenario B: after the 80+ group is vaccinated, the vaccine is distributed to everyone else with no preference for age. (iii-v) Scenario C, D, and E, after the 80+ group, essential workers are then vaccinated without regard for age. (iii) Scenario C: the rest of the population is vaccinated in decreasing order of age. (iv) Scenario D, the rest of the population is vaccinated without regard for age. (v) Scenario E, the 70–79 cohort is vaccinated next and then the rest of the population is vaccinated without regard to age.	instances of Long COVID (cases with symptoms lasting longer than 28 days) - results were similar with a strategy that vaccinates younger people sooner without targeting essential workers, although may result in higher mortality in the elderly - oldest-to-youngest vaccination program leads to considerably more cases and more Long COVID across a range of values of the vaccine's efficacy against transmission and across a range of R values - When R rises to 1.3, strategies placing essential workers after 80+, either continuing with an age-based rollout or opening to all adults aged 20-69 after those 70+, have an advantage in reducing deaths in addition to strong advantages for infections, hospitalizations and Long COVID - Oldest-first vaccination is only the best for deaths as an outcome when efficacy against transmission is extremely low (0.1-0.2) and when R is high - The most QALYs are gained when the oldest are prioritized followed by essential workers	
Rodríguez, Patón & Acuña, preprint Spain	Modelling	Age (High transmission risk)	- Population groups: preschool children (ages 0-4); school children (ages 5-14); higher school and university young (ages 15-24), young workers (ages 25-49); mature workers (ages 50-59); senior workers (ages 60-64); early retired (ages 65-69); retired (ages 70-79); elderly (ages 80+) - Vaccine produces sterilizing immunity - Contact patterns based on Spanish population	- Under the scenario with all population (including children) eligible to be vaccinated, prioritization by mortality results in a number of deaths higher than if no prioritization is followed - When coverage is >50%, prioritization by interactions (from highest to lowest), results in substantial reductions in fatalities compared to no prioritization (~40% lower at vaccine effectiveness of 75%, vaccination rate of 0.75% and population coverage of 80%)	- Authors do not state assumed R0 value

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			- Daily vaccination rate of 0.25-1.5% of population - Vaccine effectiveness: 87.5% - Vaccination scenarios: (i) No group prioritization: all population groups are called for vaccination in equal terms. (ii) Priority by mortality: Age groups are prioritized for vaccination according to their mortality per infection (from highest to lowest) (iii) Priority by interactivity: Population age groups are prioritized for vaccination according to their number of interactions (daily contacts) (from highest to lowest) (iv) R-based Projected Avoidable Deaths (RbPAD) criteria. (v) The best of all the possible sequences of groups priority. All possible permutations of the age groups. This approach selects the permutation with lowest number of deaths as the best sequence.	- a vaccine effective both against infection and transmission would have a greater impact by following a prioritization based on interactions than following a prioritization based on mortality, especially at a population coverage of 50% and above. - for a vaccine effectiveness of 87.5%, prioritizing by mortality appears to be worse than no prioritization in practically all cases except marginally the opposite in extremes of very low daily vaccination rollouts (0.1 %) and for very high coverage (95 %) - prioritizing by interactions appears to be practically equal to no prioritization at high vaccination rates but substantially superior strategy (a reduction of over 8000 fatalities) at low daily vaccination rollouts - When children are not included in the vaccination campaign, the total fatalities predicted are higher than for the scenario that includes children in vaccination. he prioritization by interactions appears still superior than no prioritization.	
Rosen, Waitzberg & Israeli, 2021 Israel	Policy analysis	n/a	- The initial target groups for vaccination in Israel were people aged 60 and over, nursing home residents, other people at very high risk due to serious specific medical conditions (mostly those related to compromised respiratory systems), and front-line health care workers - Before deciding to prioritize the groups at the greatest health risk, the relevant committee considered an alternative strategy – prioritizing those groups most involved in transmitting the disease. After deliberating the two strategies prioritization of those at greatest health risk emerged as the consensus. - Since the start of 2021, it has been possible to extend immunization to additional groups, such as teachers and persons under age 60, and significantly increase the percentage of the population covered		
Saraswat, Ansumali & Prakash, preprint India	Modelling	Risk of transmission in a multi-generational home	- Vaccine effectiveness of 67% in reducing infections, 70% in reducing the transmission - "Adult" = 20-60 years old; "Senior" = 60+ years old - The focus of this work is on how vaccination of the "Adults" (ages 20 to 60) reduces the secondary infections and deaths among the "Seniors" (ages 60 and above). - two different strategies:	- By adopting a targeted strategy, the susceptible Adults from multigenerational families may all be vaccinated in a relatively short time of 52 days if administered at 2 million doses per day, compared to a uniform age-based strategy - In most realistic scenarios, the number of deaths among the Seniors due to transmissions from the adults in the family are likely to be reduced by over 100,000 due to the targeted strategy	- Authors do not state assumed R0 value or population coverage

Reference	Study Type	Targeted Population	Vaccination Strategy / Modelling Assumptions	Effects of Vaccination Strategy / Optimal Vaccination Strategy	Notes
			(i) age-based roll-down to younger populations (ii) preferential targeted vaccination of younger members from multigenerational homes.		
[Shayak et al., preprint](#) United States (New York State)	Modelling	High interaction rate based on occupation	- Assumes all healthcare workers are prioritized first - R0 = 1.3 - Vaccination rate of 600/day - Vaccine effectiveness = 80% - Model population = 3 million people - Reference case: 10 percent of the population has an interaction rate significantly higher than the remaining 90 percent - Vaccination strategy: (i) Population-based: the vaccines are allotted to the high- and low-interaction classes in proportion to their population. (ii) Interaction-based: vaccines are allotted to the high-interaction class first	**No vaccines**: - Epidemic endpoint at 241 days. - The terminal number of cases is 1,27,600 - Epidemic peak at ~70 days **Population-based strategy**: - Entire population vaccinated in 500 days - Epidemic peak at ~70 days - Outbreak endpoint at 214 days, - Total case count is 71,000 cases have broken out - nearly 1,25,000 vaccines have been distributed **Interaction-based strategy:** - Epidemic endpoint is 203 days. - Epidemic peak however comes 20 days earlier than with the population vaccination (~50 days) - total case count has reduced to less than 16,000. - The number of vaccines distributed up to the end is just less than 1,18,000	
[Shim, 2021](#) South Korea	Modelling	Age (younger people have higher transmission rates)	- R0= 2.6 - 16 age groups (0–4, 5–9, 10–14, …, 65–69, 70–74, and ≥75 years) - Vaccine assumed to provide partial protection - Vaccine efficacy = 70% (unless otherwise stated)	**When vaccine coverage is 50% (with two doses per vaccine recipient) and vaccine efficacy is 70%** **-** the incidence-minimizing strategy prioritized the vaccination of individuals aged 20–49 years to reduce the incidence by 61% - To minimize mortality, the vaccines should be allocated to older adults aged 50 years and above, which would reduce total COVID-19 mortality by 70% across age groups - To minimize Years of Life Lost, vaccines should be allocated to adults aged 40–69 years because of the higher number of expected life-years remaining in this age group **When vaccine coverage is <50% with 70% efficacy:** - the incidence-minimizing strategy switched to prioritizing those aged 10–19 years and 30–49 years due to active transmission between school-aged children and their parents	

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				- the YLL-minimizing strategy narrowed its prioritization to adults aged 50–69 years due to a combination of the expected life years remaining and the greater infection severity in this age group - The mortality-minimizing strategy was optimized by vaccinating the elderly (age ≥70 years) and using the remaining doses for adults aged 60–69 years. **When vaccine efficacy is low (undefined):** - reducing vaccine efficacy against infection elevated the prioritization of vaccinating teenagers when the vaccine supply was increasingly limited - the YLL-minimizing strategy switching from vaccinating individuals aged 30–59 years to vaccinating those in the ≥50-year age group. When vaccine supply is very limited, individuals in the age group of 10–19 years and 50–59 years should be vaccinated in the optimal allocation strategy to minimize YLL **When R0 = 1.5 and vaccine efficacy = 90%** - the optimal vaccine allocation is generally focused on younger adults aged 30-49 years across all three aims - When vaccine supply is high, all three optimal strategies lead to a broader vaccination strategy of those aged 10–69 years, with a small fraction of vaccines prioritized for those aged 0–9 and ≥70 years. - When vaccine supply is <50%, the incidence-minimizing strategy prioritized the vaccination of individuals aged 30–59 years, while the mortality-minimizing strategy and the YLL-minimizing strategy prioritized individuals aged 10–19 and ≥50 years	
Sjödin, Rocklöv, & Britton, 2021 Sweden	Modelling	Age (younger people have higher transmission rates)	- 10-year age groups (0-10, 11-20, 21-30, …, 71-80, 80+); individuals under age 20 are not eligible for vaccination - Vaccine efficacy = 95%, 90% adherence - Strategies: (i) Ascending age order of vaccination (70+, followed by 20-29, 31-39, etc.) (ii): Descendng age order of vaccination (70+, followed by 60-69, etc.)	- The outcomes for regular healthcare, critical care and fatalities are lower (i.e., better) for a Descending age order of vaccination, whereas incidence is lower (i.e., better) for an Ascending age order of vaccination - vaccination in ascending order has a stronger effect on transmission than descending order, but doesn't compensate for the large healthcare load of later vaccination in ages 50+	

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				- Vaccinating in a descending age-order, instead of in an ascending age-order, reduces the number of patients needing critical care by 2-11% - The relative reduction effect from vaccinating in descending order is negative for number of cases; (ie increases transmission) but decreases the remaining three health burden outcomes (mortality, critical care, and hospitalization)	
Tatapudi, Das & Das, preprint United States (Florida)	Modelling	High transmission risk due to occupation	- Incorporates contact dynamics, social distancing and public health activities utilized for COVID-19 in Miami-Dade County - Pfizer and Moderna vaccines (high efficacy) - Vaccine scenarios: (i) CDC: Priority 1: healthcare providers and nursing home residents; Priority 2: first responders, educators, and people of ages 75 and over; Priority 3: people of ages 65 to 74; Priority 4: people of ages 16 to 64 (ii) Age-stratified: Priority 1: healthcare providers and nursing home residents; Priority 2: people of ages 65 and over; Priority 3: people of ages 55 to 64; Priority 4: people of ages 45 to 54; Priority 5: people of ages 16 to 44 (iii) Random: Priority 1: healthcare providers and nursing home residents; Priority 2: all people of ages 16 and over	- All strategies reduce reported cases compared to no vaccination - No significant difference between reported cases, hospitalizations, or deaths between the three strategies - For a vaccination campaign starting on Dec. 15, 2020 the Random strategy is expected to have <100 cases/day on May 7, 2021, compared to May 17 for the CDC strategy, May 22 for Age-Stratified, and June 12 for no vaccination	- Does not state assumed R0 or vaccine efficacy
Tran et al., preprint United States (Rhode Island & Massachusetts)	Modelling	Transmission risk based on age	- Assumed vaccine efficacy = 95% - Medium transmission: transmission levels are set to their September through November mean value (16.8% for RI and 16.5% for MA) - Vaccination strategies are considered where doses are made available for 4.7% or 28.3% of the population - total cumulative number of cases, hospitalizations, and deaths through to 30 June 2021 - Vaccine strategies:	**Reducing case numbers:** - Including the middle age groups (20-39 or 20-49) results in an overall benefit with average reductions of 1.24% (IQR: 0.94% − 1.64%) when including the 20-29 age group, 1.08% (IQR: 0.73% − 1.46%) for the 30-39 group, and 0.34%(IQR: 0.17% −0.63%) for the 40-49 group **Reducing hospitalizations:** - Including the 70-79 age group results in 0.55% (IQR: 0.43% − 0.72%) fewer hospitalizations, and including the 80+ age group results in 1.06% (IQR: 0.84% − 1.35%) fewer hospitalizations	

Reference	Study Type	Targeted Population	Vaccination Strategy / Modelling Assumptions	Effects of Vaccination Strategy / Optimal Vaccination Strategy	Notes
			(1) random, where any individual ≥ 16 in the population can be chosen for vaccination on a particular day (2) 16-29 age group only (3) 30-59 age group only (4) 60-and-above age group only; vaccine supply is allocated to the 20-39 and 60+ age groups in proportions of (4a) 75/25, (4b) 50/50, (4c) 25/75; vaccine supply is allocated to the 20-49 and 70+ age groups in proportions of (4d) 75/25, (4e) 50/50, and (4f) 25/75 - If there is sufficient supply to cover an entire age group, the remaining vaccines are allocated to the second age group. If both age groups have been covered completely, the remaining vaccines are distributed at random in the population to all individuals over the age of 16.	**Reducing deaths:** - including the 70-79 age group results in 0.67% (IQR: 0.48% − 0.95%) fewer deaths, and including the 80+ age group results in 3.95% (IQR: 3.28% − 5.08%) fewer deaths **Low supply scenario (4.7% coverage):** - allocating 25% of vaccines to the 20-49 age group and the remaining 75% to the 70+ age group is optimal in terms of minimizing deaths and hospitalizations - 75/25 allocations (younger/older) are best at reducing case counts and near-optimal at reducing hospitalizations but they are associated with a substantially higher final death count - prioritization of vaccine allocation to the 70+ age group has a modest effect on reducing hospitalizations and a substantial effect on reducing deaths, as much as a 7% difference in cumulative deaths **High supply scenario (28.3% coverage):** - strategies focused on the elderly can reduce cumulative death numbers by as much as 10% when compared to a random distribution strategy - The optimal strategy among those evaluated is a 25/75 distribution to the 20-49 and 70+ age groups, outperforming the 60+ strategy and the 20-39 and 60+ strategy with 25/75 allocation, both of which vaccinate more elderly individuals but do not reduce transmission - Under a 10/90 allocation (younger/older), the mortality benefits are substantial, with 11% fewer deaths when compared to a 90/10 allocation in which the 20-49 age group is vaccinated earlier	
Wang, Wu, & Tang, preprint China	Modelling	Transmission risk based on age	- 16 age groups (0-4,5-9,10-14,…,75+) based on contact data - Vaccination rates = 0.05%, 0.1%, and 0.15% - Outcomes: basic reproduction number (R0), the cumulative number of infections (Ic) and the cumulative number of deaths (Dc) - The optimal age-specific vaccination distribution (OAVD) is determined by minimizing each of the	**India Case:** - Priority of vaccination should be given to teenagers and young people, i.e., those around 10-34 years old to minimize R0 and number of infections - In order to minimize mortality, the OAVD suggests that the high priority should be given to elders in India - the optimal age-specific vaccination strategy can reduce infections by 177,270(8.5%) or reduce deaths by 1,514	

Reference	Study Type	Targeted Population	Vaccination Strategy / Modelling Assumptions	Effects of Vaccination Strategy / Optimal Vaccination Strategy	Notes
			three endpoints from the vaccination initiating time (T) to T+180 days for each country - Models set using population age distributions from India, China and Italy - Vaccination scenarios: (i) uniform vaccination strategy (ii) age-specific vaccination strategy	(27%) compared to that of the uniform vaccination strategy - the effect of age-specific vaccination distribution on the three endpoints is larger when the vaccination rate is higher **Italy case:** - the vaccination priority should be given to young and middle aged people in order to control infections while the priority should be given to the elderly in order to control mortality **China case:** - Priority to the young and middle-aged people to control infections and R0 - Unlike Italy and India, prioritizing the young and middle-aged will also control deaths - Use of the optimal age-specific vaccination strategy could reduce infections from 6,873,110 to 2,178,877 or more than 3-fold reduction or it can reduce deaths from 28,575 to 11,953 (2.4-fold reduction) compared to that of uniform distribution in China	
Yu et al., preprint China	Modelling	Hotspots	- "Dynamic prioritization of vaccines based on epidemiological situation" - Prioritization decisions are made to keep R0 at 1.5 - 2 million doses per day (0.14% rollout speed) - Vaccine efficacy = 80% for ages 15-59 years, 60% for ages 60+, 60% for ages <14 years - Vaccination is administered to essential workers first. Each age group is stratified into two categories: essential workers (tier 1) and other individuals (tier 2). Essential workers include healthcare workers (either front-line or not) and workers in the following sectors: law enforcement and security, nursing home and social welfare institutes, community, energy, food and transportation.	- The optimal prioritization strategies perform dramatically better than the uniform strategy with respect to any risk metric (more than 87% reduction vs. less than 70% **Minimizing infections:** - the optimal strategy prioritizes individuals aged 15-39 year until 46.6% coverage is reached; then, vaccines are administered to individuals aged 40-64 years until 26.9% coverage is reached - Optimal strategy can reduce infections by 88-89% compared to uniform strategy **Minimizing deaths:** - individuals aged 65 years and older are identified as the first priority until 58.6% coverage is reached, followed by aged 40-64 until 18.5% coverage and then aged 65+ until an almost full coverage is achieved - Optimal strategy can reduce deaths by 87-92% compared to uniform strategy **Minimizing ICU admissions**	

Reference	Study Type	Targeted Population	Vaccination Strategy / Modelling Assumptions	Effects of Vaccination Strategy / Optimal Vaccination Strategy	Notes
			- Optimal strategies are compared to a uniform (random) vaccination strategy for non-essential worker in each age group	- first priority is given to individuals aged 65+ years and nearly all of them need to be vaccinated before moving to other age groups - Optimal strategy can reduce ICU admissions by 88-92% compared to uniform strategy	
Zhao, Ismail & Tunis, preprint Canada	Canadian expert stakeholder analysis	n/a	- Surveyed stakeholders: Clinical and public health experts (Federal), national health professional associations, provincial, territorial, and national Indigenous groups, Federal government departments, patient and community advocacy groups - 156 surveys, distributed, 47.4% response rate. 22 (29.7%) respondents were members of clinical or public health expert groups involved with PHAC, 19 (25.7%) were patient or community advocacy representatives or experts from the CanCOVID network, 16 (21.6%) were executives of Canadian health professional associations, nine (12.2%) were members of provincial and territorial committees or national Indigenous groups, and eight (10.8%) were representatives of federal government departments - Stakeholders asked to rank the importance of four strategies over four different COVID-19 transmission scenarios: Protecting those with the highest medical risk; protecting healthcare capacity; minimizing COVID-19 transmission; protecting critical infrastructure - Across all four scenarios, stakeholders generally considered protecting the vulnerable to be first priority, followed by protecting healthcare capacity and minimizing transmission. Protecting critical infrastructure was ranked least important. - These rankings mirror surveys of general public opinion on vaccine prioritization		

Current State of COVID-19 Transmission in Alberta

Data from Immunization dashboard (Reviewed April 27, 2021)

Total population denominator in LGA dashboard:
ALBERTA: 4,391,068 with average of 407 active cases/100,000, 1114504 vaccinated, 26.4%

Areas with < 300 cases/100,000: 25% of the Alberta population:
1,111,093 population, average case rate 231.2 per 100,000, 293,556 vaccinated, 26.4 %

Areas with >300 active cases/100,000: 75% of the Alberta population
Overall active case rate 494.2/ 100,000, 854757 vaccinated, 26%

Table 5. More than 300 active cases/100,000 by zone (full tables below)

	Number of LGA with >300 active cases/100,000 (%)	Population in high activity areas (% of high risk area population)	Percent of overall population (difference)	Average Active cases /100,000	Number vaccinated	% vaccinated at least 1 dose
Calgary Zone	24 (41%)	1,660,866 (51%)	38% (-13)	469.9	432,647	26.0
Central Zone	16 (10.3%)	357,649 (11%)	8% (-3)	546.9	91,135	25.5
Edmonton Zone	15 (25.8%)	848,244 (26%)	19% (-7)	432	238,926	28.2
North Zone	10 (17.2%)	262,604 (8%)	6% (-2)	819.5	33,345	16.9
South Zone	7 (12.1%)	153,810 (5%)	4% (-1)	422.6	46,704	30.4
Total	58	3,283,173		494.2	853,757	26

Table 6. Areas with >400 cases/100,000 and low vaccination rates (<=20%)

	Cases/100,000	% vaccinated
Fort McMurray	1414	14%
Banff	1078	11%
High Prairie	856.6	20%
Calgary Upper NE	658	17%
Grand Prairie County	594.6	19%
City of Grand Prairie	552.9	17%
Beaverlodge	528.6	19%
Sylvan Lake	520.2	20%
Calgary East	462.3	20%
Airdrie	423.8	20%
Drayton Valley	404	20%

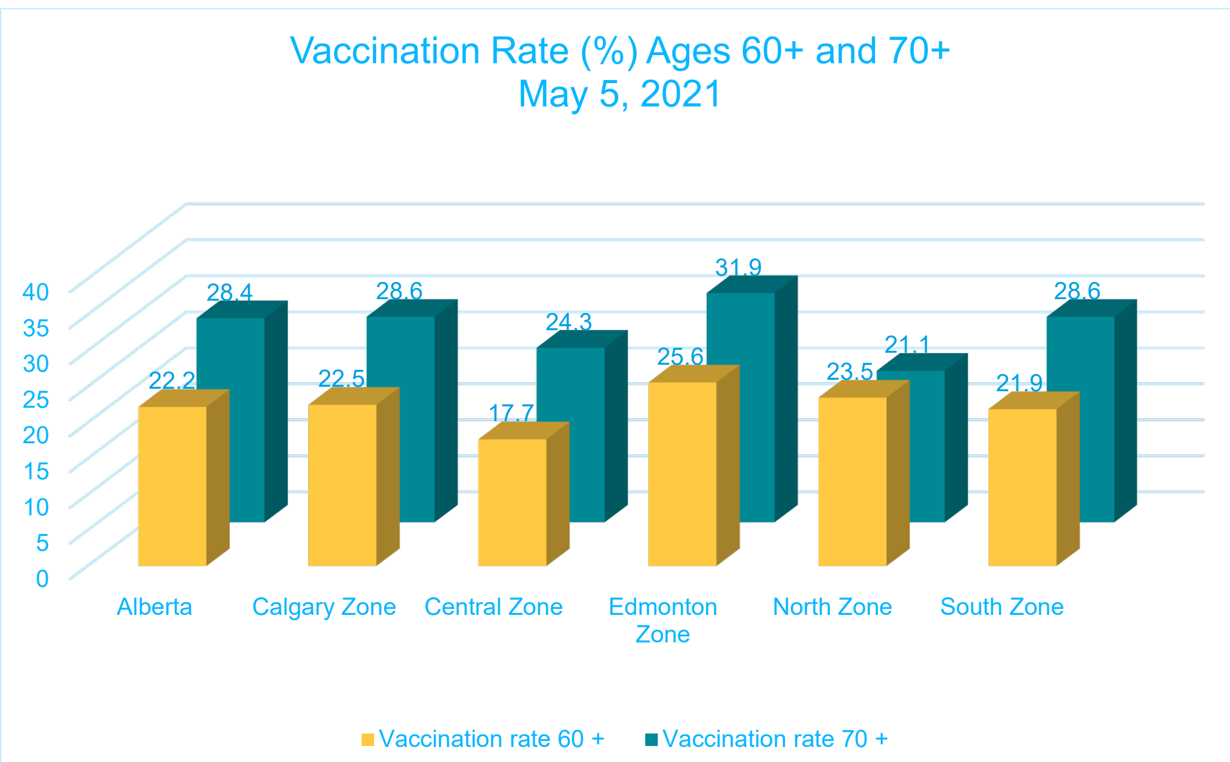
Table 7. Example: Active COVID-19 cases by age for Fort McMurray

Age range (years)	Number of active cases	Case rate / 100000 people	% immunized with at least one dose
Overall	1181	1480	15.5
0-18	257	1401	0.5
19-40	515	1593	8.0
41-65	384	1460	29.9
66+	25	879	65.5

Table 8. Example: Active COVID-19 cases by age for Calgary – Upper Northeast

Age range (years)	Number of active cases	Case rate / 100000 people	% immunized with at least one dose
Overall	812	725	18.4
0-18	165	525	0.5
19-40	380	926	10.5
41-65	232	734	30.8
66+	35	438	82.0

High risk age groups vaccination rate across zones, Alberta



https://tableau.albertahealthservices.ca/#/views/COVID-19ImmunizationVaccineTracking/ImmunizationbyLGA?:iid=1

By Zone : Community, Population, Case Rate, Number Vaccinated, % Vaccinated

Calgary Zone:

Total		1,660,866	469.9	432,647	26.0%
Calgary - Elbow	Calgary	42,667	328.1	15,193	35.6%
Calgary - Lower Nw	Calgary	63,883	377.3	21,048	32.9%
Calgary - Centre North	Calgary	47,244	389.5	14,949	31.6%
Calgary - Fish Creek	Calgary	115,908	386.5	36,233	31.3%
Cochrane-Springbank	Calgary	50,105	457.0	15,516	31.0%
Calgary - Centre West	Calgary	68,101	490.5	20,773	30.5%
Calgary - West	Calgary	95,860	395.4	29,164	30.4%
Calgary - Upper Nw	Calgary	122,851	437.9	35,438	28.8%
Calgary - Nose Hill	Calgary	80,635	359.6	22,296	27.7%
Okotoks-Priddis	Calgary	47,255	514.2	13,035	27.6%
High River	Calgary	24,015	366.4	6,575	27.4%
Calgary - Sw	Calgary	117,523	466.3	31,102	26.5%
Strathmore	Calgary	35,583	483.4	9,298	26.1%
Didsbury	Calgary	16,580	428.2	4,261	25.7%
Crossfield	Calgary	8,465	354.4	2,143	25.3%
Calgary - Centre	Calgary	66,726	425.6	16,289	24.4%
Calgary - Se	Calgary	136,703	574.2	32,929	24.1%
Calgary - North	Calgary	117,801	513.6	28,076	23.8%
Chestermere	Calgary	25,424	491.7	5,954	23.4%
Calgary - Lower Ne	Calgary	100,138	511.3	20,607	20.6%
Airdrie	Calgary	74,799	423.8	15,053	20.1%
Calgary - East	Calgary	76,566	462.3	15,267	19.9%
Calgary - Upper Ne	Calgary	112,029	657.9	19,776	17.7%
Banff	Calgary	14,005	1,078.2	1,672	11.9%

South Zone

LGA Name	Zone	Population Estimate	Active COVID-19 case rate/100,000	# of people received at least one dose	% immunized with at least one dose
Total		153,810	422.6	46,704	30.4%
Lethbridge - South	South	34,607	320.7	13,463	38.9%
Lethbridge - West	South	37,041	421.2	11,893	32.1%
Lethbridge - North	South	27,683	469.6	8,692	31.4%
Fort Macleod	South	6,583	607.6	1,628	24.7%
Cypress County	South	11,432	384.9	2,717	23.8%
County Of Lethbridge	South	25,401	429.1	5,809	22.9%
County Of Warner	South	11,063	542.4	2,502	22.6%

Central Zone

Total		357,649	546.9	91,135	25.5%
Camrose & County	Central	30,958	655.7	10,611	34.3%
Red Deer - East	Central	56,720	648.8	16,005	28.2%
Wetaskiwin County	Central	34,451	449.9	9,534	27.7%
Innisfail	Central	16,764	459.3	4,622	27.6%
Sundre	Central	6,847	350.5	1,856	27.1%
Ponoka	Central	12,343	737.3	3,329	27.0%
Olds	Central	13,129	807.4	3,474	26.5%
Stettler & County	Central	12,461	393.2	3,129	25.1%
Lacombe	Central	23,198	698.3	5,766	24.9%
Red Deer - Sw	Central	16,439	596.2	3,989	24.3%
Three Hills/Highway 21	Central	10,806	388.7	2,615	24.2%
Red Deer County	Central	28,307	420.4	6,253	22.1%
Rocky Mountain House	Central	20,852	335.7	4,582	22.0%
Red Deer - North	Central	37,739	590.9	8,031	21.3%
Drayton Valley	Central	18,563	404.0	3,729	20.1%
Sylvan Lake	Central	18,071	520.2	3,610	20.0%

Edmonton Zone

LGA Name	Zone	Population Estimate	Active COVID-19 case rate/100,000	# of people received at least one dose	% immunized with at least one dose
Total		848,244	432.0	238,926	28.2%
Sherwood Park	Edmonton	83,773	415.4	29,943	35.7%
Edmonton - West Jasper Pla..	Edmonton	101,745	383.3	34,176	33.6%
Edmonton - Woodcroft West	Edmonton	32,921	325.0	10,355	31.5%
Westview Excluding Stony ..	Edmonton	36,950	305.8	10,136	27.4%
Edmonton - Castle Downs	Edmonton	71,010	411.2	19,352	27.3%
Edmonton - Northgate	Edmonton	83,990	313.1	22,887	27.2%
Beaumont	Edmonton	26,142	351.9	7,120	27.2%
Leduc & Devon	Edmonton	43,855	602.0	11,716	26.7%
Fort Saskatchewan	Edmonton	27,008	377.7	7,213	26.7%
Edmonton - Mill Woods West	Edmonton	52,252	348.3	13,792	26.4%
Edmonton - Rutherford	Edmonton	102,027	607.7	26,213	25.7%
Thorsby	Edmonton	9,298	387.2	2,368	25.5%
Edmonton - Mill Woods Sou..	Edmonton	82,634	620.8	20,542	24.9%
Edmonton - Ne	Edmonton	88,228	365.0	21,569	24.4%
Sturgeon County East	Edmonton	6,411	312.0	1,544	24.1%

North Zone

LGA Name	Zone	Population Estimate	Active COVID-19 case rate/100,000	# of people received at least one dose	% immunized with at least one dose
Total		262,604	819.5	44,345	16.9%
Athabasca	North	11,034	389.7	3,228	29.3%
Barrhead	North	11,132	772.5	2,998	26.9%
Lac La Biche	North	10,776	417.6	2,247	20.9%
High Prairie	North	11,557	856.6	2,304	19.9%
Beaverlodge	North	12,485	528.6	2,463	19.7%
Grande Prairie County	North	21,189	594.6	4,143	19.6%
City Of Grande Prairie	North	75,601	552.9	13,123	17.4%
Wood Buffalo	North	4,237	330.4	705	16.6%
Fort Mcmurray	North	79,824	1,414.4	11,676	14.6%
High Level	North	24,768	508.7	1,458	5.9%

Methods

Literature Search

A literature search was conducted by Nicole Loroff from Knowledge Resources Services (KRS) within the Knowledge Management Department of Alberta Health Services. KRS searched databases for articles published from 2020-2021 and included: Medline, Healthstar, Pubmed, Trip Pro, MedRxiv, BioRxiv, WHO Global Research Database on COVID-19 /LitCovid, and Google Scholar. The search strategy is included below; briefly, the strategy involved two key concepts: “COVID-19” and “vaccination strategies”.

Articles identified by KRS in their search were initially screened for obvious irrelevance by title against the inclusion/exclusion criteria listed in Table 9 below. 140 articles were identified by KRS with references and abstracts provided for further review. 20 additional articles were identified *ad hoc*. 148 articles remained following deduplication.15 articles were excluded based on information in the title and abstract, and an additional 102 articles were excluded following full-text screening. In total,133 articles were excluded from the review in accordance with the inclusion/exclusion criteria stated below; 41 articles were retained for the final narrative synthesis.

Table 9. Inclusion and exclusion criteria for results of the literature search

Inclusion Criteria	Exclusion Criteria
- COVID-19 - Article describes exposure risk vaccination strategy or model - Article describes effect on disease transmission / dynamics - Meta-analysis, systematic review, RCT, observational studies, epidemiological studies, computer modelling study - Published last 2 years - Any jurisdiction - English language	- Article is not from a credible source - Article does not have a clear research question or issue - Presented data/evidence is not sufficient to address the research questions - Editorial, commentary, narrative review, abstract only - Study does not consider exposure/transmission risk - Study does not describe the effect of the vaccination strategy - Viruses other than COVID-19

Critical Evaluation of the Evidence

Exclusion criteria for study quality were adapted from the Mixed Methods Appraisal Tool (MMAT) (Hong et al., 2018). Potential articles were evaluated on three criteria: 1) Peer reviewed or from a reputable source; 2) Clear research question or issue; 3) Whether the presented data/evidence is appropriate to address the research question. Preprints and non peer-reviewed literature (such as commentaries and letters from credible journals) are not excluded out of hand due to the novelty of COVID-19 and the speed with which new evidence is available.

Table 10 below is a narrative summary of the body of evidence included in this review. The categories, format, and suggested information for inclusion were adapted from the Oxford Centre for Evidence-Based Medicine, the Cochrane Library, and the AGREE Trust (Urwin, Gavinder & Graziadio, 2020; Viswanathan et al, 2012; Wynants et al., 2020; Brouwers et al., 2010).

Table 10. Narrative overview of the literature included in this review.

	Description
Volume	1 systematic reviews were included, 30 modelling studies were included (20 were pre-review, five studies of other methodologies (two were pre-review). Five pieces of grey literature were identified and included.
Quality	In general, the body of evidence for this topic is of low quality. The majority of included articles are preprints, and there is limited real-world evidence to support the findings of the extensive modelling studies that were identified. The grey literature is from reputable sources and can be used to confirm that other jurisdictions are considering or using transmission risk as a prioritization criteria for vaccination campaigns.
Applicability	No evidence was identified from Alberta; however, there were five articles that were from Canadian research groups and produced a model or study results based on Canadian data and preferences. The study evidence is applicable to the review questions, although the lack of real-world evidence limits the utility of this review.
Consistency	The evidence is remarkably consistent across included studies.

Search Strategy

Ovid MEDLINE(R) and In-Process, In-Data-Review & Other Non-Indexed Citations 1946 to April 15, 2021**, Ovid Healthstar** 1966 to November 2020

Date Searched: April 15-16, 2021

Search Strategy:

#	Searches	Results
1	COVID-19/ or exp Coronavirus/ or Coronavirus Infections/	128455
2	(covid or coronaviru* or corona viru* or ncov* or n-cov* or novel cov* or COVID-19 or COVID19 or COVID-2019 or COVID2019 or SARS-CoV-2 or SARSCoV-2 or SARSCoV2 or SARSCoV19 or SARS-Cov-19 or SARSCov-19 or SARSCoV2019 or SARS-Cov-2019 or SARSCov-2019 or "severe acute respiratory syndrome cov 2" or 2019 ncov or 2019ncov).ti,ab.	154892
3	1 or 2	165506
4	COVID-19 Vaccines/ or Vaccines/ or Viral Vaccines/ or Immunization/ or Immunization Schedule/ or Immunization, Secondary/ or Immunotherapy/ or Immunotherapy, Active/ or Vaccination/ or Mass Vaccination/ or Immunization Programs/	378570
5	((vaccine* or vaccinat* or mass-vaccin* or immuniz* or immunis*) adj5 (strateg* or allocate* or rollout or roll-out or distribu* or administer* or administrat* or priorit* or deliver* or program* or deploy* or optimal* or optimiz*)).ti,ab.	99196
6	(ring vaccin* or shield vaccin*).ti,ab.	205
7	5 or 6	99292
8	3 and 4 and 7	853
9	limit 8 to (english language and yr="2020 -Current")	577
10	remove duplicates from 9	433

PubMed

Date Searched: April 15-16, 2021

Search Strategy:

#	Searches	Results
1	"covid 19"[MeSH Terms] OR "coronavirus"[MeSH Terms] OR "coronavirus infections"[MeSH Terms]	87450
2	"covid"[Title/Abstract] OR "coronaviru*"[Title/Abstract] OR "corona viru*"[Title/Abstract] OR "ncov*"[Title/Abstract] OR "n cov*"[Title/Abstract] OR "novel cov*"[Title/Abstract] OR "COVID-19"[Title/Abstract] OR "COVID19"[Title/Abstract] OR "COVID-2019"[Title/Abstract] OR "COVID2019"[Title/Abstract] OR "SARS-CoV-2"[Title/Abstract] OR "SARSCoV-2"[Title/Abstract] OR "SARSCoV2"[Title/Abstract] OR "SARSCoV19"[Title/Abstract] OR "SARS-Cov-19"[Title/Abstract] OR "SARSCoV2019"[Title/Abstract] OR "SARS-Cov-2019"[Title/Abstract] OR "severe acute respiratory syndrome cov 2"[Title/Abstract] OR "2019 ncov"[Title/Abstract] OR "2019ncov"[Title/Abstract]	132753
3	1 or 2	142772
4	"COVID-19 Vaccines"[MeSH Terms] OR "vaccines"[MeSH Terms] OR "viral vaccines"[MeSH Terms] OR "vaccination"[MeSH Terms] OR "immunization"[MeSH Terms] OR "immunization schedule"[MeSH Terms] OR "immunization, secondary"[MeSH Terms] OR "immunotherapy"[MeSH Terms] OR "immunotherapy, active"[MeSH Terms] OR "vaccination"[MeSH Terms] OR "mass vaccination"[MeSH Terms] OR "immunization programs"[MeSH Terms]	431597
5	("vaccine*"[Title] OR "vaccinat*"[Title] OR "mass vaccin*"[Title] OR "immuniz*"[Title] OR "immunis*"[Title) AND ("strateg*"[Title] OR "allocate*"[Title] OR "rollout"[Title] OR "roll-	14782

	out"[Title] OR "distribu*"[Title] OR "administer*"[Title] OR "administrat*"[Title] OR "priorit*"[Title] OR "deliver*"[Title] OR "program*"[Title] OR "deploy*"[Title] OR "optimal*"[Title] OR "optimiz*"[Title])	
6	ring vaccin*[Title/Abstract] OR shield vaccin*[Title/Abstract]	727
7	5 or 6	15473
8	3 and 4 and 7	517
9	limit 8 to (english language and yr="2020 -Current")	429

Trip Pro

Date Searched: April 15-16, 2021

Search Strategy:

title:(covid-19 or coronavirus or SARS-CoV-2) AND title:(vaccine* or vaccinat* or mass-vaccin* or immuniz* or immunis*) AND (strateg* or allocat* or rollout or roll-out or distribu* or administer* or administrat* or priorit* or deliver* or program* or deploy* or optimal* or optimiz*)from:2020 (734)

First 10 pages reviewed.

medRxiv & bioRxiv

Date Searched: April 15-16, 2021

Search Strategy:

title and abstract (all), Jan. 01, 2020-Apr. 16, 2021: covid-19 vaccine strategy; covid-19 vaccine strategies; covid-19 vaccine priority; covid-19 vaccine prioritizing; covid-19 vaccine prioritization; covid-19 vaccine optimal; covid-19 vaccine optimization; covid-19 vaccine optimizing; covid-19 vaccine allocation; covid-19 vaccine rollout; covid-19 vaccine program

title and abstract (all), Jan. 01, 2020-Apr. 16, 2021: covid-19 vaccination strategy; covid-19 vaccination strategies; covid-19 vaccination priority; covid-19 vaccination prioritizing; covid-19 vaccination prioritization; covid-19 vaccination optimal; covid-19 vaccination optimization; covid-19 vaccine optimizing; covid-19 vaccination allocation; covid-19 vaccination rollout; covid-19 vaccination program

WHO Global Research Database on COVID-19 /LitCovid

Date Searched: April15-16, 2021

Search Strategy:

(vaccine or vaccination) AND (strategy or strategies or allocate or allocation or priority or prioritization or optimal or optimization or rollout or program)

First 10 pages reviewed if required.

Google Scholar

Date Searched: April 15-16, 2021

Citation tracking of selected articles.

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