Risk Profiles based on COVID-19 Mortality Risk Factors in Long-term Care Settings: Evidence from Canada, United States and New Zealand

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Abstract

Objectives: To apply WHO and CDC reported risk factors for COVID-19-related mortality to assessment in long-term care and to estimate the potential impact of variations in care on COVID-19 deaths.

Design: Population-based cohort study linking Canadian assessment records to 90-day mortality in home care, assisted living, nursing homes, and post-acute hospitals. These mortality rates were applied to Canadian, US, and New Zealand data to estimate the impact of variations in care.

Setting and participants: Adults in nursing homes and home care in three countries, as well as assisted living and post-acute hospitals in Canada between 1998-2019. Mortality estimates were based on a sample of 1,653,866 Canadians. Simulation models for potential impact of COVID-19 were based on 2,438,761 individuals from the US, 134,512 from New Zealand, and 406,216 Canadians.

Measures: interRAI assessment records from 4 care settings were used to estimate 90-day mortality based on age, sex, and count of major comorbidities. Pneumonia at baseline was used as a proxy in simulation models with 18 age-comorbidity subgroups to examine the impact of COVID-19 on mortality with different assumptions of care.

Results: The age-sex adjusted hazard ratios for mortality associated with pneumonia varied by care setting and major comorbidity count with maximal hazard ratios between 1.75 (1.36-2.26) and 4.14 (1.36-12.56) compared with reference groups without major comorbidities and pneumonia. Depending on the extent to which exposure to COVID-19 is prevented, spread is minimized, and severity of disease is limited, expected death rates could increase by up to 492.1% and 405.2% in nursing homes and home care, respectively.

Conclusions/Implications: Assuming that historical mortality rates associated with pneumonia in long-term care represent a lower-bound estimate, the impact of COVID-19 is expected to be substantial. Efforts to reduce its impact by minimizing exposure, containing spread, and insuring continued effective chronic disease management are essential.

BACKGROUND

As the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) spreads causing global outbreaks of coronavirus disease 2019 (COVID-19), older adults have been the most vulnerable[1, 2]. Case fatality rates in hospital settings increase exponentially with age[3-5], with variations partly attributable to international differences in testing and to coding causes of death. In addition, early bivariate analyses suggest comorbid conditions (e.g., cardiovascular disease, cancer, chronic respiratory disease) were associated with higher death rates in COVID-19 patients[3-6].

European and North American experience points to higher mortality rates among frail older populations in long-term care settings (e.g., nursing homes, home care). However, little detailed information about these settings other than single-site descriptive studies has been published[7, 8]. A US nursing home with a COVID-19 outbreak had a hospitalization rate of 57% and a case fatality rate of 34% [8]. More than half of residents testing positive were asymptomatic, suggesting a substantial risk of under-detection if relying on symptom-based screening[9]. In a severe outbreak in a Canadian nursing home, 29 (45%) residents died in a small, older facility [10]. The Chief Public Health Officer of Canada recently indicated that half of Canadian COVID-19 deaths involved residents of long-term care homes[11], which is similar to the European Union[12] and some US states[13]. New Zealand has had a remarkably low COVID-19 mortality rate, but 10 of its 17 deaths occurred in one nursing home.

As the pandemic expands in long-term care settings, there is little evidence to inform risk management strategies. Our analyses provide a description of nursing home and home care populations in three nations, using epidemiological reports from World Health Organization[6], Centers for Disease Control[14], to estimate the size of populations at the highest risk and to model the consequences of different approaches to managing the pandemic.

METHODS

We examined clinical assessment records from Canada, US and New Zealand (NZ) to create risk profiles matching those reported in COVID-19 studies. Canadian data confirmed which major underlying comorbidities mentioned in elsewhere[5, 6, 14] were associated with mortality prior to the pandemic in home care, nursing homes, assisted living, and post-acute hospitals. These were then used to estimate the size of different at-risk subpopulations in those settings. We also applied these risk profiles to US and NZ data to create comparable population estimates in those countries. Finally, we created models simulating the impact of different management strategies on mortality. Since there are not yet large data holdings available with COVID-19 cases linked to clinical assessment records, we examined the influence of non-COVID-19 pneumonia on mortality within age/risk groups using existing data. Pneumonia was used as a proxy variable for COVID-19, since it is a common feature in severe cases[15].

Data Sources

The common source of population-level clinical data for Canada, US and NZ was interRAI assessments completed as part of routine practice in community and facility-based long-term care[16-23]. Although these countries use different generations of the nursing home and home care assessments, the underlying measures are sufficiently consistent to allow valid and reliable cross-national comparisons[18, 24-34].

For the mortality analyses, the Canadian data span four types of care settings in Ontario, Nova Scotia, Manitoba, Saskatchewan, Alberta, British Columbia, and Yukon Territory: home care clients (n=841,440 individuals) and assisted living residents (n=98,406 individuals) assessed between 2002-2018; nursing home residents assessed between 2005-2017 (n=422,903 individuals); and post-acute hospital patients

assessed between 1998-2017 (n=291,117 individuals). Assessments for these 1,653,866 individuals were linked to acute hospital and emergency department administrative records by the Canadian Institute for Health Information (CIHI) to determine 90-day mortality rates.

For the simulation models, we used the 2019 Canadian intake assessment records for home care (n= 232,857) and nursing homes (n=173,979), respectively, to estimate the number of individuals in those two settings.

US and NZ data provided cross-sectional estimates of at-risk populations in home care and nursing homes, which were used in our simulation to estimate the impact of practice changes on mortality. US home care data were for persons assessed in 2017 in New York, New Jersey, Michigan, Georgia, and South Dakota (n=391,910 individuals). The US nursing home data represented the national population of long-term care residents in all facilities, assessed in 2016 (n=2,904,576 individuals). NZ data provided a national sample of individuals assessed between 2017 and 2019 in home care (n=75,195 individuals) and in long-term care facilities (n=59,317 individuals). Two years of NZ data were used for the simulation models to ensure adequate cells sizes for smaller subpopulations.

Outcomes

The main outcome of interest was mortality within a 90-day follow-up period. COVID-19 deaths occur relatively quickly after onset, so longer follow-up periods were not considered. The unadjusted 90-day mortality rates vary markedly across care settings as follows: home care - 4.0%; assisted living – 4.0%; nursing homes – 8.8%; and post-acute hospitals – 25.3%. Death rates for specific age and co-morbidity subgroups could only be calculated for the Canadian sample, so these were applied to the cross-sectional US and NZ data to simulate expected mortality. Although COVID-19 is associated with pneumonia as the disease becomes more severe, we cannot quantify how pneumonia experienced by persons in our data compares to that experienced by COVID-19 patients.

The independent variables used to predict mortality were age, sex, and comorbid medical conditions cited as risk factors for COVID-19 mortality by CDC[14] and WHO[6]. Our aim was not to maximize the prediction of death in these patients, but rather to quantify mortality rates based on risk factors that a plurality of current COVID-19 studies suggest are important.

Statistical Analyses

We used cross-tabulations with Chi-square tests to evaluate the impact of age, sex and specific diagnoses on 90-day mortality. Time to death within a 90-day window was also examined using survival curves with Mantel-Haenszel tests of significance. We then grouped comorbid diagnoses strongly related with mortality into six initial groups (cardiac, liver, lung, kidney, cancer, and neurological conditions) within which higher rated of death could be expected[35]. Appendix A provides a more detailed description of the construction of this variable. A count of the number of groups with one or more related diagnosis was created and was then collapsed into an ordinal variable of zero, one, and two or more major comorbid conditions.

The next step used survival models with time to death to determine the age-sex-adjusted hazard ratios of the relationship of this major comorbidity count with the presence of a baseline pneumonia diagnosis. Survivors were censored at the 90-day endpoint of follow-up.

Finally, a simulation model was developed based on the specific 90-day mortality rates with and without pneumonia at baseline for each 10-year age group and major comorbidity count. The model considered the impact of five assumptions in nursing homes and home care in the three countries (post-acute

hospital and assisted living data were not available for the US and NZ): (1) rate of COVID-19 in the general population, (2) percentage of cases progressing to severe pneumonia, (3) percentage of home care clients becoming COVID-19 positive as a proportion of the general population rate, (4) percentage of nursing homes with a COVID-19 outbreak, and (5) rate of spread of COVID-19 within homes that have an outbreak. The latter four conditions all can be considered as indicators of the effectiveness of the health system in managing the COVID-19 pandemic.

RESULTS

Table 1 shows the age, sex and comorbidity counts for all study samples. The majority of individuals in all settings were above the age-based high-risk threshold (80+) for COVID-19 mortality reported by WHO[6]. The sex distributions were comparable between all settings, with the majority of individuals being female. The percentage of individuals with at least one major comorbidity ranged from 69.8% (home care) to 88.9% (nursing homes). In home care, 5.3% had three or more major comorbidities, but that almost tripled in post-acute hospitals (14.0%).

Considering the cross-national distributions of mortality risk factors, NZ served a somewhat older population than Canada and the US in home care and nursing homes, whereas the US tended to have the youngest overall sample. The sex distributions were similar for Canada and NZ, whereas the US had a somewhat higher percentage of males in nursing homes. The comorbidity count was similar in Canadian and US samples, but NZ had a notably lower percentage of individuals with three or more comorbidities in nursing home settings.

Table 2 shows the age-sex adjusted hazard ratios for the comorbidity count from survival models for 90-day mortality by sector in Canada. Pneumonia at baseline is used as a “stand-in” variable for COVID-19, although one might expect the impact of COVID-19 to be more pronounced when it progresses to pneumonia. In almost all cases and all settings, the hazard ratio increased with higher comorbidity counts. The hazard ratios for 90-day mortality also increased with pneumonia across all settings, and the interaction term between pneumonia and comorbidity count was significant in each care setting.

Figure 1 shows the 90-day mortality rates in Canadian home care and nursing home settings in the general population and among those with pneumonia present at baseline. For almost all age-comorbidity combinations, pneumonia was associated with increased mortality but the magnitude of change was greater in nursing homes. Pneumonia was important in all but three of 36 age-comorbidity comparisons. In the most populous subgroups (1-2 major comorbidities), pneumonia increased the age-specific 90-day mortalities at least 1.62 and 2.08 times in home care and nursing homes, respectively.

Table 3 shows the potential impact of factors related to exposure to and severity of COVID-19, in nursing homes and home care in three countries. The age-comorbidity distributions for each country were used to estimate the numbers of individuals in each of 18 different subgroups for each setting. The percentages obtained from our earlier analyses were applied to estimated home care and nursing home population sizes. We applied the Canadian mortality rates for each age-comorbidity group with and without pneumonia to the estimated number of individuals in each subgroup to derive proxy estimates of expected deaths with and without COVID-19. Our aim is not to produce definitive prognoses of long-term care deaths in each country, but rather to illustrate how approaches to care might influence mortality patterns.

Three main assumptions were manipulated for nursing homes: a) percentage of COVID-19 cases causing pneumonia of the severity found in previous years; b) percentage of facilities with outbreaks; and c)

infection rate among residents when an outbreak occurs. These could indicate of how well homes manage COVID-19 when a resident is infected; keep COVID-19 out of the facility; and contain the spread of COVID-19 when it enters the facility. If 20% of COVID-19 cases progress to severe pneumonia, 10% of facilities have outbreaks, and 30% of residents become infected when an outbreak occurs, we could expect 229, 2,027 and 38 nursing home deaths in Canada, US and NZ, respectively (Table 3). For context, at the time of writing there were 2,028, 23,358 and 16 COVID-19 deaths in Canada, US and NZ, respectively. If the infection rate within facilities increases to 40%, the number of deaths in all three countries would rise by about 132%. If one also doubles the percentage of facilities with outbreaks, deaths would increase by 260%. Finally, if we increase the percentage of severe pneumonia to 30% and infection rate within homes to 50%, the numbers increase by about 490% in each country. For Canada, the model under those assumptions would predict 1,115 deaths, which roughly corresponds to recent estimates of COVID-19 deaths in those settings.

The simulation parameters for the home care settings are: a) percentage of COVID-19 cases causing severe pneumonia; b) COVID-19 rates in the general population; and c) infection rate of home care clients, as a percentage of the general population rate. The second assumption relates to the general effectiveness of public health strategies to use social distancing to contain spread, while the third pertains to how well home care services prevent clients' exposure to COVID-19. The baseline model assumes that 20% of COVID-19 cases transition to severe pneumonia, 1% of the general population is exposed, and the client population rate is 10% of the general population rate. If the general population rate were to rise to 10%, the number of long-term care deaths in each country would rise by between 121% in NZ and 131% in Canada. However, if the home care client infection rate rises to 50% of the general population rate, deaths would increase between 218% and 270% in NZ and Canada, respectively. Finally, if the severity of COVID-19 increases such that 30% develop pneumonia, the number of deaths would rise by 329% to 405% in Canada and NZ, respectively.

DISCUSSION

As COVID-19 began to take hold in North America, there were calls for epidemiological studies to provide insights into the extent and severity of the pandemic [36]. Although long-term care settings serve populations at the highest risk levels for adverse outcomes related to COVID-19, the magnitude of the problem has not yet been quantified. Recent reports have highlighted horrendous outcomes in some North American facilities[37]. Using relatively simple indicators based on age and underlying comorbid health conditions, a clear majority of persons cared for by these organizations are at the highest levels of risk. When pneumonia strikes, the already high levels of short-term mortality can increase substantially. Therefore, if the spread of COVID-19 is pervasive in these populations, the impact will be devastating. Our simulation suggests that both minimizing exposure within these care settings and containing the spread of COVID-19 when an outbreak occurs will be critical to attenuating the impact of the pandemic.

Compared with post-acute hospitals, Canadian nursing homes have much lower staffing levels with substantially less access to registered nurses or physicians. Personal support workers provide about 75% of nursing care within nursing homes compared with 8% in post-acute hospitals [38]. Thus, nursing homes may not have the capacity to manage a serious outbreak. This problem is further magnified in assisted living, which serves a population similar to home care and nursing homes, but with few clinical services.

In home care, 75% of care received comes from caregivers who often experienced high levels of distress prior to the pandemic [39-41]. As health services become strained and *less* support is provided in home care, the chance of serious adverse outcomes may rise markedly for both the client and the caregiver.

With this in mind, what are practical things to do? First, tight controls are needed for who enters nursing homes and home care clients' homes. Only essential persons providing care, dietary staff, and those ensuring cleaning and infection control should enter the facility. In home care, it may mean only one family caregiver and home care staff can visit. For those who do enter the home, screening for COVID-19 symptoms should occur at every shift. Previous experience has shown the importance of restricting nursing home staff to work in a single organization, to reduce cross-contamination. However, that restriction is impractical in-home care, where care staff may support 6-10 clients in different homes daily. Some might consider suspending formal care for a time with family members providing even more care; however, families that are already overwhelmed may be unable to cope, potentially resulting in hospitalizations of both the caregiver and home care client[41].

The importance of hand hygiene is widely recognized, but there is less clarity about personal protective equipment (PPE) in nursing homes and home care. While in the US use of such equipment is becoming more common, PPE use in Canada has been restricted to protecting staff from infected patients. However, it can also protect patients from staff who may be asymptomatically infected with COVID-19. Training in the appropriate use of PPE is likely to be needed in nursing homes and home care where they have not been used frequently.

New admissions to nursing home and assisted living settings should be isolated for at least 14 days. Use of ward rooms should be avoided and discrete areas should be used to treat residents with the infection. At a minimum, infected residents should not share rooms with other. Separated units should be used for residents infected with COVID-19. The problem is further complicated because about half of nursing home residents who tested positive for COVID-19 were asymptomatic[9]. It should not be assumed only symptomatic residents can spread the infection, so increased detection with testing is essential.

Strict controls to lock down access to nursing homes and clients' homes in community-based services are important to control the pandemic, but those actions may also create other adverse outcomes (e.g., depression, delirium, functional decline). Those unanticipated negative consequences should be addressed with effective chronic disease management strategies[42] and mobilization of additional clinical resources[43]. Failure to do so will place additional strains on the health system.

Careful thought should also be given to who is admitted to nursing home settings from hospital or community settings. Based on reports by Italian physicians[44], discharge of hospital patients to nursing homes to "make room for COVID-19 patients" may simply be throwing fuel on the fire. One cannot assume that asymptomatic hospital patients pose no risk to nursing home residents.

Having advance care plans in place is another important consideration[45]. A health system under stress from a pandemic may not have the capacity to provide elegant person-centered care in the context of shortages of staff, equipment, space, and time. If possible, the person and the support network should engage in a meaningful process of shared end-of-life decision making before a crisis strikes.

CONCLUSIONS/IMPLICATIONS

It behooves all stakeholders engaged in health system policy development and service delivery to work together on pandemic strategies that protect long-term care services. Much of the focus so far has been on "flattening the curve" to prevent peak demand on emergency departments and hospital intensive care units. These are critical parts of the health system, but they are not the *only* parts of concerned. Providing better clinical support to nursing home and home care is an essential part of any strategy to reduce the impact of the COVID-19 pandemic on our most vulnerable citizens.

References

1. Lloyd-Sherlock P, Ebrahim S, Geffen L, McKee M. Bearing the brunt of covid-19: older people in low and middle income countries. *BMJ*. Mar 13 2020;368:m1052. doi:10.1136/bmj.m1052
2. Lloyd-Sherlock PG, Kalache A, McKee M, Derbyshire J, Geffen L, Casas FG. WHO must prioritise the needs of older people in its response to the covid-19 pandemic. *BMJ*. Mar 23 2020;368:m1164. doi:10.1136/bmj.m1164
3. Huang C, Wang Y, Li X, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *Lancet*. Feb 15 2020;395(10223):497-506. doi:10.1016/S0140-6736(20)30183-5
4. Zhang N, Wang L, Deng X, et al. Recent advances in the detection of respiratory virus infection in humans. *J Med Virol*. Apr 2020;92(4):408-417. doi:10.1002/jmv.25674
5. Eurosurveillance Editorial T. Updated rapid risk assessment from ECDC on coronavirus disease 2019 (COVID-19) pandemic: increased transmission in the EU/EEA and the UK. *Euro Surveill*. Mar 2020;25(12)doi:10.2807/1560-7917.ES.2020.25.12.2003261
6. World Health O, World Health O. Report of the who-china joint mission on coronavirus disease 2019 (covid-19). 2020.
7. McMichael TM, Clark S, Pogosjans S, et al. COVID-19 in a Long-Term Care Facility - King County, Washington, February 27-March 9, 2020. *MMWR Morb Mortal Wkly Rep*. Mar 27 2020;69(12):339-342. doi:10.15585/mmwr.mm6912e1
8. McMichael TM, Currie DW, Clark S, et al. Epidemiology of Covid-19 in a Long-Term Care Facility in King County, Washington. *N Engl J Med*. Mar 27 2020;doi:10.1056/NEJMoa2005412
9. Kimball A, Hatfield KM, Arons M, et al. Asymptomatic and Presymptomatic SARS-CoV-2 Infections in Residents of a Long-Term Care Skilled Nursing Facility - King County, Washington, March 2020. *MMWR Morb Mortal Wkly Rep*. Apr 3 2020;69(13):377-381. doi:10.15585/mmwr.mm6913e1
10. Riches S. What went wrong in Bobcaygeon: How the COVID-19 pandemic killed 29 people at an ill-prepared nursing home. Accessed 4/22/2020, https://nationalpost.com/news/canada/covid-19-coronavirus-pinecrest-nursing-home-bobcaygeon
11. Bensadoun E. Nearly half of Canada's COVID-19 deaths linked to long-term care facilities: Tam. Accessed 4/22/2020, https://globalnews.ca/news/6811726/coronavirus-long-term-care-deaths-canada/
12. Booth MBW. Nursing homes linked to up to half of coronavirus deaths in Europe, WHO says. Accessed 4/23/2020, 2020. https://www.washingtonpost.com/world/europe/nursing-homes-coronavirus-deaths-europe/2020/04/23/d635619c-8561-11ea-81a3-9690c9881111_story.html
13. Rhett Miller J. Coronavirus deaths at US nursing homes, long-term facilities reach over 10,000. Accessed 4/23/2020, https://nypost.com/2020/04/23/coronavirus-deaths-at-us-nursing-homes-reach-over-10000/
14. Prevention CfDCa. Interim Clinical Guidance for Management of Patients with Confirmed Coronavirus Disease (COVID-19). Accessed 4/23/2020, https://www.cdc.gov/coronavirus/2019-ncov/hcp/clinical-guidance-management-patients.html
15. Guan WJ, Ni ZY, Hu Y, et al. Clinical Characteristics of Coronavirus Disease 2019 in China. *N Engl J Med*. Feb 28 2020;doi:10.1056/NEJMoa2002032
16. Hirdes JP, Mitchell L, Maxwell CJ, White N. Beyond the 'iron lungs of gerontology': using evidence to shape the future of nursing homes in Canada. *Can J Aging*. Sep 2011;30(3):371-90. doi:10.1017/S0714980811000304
17. Schluter PJ, Ahuriri-Driscoll A, Anderson TJ, et al. Comprehensive clinical assessment of home-based older persons within New Zealand: an epidemiological profile of a national cross-section. *Aust N Z J Public Health*. Aug 2016;40(4):349-55. doi:10.1111/1753-6405.12525
18. Morris JN, Nonemaker S, Murphy K, et al. A commitment to change: revision of HCFA's RAI. *J Am Geriatr Soc*. Aug 1997;45(8):1011-6. doi:10.1111/j.1532-5415.1997.tb02974.x

19. Morris JN, Fries BE, Steel K, et al. Comprehensive clinical assessment in community setting: applicability of the MDS-HC. *Journal of the American Geriatrics Society*. 1997;45(8):1017-1024.
20. Carpenter GI, Hirdes JP. Using interRAI assessment systems to measure and maintain quality of long-term care. *A good life in old age? Monitoring and improving quality in long-term care*. OECD Publishing; 2013:2017. *OECD Health Policy Studies*.
21. Bernabei R, Landi F, Onder G, Liperoti R, Gambassi G. Second and third generation assessment instruments: the birth of standardization in geriatric care. *J Gerontol A Biol Sci Med Sci*. Mar 2008;63(3):308-13. doi:10.1093/gerona/63.3.308
22. Bernabei R, Gray L, Hirdes J, et al. International gerontology. *Hazzard's geriatric medicine and gerontology*. 2009:69-96.
23. Saliba D, Buchanan J. Making the investment count: revision of the Minimum Data Set for nursing homes, MDS 3.0. *J Am Med Dir Assoc*. Sep 2012;13(7):602-10. doi:10.1016/j.jamda.2012.06.002
24. Hirdes JP, Ljunggren G, Morris JN, et al. Reliability of the interRAI suite of assessment instruments: a 12-country study of an integrated health information system. *BMC Health Serv Res*. Dec 30 2008;8:277. doi:10.1186/1472-6963-8-277
25. Hirdes JP, Poss JW, Caldarelli H, et al. An evaluation of data quality in Canada's Continuing Care Reporting System (CCRS): secondary analyses of Ontario data submitted between 1996 and 2011. *BMC Med Inform Decis Mak*. Feb 26 2013;13:27. doi:10.1186/1472-6947-13-27
26. Hogeveen SE, Chen J, Hirdes JP. Evaluation of data quality of interRAI assessments in home and community care. *BMC Med Inform Decis Mak*. Oct 30 2017;17(1):150. doi:10.1186/s12911-017-0547-9
27. Kim H, Jung YI, Sung M, Lee JY, Yoon JY, Yoon JL. Reliability of the interRAI Long Term Care Facilities (LTCF) and interRAI Home Care (HC). *Geriatr Gerontol Int*. Feb 2015;15(2):220-8. doi:10.1111/ggi.12330
28. Morris JN, Hawes C, Fries BE, et al. Designing the national resident assessment instrument for nursing homes. *Gerontologist*. Jun 1990;30(3):293-307. doi:10.1093/geront/30.3.293
29. Poss JW, Jutan NM, Hirdes JP, et al. A review of evidence on the reliability and validity of Minimum Data Set data. *Healthcare Management Forum*. 2008;21:33-39.
30. Foebel AD, Hirdes JP, Heckman GA, Kergoat MJ, Patten S, Marrie RA. Diagnostic data for neurological conditions in interRAI assessments in home care, nursing home and mental health care settings: a validity study. *BMC Health Serv Res*. Nov 1 2013;13:457. doi:10.1186/1472-6963-13-457
31. Morris JN, Berg K, Fries BE, Steel K, Howard EP. Scaling functional status within the interRAI suite of assessment instruments. *BMC Geriatr*. Nov 21 2013;13:128. doi:10.1186/1471-2318-13-128
32. Landi F, Tua E, Onder G, et al. Minimum data set for home care: a valid instrument to assess frail older people living in the community. *Medical care*. 2000:1184-1190.
33. Landi F, Onder G, Tua E, et al. Impact of a new assessment system, the MDS-HC, on function and hospitalization of homebound older people: A controlled clinical trial. *Journal of the American Geriatrics Society*. 2001;49(10):1288-1293.
34. Gambassi G, Landi F, Peng L, et al. Validity of diagnostic and drug data in standardized nursing home resident assessments: potential for geriatric pharmacoepidemiology. SAGE Study Group. Systematic Assessment of Geriatric drug use via Epidemiology. *Med Care*. Feb 1998;36(2):167-79. doi:10.1097/00005650-199802000-00006
35. Nunes BP, Flores TR, Mielke GI, Thume E, Facchini LA. Multimorbidity and mortality in older adults: A systematic review and meta-analysis. *Arch Gerontol Geriatr*. Nov-Dec 2016;67:130-8. doi:10.1016/j.archger.2016.07.008
36. Lipsitch M, Swerdlow DL, Finelli L. Defining the Epidemiology of Covid-19 - Studies Needed. *N Engl J Med*. Mar 26 2020;382(13):1194-1196. doi:10.1056/NEJMp2002125

37. Maddow R. Nursing home deaths should be obvious target of COVID-19 response. Accessed 4/23/2020, https://www.msnbc.com/rachel-maddow/watch/nursing-home-deaths-should-be-obvious-target-of-covid-19-response-82189381550
38. Turcotte LA, Poss J, Fries B, Hirdes JP. An Overview of International Staff Time Measurement Validation Studies of the RUG-III Case-mix System. *Health Serv Insights*. 2019;12:1178632919827926. doi:10.1177/1178632919827926
39. Betini RSD, Hirdes JP, Curtin-Telegdi N, et al. Development and validation of a screener based on interRAI assessments to measure informal caregiver wellbeing in the community. *BMC Geriatr*. Dec 13 2018;18(1):310. doi:10.1186/s12877-018-0986-x
40. Hirdes JP, Freeman S, Smith TF, Stolee P. Predictors of caregiver distress among palliative home care clients in Ontario: evidence based on the interRAI Palliative Care. *Palliat Support Care*. Sep 2012;10(3):155-63. doi:10.1017/S1478951511000824
41. Health Council of C. Seniors in need, caregivers in distress: What are the home care priorities for seniors in Canada? : Health Council of Canada Toronto; 2012.
42. Heckman GA, Saari M, McArthur C, Wellens NIH, Hirdes JP. RE: COVID-19 Response and Chronic Disease Management. 2020;192(14)
43. Lisk R, Yeong K, Nasim A, et al. Geriatrician input into nursing homes reduces emergency hospital admissions. *Arch Gerontol Geriatr*. Sep-Oct 2012;55(2):331-7. doi:10.1016/j.archger.2011.10.014
44. AFP. COVID-19: Italy doctors warn of 'bio bombs' from patients sent to care homes. *Gulf News*. 4/1/2020. https://gulfnews.com/world/europe/covid-19-italy-doctors-warn-of-bio-bombs-from-patients-sent-to-care-homes-1.70748345
45. Flo E, Husebo BS, Bruusgaard P, et al. A review of the implementation and research strategies of advance care planning in nursing homes. *BMC geriatrics*. 2016;16(1):24.

Table 1. Sample characteristics for mortality analyses (Canada only) and simulation model (Canada, US, New Zealand).

Characteristic	Canada						United States Simulation Model Cohort		New Zealand Simulation Model Cohort	
	Mortality Cohort				Simulation Model Cohort					
	Home Care (n=841,440)	Assisted Living (n=98,406)	Nursing Homes (n=422,903)	Post-acute Hospitals (n=291,117)	Home Care (n=232,857)	Nursing Home (n=173,359)	Home Care (n= 391,910)	Nursing Homes (n= 2,046,851)	Home Care (n=75,195)	Nursing Homes (n=59,317)
Age Groups (%)										
18-49	4.9	2.5	1.0	3.6	4.1	1.0	7.3	2.8	0.9	0.4
50-59	6.6	3.4	2.4	5.8	5.2	2.5	10.4	6.5	2.1	1.3
60-69	12.3	6.0	6.6	12.5	11.2	7.3	19.0	14.4	8.3	5.3
70-79	24.5	13.6	18.8	26.5	22.0	17.6	26.1	22.1	25.9	18.2
80-89	39.3	46.0	45.4	37.8	37.4	38.1	27.3	32.7	43.8	42.7
90-119	12.5	28.5	25.8	13.8	20.2	33.6	9.9	21.4	18.9	32.2
Sex (%)										
Male	40.3	33.6	36.8	43.0	38.1	34.3	33.7	42.4	40.5	36.9
Female	59.7	66.4	63.2	57.0	61.9	65.7	66.3	57.6	59.5	63.1
Major Comorbidity Count (%)										
None	30.2	23.0	11.1	17.8	26.6	9.3	29.9	19.8	26.9	15.6
1-2	64.5	70.2	77.4	68.2	68.1	78.6	64.6	69.2	70.0	80.6
3+	5.3	6.9	11.6	14.0	5.3	12.1	5.5	11.0	3.1	3.8
Years	2002-2018	2002-2018	2005-2017	1998-2017	2019	2019	2017	2016	2017-2019	2017-2019

Table 2. Age-sex-adjusted hazard ratios (94% CL) for 90-day mortality in four Canadian care settings by presence of count of major comorbidities and pneumonia at baseline

Major Comorbidity Count	Home Care (n=841,440)		Assisted Living (n=98,406)		Nursing Homes (n=422,903)		Post-acute Hospitals (n=291,117)	
	Pneumonia at Baseline?		Pneumonia at Baseline?		Pneumonia at Baseline?		Pneumonia at Baseline?	
	No	Yes	No	Yes	No	Yes	No	Yes
0	1.00	1.73 (1.51-1.98)	1.00	1.74 (1.10-2.75)	1.00	1.73 (1.35-2.23)	1.00	1.07 (0.96-1.20)
1-2	1.08 (1.06-1.11)	2.04 (1.50-2.77)	1.41 (1.29-1.54)	3.29 (1.18-9.18)	1.12 (1.07-1.16)	2.94 (1.69-5.09)	0.91 (0.89-0.92)	1.36 (1.07-1.74)
3+	1.71 (1.64-1.79)	2.69 (1.89-3.84)	2.69 (2.38-3.04)	4.14 (1.36-12.56)	2.02 (1.93-2.11)	4.25 (2.42-7.46)	1.26 (1.23-1.30)	1.75 (1.36-2.26)

Table 3. Simulation models for the impact of different assumptions about spread of COVID-19 on the expected number of deaths in a) nursing homes and b) home care settings

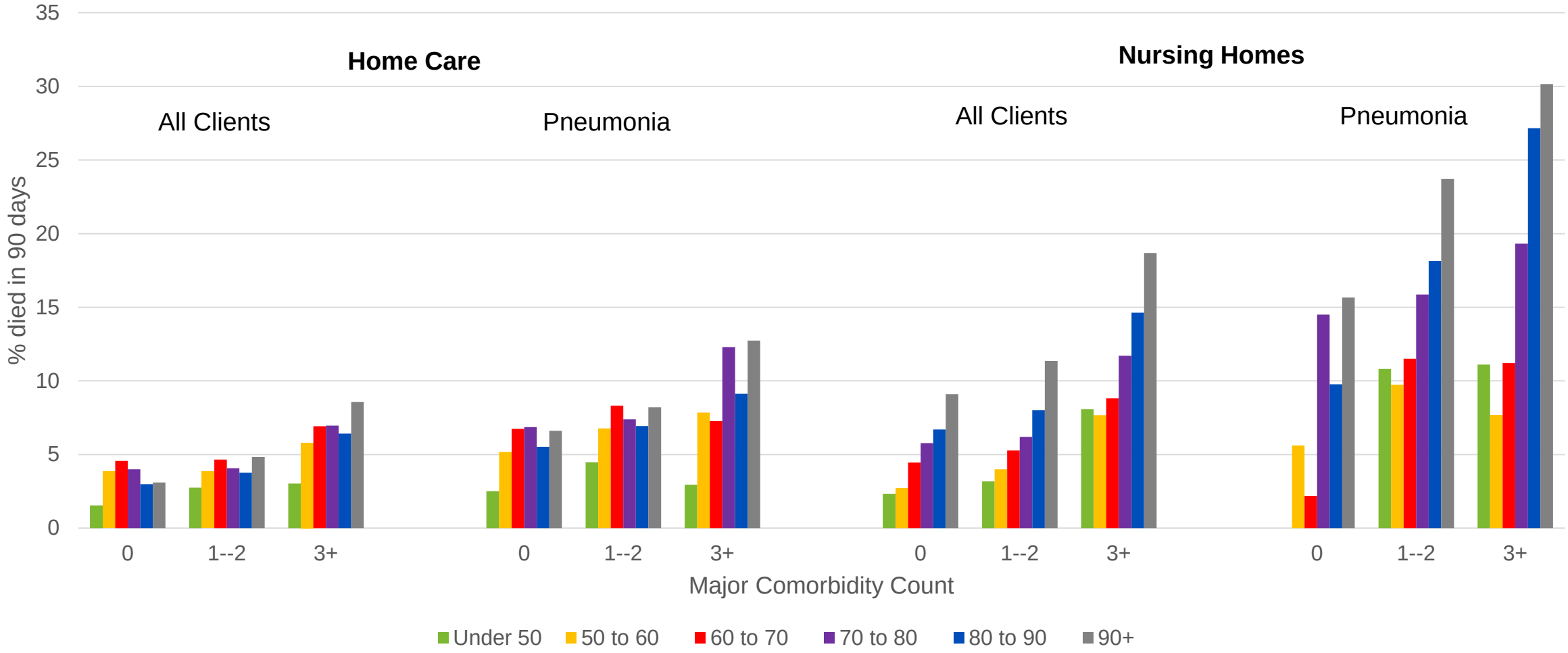
A) Nursing Homes

Assumptions			Expected COVID-19 Deaths					
			Canada (Sample n=173,359; Est Population=207,000)		United States (Sample n=2,046,851; Est Population=2,000,000)		New Zealand (Sample n=59,317; Est Population=34,000)	
COVID-19 cases with Severe Pneumonia (%)	Facilities with COVID-19 Outbreaks (%)	Infection of Residents When Outbreak Occurs (%)	Expected Number	% change	Expected Number	% increase	Expected Number	% increase
20	10	30	229	--	2,027	--	38	--
20	50	15	560	244.5	4972	245.3	94	247.4
20	10	40	302	131.9	2,681	132.3	50	131.6
20	20	40	596	260.3	5,300	261.5	100	263.2
20	20	50	744	324.9	6,609	326.0	125	328.9
30	20	50	1,115	487.9	9,913	489.0	187	492.1

B) Home Care

Assumptions			Expected COVID-19 Deaths					
			Canada (Sample n=232,857; Est Population=560,000)		United States (Sample n=391,910; Est Population=4,500,000)		New Zealand (Sample n=75,195; Est Population=65,000)	
COVID-19 cases with Severe Pneumonia (%)	General Population COVID-19 Prevalence (%)	Home care infections (% of general population rate)	Expected Number	% change	Expected Number	% increase	Expected Number	% increase
20	1	10	229	--	2,027	--	38	--
20	10	10	300	131.0	2,594	128.0	46	121.1
20	10	50	619	270.3	5,116	252.4	83	218.4
30	10	50	928	405.2	7,675	378.6	125	328.9

Figure 1. 90-day Mortality Rates by Age, Pneumonia and Major Comorbidity Count, Home Care and Nursing Homes, Canada, 2002-2018



Appendix A – Construction of Major Comorbidity Count Algorithm

The diagnoses included in this algorithm were derived from the disease pick lists included in various interRAI assessments. The specific interRAI assessments used in each country and care setting were as follows:

1) Canada
   a) Home Care – Resident Assessment Instrument for Home Care (RAI-HC) for all provinces and territories for all years; except Ontario after 2019, where the interRAI Home Care assessment is used.
   b) Assisted Living/Retirement Homes - Resident Assessment Instrument for Home Care (RAI-HC) for all provinces and territories for all years; except Ontario after 2019, where the interRAI Home Care assessment is used. Population is limited to residents receiving home care services in the assisted living/retirement home setting.
   c) Nursing Homes – Resident Assessment Instrument 2.0 (RAI 2.0) for all provinces and territories for all years.
   d) Post-acute Hospitals (referred to as complex, continuing care hospitals/units) - Resident Assessment Instrument 2.0 (RAI 2.0) for all provinces and territories for all years.
2) United States
   a) Home Care – interRAI Home Care assessment is used in all states included in our analyses.
   b) Nursing Homes – Minimum Data Set 3.0 is used in all US states.
3) New Zealand
   a) Home Care – interRAI Home Care assessment is used in all regions of the country.
   b) Nursing Homes – interRAI Long Term Care Facility assessment is used in all regions of the country.

Major comorbidity count variable is the sum of six major types of diagnosis/health conditions indicated by the presence of one or more medical diagnoses and/or treatments. The types included are:

1) Heart – coronary heart disease; congestive heart failure; irregularly irregular pulse; other cardiovascular disease;
2) Liver – liver disease; viral hepatitis;
3) Kidney – renal failure; dialysis;
4) Cancer with treatment – any cancer with radiation or chemotherapy;
5) Neurological – Alzheimer's disease or other dementia; cerebrovascular accident; aphasia; transient ischemic attack; hemi/para/quadriplegia; Huntington's disease; multiple sclerosis; Parkinson's disease; amyotrophic lateral sclerosis; seizure disorder/epilepsy; cerebral palsy;
6) Lungs – Emphysema; chronic obstructive pulmonary disease; respiratory infection other than pneumonia; tuberculosis; respirator in nursing home; tracheostomy care; oxygen therapy and other respiratory treatments;