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Joint impact of dementia and frailty on healthcare utilization and outcomes: A population-based, retrospective cohort study of home care recipients.

(Short Title: Dementia, frailty and healthcare utilization)

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ABSTRACT

Objectives: To examine the associations between dementia and 1-year health outcomes (urgent hospitalization, long-term care [LTC] admission, mortality) among home care recipients and the extent to which these associations vary by clients' frailty level.

Design: A population-based, retrospective cohort study using linked clinical and health administrative databases.

Setting: Home care in Ontario, Canada.

Participants: Long-stay home care clients (n=153,125) aged ≥50 years assessed between April 2014 and March 2015.

Main outcome measures: Dementia was ascertained with a validated administrative data algorithm and frailty with a 66-item frailty index (FI) based on a previously validated FI derived from the clinical assessment. We examined associations between dementia, FI, and their interactions, with 1-year outcomes using multivariable Fine-Gray competing risk (urgent hospitalization and LTC admission) and Cox proportional hazards (mortality) models.

Results: Clients with dementia (vs without) were older (mean ± SD, 83.3±7.9 vs 78.9±11.3 years, p<0.001) and more likely to be frail (30.3% vs 24.2%, p<0.001). In models adjusted for FI (as a continuous variable) and other confounders, clients with dementia showed a lower incidence of urgent hospitalization (adjusted sub-distribution hazard ratio (sHR) = 0.84, 95%CI: 0.83-0.86) and mortality rate (adjusted hazard ratio (HR) = 0.87, 95%CI: 0.84-0.89) but higher incidence of LTC admission (adjusted sHR = 2.60, 95%CI: 2.53-2.67). The impact of dementia on LTC admission and mortality was significantly modified by clients' FI (p<0.001 interaction

terms), showing a lower magnitude of association (i.e., attenuated positive [for LTC admission] and negative [for mortality] association) with increasing frailty.

Conclusions: The strength of associations between dementia and LTC admission and death (but not urgent hospitalization) among home care recipients was significantly modified by their frailty status. Understanding the public health impact of dementia requires consideration of frailty levels among older populations, including those with and without dementia and varying degrees of multimorbidity.

Strengths and limitations of this study

- This population-based long-stay home care study included a large sample size and employed robust statistical modeling techniques to explore relevant interactions and to account for competing risks over follow-up.
- Both exposures of interest (dementia and frailty) were based on previously validated measures for older care recipients in Ontario.
- The availability of linked clinical and health administrative databases allowed for an investigation of the impact of a comprehensive, multi-domain frailty index (FI) on dementia – outcome associations of interest.
- Findings from this study may not be generalizable to community-residing older adults not currently receiving home care services.
- Data regarding other covariates (e.g., support services received) and health outcomes (e.g., functional and/or cognitive decline, quality of life) of interest to home care clients, were not available for this cohort and should be explored in future research.

BACKGROUND

An estimated 500,000 Canadians currently live with dementia and this number is expected to double over the next 10-15 years.[1] Though increasing functional impairment and behavioural challenges often lead to institutionalization, many with dementia reside in the community with substantial support provided by family, friends, and formal home care services.[2,3] Beyond the implications for the health and well-being of those living with or affected by dementia, projected increases in dementia prevalence raise concerns about the ability of the healthcare system to deal with anticipated demand and costs.[1,4]

Previous work, largely from the U.S., has demonstrated elevated healthcare utilization and expenditures for community-dwelling older adults with dementia relative to matched comparison groups.[5,6] This includes an increased likelihood for hospitalization,[7-10] emergency department visits,[7,9] and long-term care (LTC) placement.[11,12] These utilization patterns are important from a public payer perspective but may also highlight possible inadequacies in the availability and/or effectiveness of community-based care for persons with dementia.[12] Many of the resultant transitions in care, especially hospitalizations, are associated with worse outcomes for those with dementia,[13] and may be potentially avoidable with timely and adequate care in the community setting.[6-8,14]

Population-based reports on the impact of dementia on health outcomes and healthcare use are relatively scarce in Canada,[4] with the exception of a few recent studies on dementia in the context of multimorbidity only,[3,15] including previous work by our team.[3] Notably absent are studies examining the joint impact of dementia *and* frailty on healthcare outcomes in community-dwelling older adults.[16,17] Frailty, defined as an increased vulnerability to stressors arising from multi-system dysfunction and subsequent loss of homeostatic reserve and

resiliency,[18] is an important predictor of care transitions among older populations,[19,20] though its predictive value in dementia is less clear.[21,22] Emerging data support a bidirectional relationship between frailty and dementia[23,24] with both becoming more common with increasing age.[4,16,19] As frailty level may reflect dementia severity or stage as well as overall vulnerability, it is an important consideration in understanding the health system implications of dementia prevalence trends.

To inform current and future regional and national dementia strategies,[25] we sought to: 1) investigate the relative effect of dementia on the incidence of urgent (non-elective) hospitalization and LTC admission and rate of death over 1-year among a current population-based cohort of community-dwelling home care recipients in Ontario, and 2) explore variation in these associations by client frailty. In doing so, we provide important baseline empirical data to assist with the prioritization and evaluation of novel client and system level interventions to improve the healthcare and outcomes of vulnerable persons with and without dementia.

METHODS

Study Design and Setting

We conducted a retrospective cohort study of long-stay home care clients in Ontario from April 2014 to March 2016 using linked health administrative and clinical databases. During this period, Ontario's population included over 13.5 million residents with approximately 5 million aged 50 years and older. Most are covered by a universal, publicly funded health insurance program for all necessary medical and emergency care services. Included are costs for hospital and physician services and prescription drugs for those aged 65 years and older or on social assistance or receiving services under the home care program. All referrals for publicly funded home care are assessed for eligibility and level of care by regional case managers. For all clients

receiving long-stay services (i.e., ≥60 days in a single episode), the province has mandated the administration of the Resident Assessment Instrument for Home Care (RAI-HC) on admission and at regular (~6-month) intervals. The RAI-HC is completed by trained staff and provides standardized data on clients' sociodemographic characteristics, health conditions, physical and cognitive status, behaviours and service use.[26]

RAI-HC data were linked with several provincial administrative databases using unique encoded identifiers and analyzed at ICES. These included the Continuing Care Reporting System for Long-Term Care (CCRS-LTC), Canadian Institute for Health Information's Discharge Abstract database (DAD), Ontario Health Insurance Plan database (OHIP), Ontario Drug Benefit database (ODB), and Registered Persons Database (RPDB).

The use of data in this project was authorized under section 45 of Ontario's Personal Health Information Protection Act, which does not require review by a Research Ethics Board. Informed consent from participants was not required because we used health information routinely collected in Ontario and held in health administrative databases. The study is reported as per RECORD guidelines (**S1 Table**).

Study Cohort

All RAI-HC assessments dated between April 1, 2014 and March 31, 2015 among clients aged 50-105 years (n=250,987) were identified. Records were excluded for data quality issues (n=609) and for those ineligible to receive health care services or who resided outside the province (n=230). Given our interest in community-based home care clients, we excluded records for those who had resided in LTC (n=8,816) or had received designated palliative care (n=14,003), or only case management (n=5,775) in the year prior to RAI-HC assessment. We excluded clients receiving palliative home care as they represent a unique subgroup with

different objectives of care and drivers of healthcare utilization with their own policy and practice implications.[27] For those with multiple RAI-HC assessments, only the first assessment in the study period was examined (*index* assessment, n=160,209). We excluded those in hospital at the time of this assessment (n=7,084), resulting in a final sample of 153,125 clients.

Dementia and Frailty

Presence of a dementia diagnosis prior to the index assessment was ascertained using a validated algorithm based on the presence of: a dementia-related hospitalization code (DAD), or three physician claims for dementia within a 2-year period each separated by 30-days (OHIP), or a prescription filled for a cholinesterase inhibitor (ODB).[28]

Baseline frailty was defined using a validated frailty index (FI), calculated as the proportion of accumulated to potential health deficits based on 72 variables derived from the RAI-HC.[19,20] Given our focus on both dementia and frailty as predictors, we excluded dementia diagnoses and cognitive items from the original FI, an approach consistent with that employed by other researchers,[29] resulting in a 66-item FI. This FI was examined as a continuous variable, with higher values indicative of greater frailty. In sensitivity analyses, a categorical FI was examined with robust (FI<0.2), pre-frail (FI 0.2-0.3) and frail (FI>0.3) clients identified based on previously defined thresholds.[19]

Covariates

Client age (at index assessment) and sex were identified from the RPDB, and neighbourhood-level income quintile and rural residence (i.e., community with <10,000 individuals) from the 2006 Statistics Canada census. Marital status was derived from the index RAI-HC. Multimorbidity was based on a count of 16 high-impact chronic conditions (exclusive

of dementia) using common case ascertainment algorithms for DAD and OHIP databases. Additional details regarding these conditions and codes are provided in **S2 Table** and elsewhere.[3,30] Multimorbidity was coded as zero or one, two, three, four, five, or six-plus conditions.

Outcomes

We determined the time (in days) to first urgent hospitalization (DAD data), first LTC admission (CCRS-LTC data) and death (RPDB data) during the 1-year period following clients' index assessment. Of note, 92% of first hospital admissions were urgent (i.e., non-elective or unplanned).

Statistical Analyses

Descriptive statistics were calculated for baseline characteristics (including frailty) and key outcomes by dementia status, using chi-squared tests for categorical variables and one-way analysis of variance for continuous variables.

We modeled associations between dementia, frailty and 1-year outcomes using Fine-Gray competing risk models for urgent hospitalization (accounting for death and LTC admission)[3] and LTC admission (accounting for death) and Cox proportional hazards models for mortality.[31] Associations are reported as either subdistribution-hazard ratios (sHR, Fine-Gray models) or hazard ratios (HR, Cox models) with corresponding 95% confidence intervals (CI). For clients where no event was observed, follow-up time was censored at 1-year after the index assessment. For interpretation, continuous FI estimates are expressed per 0.1-unit increase, which equates to 6-7 additional deficits.

Initial models assessed the separate associations of dementia and frailty with outcomes, adjusting for age and sex. Full multivariable models included dementia and frailty adjusting for age, sex, marital status, income quintile, rural/urban residence and multimorbidity, consistent with previous work.[3,19] A 2-way dementia-frailty interaction was then added to this model and statistical significance of the regression term assessed. From these models, we estimated the sHR or HR and corresponding CI for dementia (yes vs no) across the FI continuum. To assist with interpretation, we report the estimated associations of dementia with outcomes at the 25th and 75th percentiles of the FI distribution in the study population (FI = 0.177 and 0.303, respectively).

In sensitivity analyses (i.e., categorical FI variable), the significance of dementia-frailty interaction terms for all outcomes were examined with Wald tests, with resulting coefficients plotted for visual representation. Coefficients represent sHR or HR for each dementia-frailty group relative to a reference group of robust clients without dementia (considered the lowest risk group for comparative purposes).

Observations with missing data (<0.4% of cohort) were excluded from all analyses. All statistical analyses were conducted using Stata/MP v15 (StataCorp, College Station, TX).

RESULTS

The mean age of the sample was 80.1 (±10.7) years, 65% were women, almost half were widowed and the majority (87%) resided in an urban setting (**Table 1**). Twenty-seven percent (n=40,956) had a dementia diagnosis. High levels of multimorbidity were evident. The most prevalent were hypertension (83.6%), osteoarthritis (66.3%), diabetes (40.8%), coronary syndrome (33.9%) and congestive heart failure (26.8%) (**S3 Table**). Clients' mean FI was 0.24 (±0.09) and 26% were categorized as frail (with 40% pre-frail and 34% robust). Clients with dementia (vs without) were significantly more likely to be older, male, and to have lower levels

of multimorbidity but a higher mean FI, with a greater proportion categorized as frail (30.3% vs 24.2%) (**Figure 1**).

Over the 1-year, a greater proportion of clients with dementia were admitted to LTC (30.0% vs. 11.1%), while slightly fewer had an urgent hospitalization (36.7% vs 38.8%). The distribution of the most common causes of all urgent hospitalizations by dementia status are shown in **S4 Table**. Crude mortality did not vary significantly by dementia status (~ 15% for both groups).

In age-sex and fully adjusted models, the incidence of urgent hospitalization was significantly lower among clients with dementia and higher for those with greater frailty (**Table 2**). The dementia-FI interaction term was modestly significant (p=0.036) and suggested that the lower incidence of urgent hospitalization for dementia was slightly more pronounced with increasing frailty (**Figure 2A**). For example, the estimated sHR for urgent hospitalization associated with dementia at the 25th and 75th percentile of FI was 0.86 (CI: 0.84-0.88) and 0.84 (CI: 0.82-0.86), respectively.

In age-sex and fully adjusted models, both dementia and higher frailty levels were significantly associated with a higher incidence of LTC admission. The dementia-FI interaction term was significant (p<0.001, **Table 2**), and showed that the relative magnitude of the increased incidence of LTC admission associated with dementia was lower with increasing frailty (**Figure 2B**). The estimated sHR for LTC admission among those with dementia (vs without) at the 25th and 75th percentile of FI was 3.48 (3.36-3.61) and 2.42 (2.35-2.48), respectively.

The rate of mortality was significantly lower for clients with dementia and higher for those with greater frailty in both age-sex and fully adjusted models. The dementia-FI interaction term was significant (p<0.001, **Table 2**) and indicated that the lower mortality rate associated

with dementia was attenuated with increasing frailty (**Figure 2C**). The estimated HR for death among clients with dementia (vs without) at the 25th and 75th percentile of FI was 0.79 (0.76-0.83) and 0.88 (0.85-0.91), respectively. At FI levels beyond 0.5 (i.e., the most frail 1%), clients with dementia showed an increased mortality rate.

Sensitivity Analyses

Incorporating a 3-level categorical FI variable (to define robust, pre-frail and frail groups) into the models for each outcome produced comparable findings, except that the dementia-FI interaction term was no longer statistically significant for urgent hospitalization (p=0.124; see **S5 Table** and **S1 Figure [A-C]**). Cumulative incidence plots illustrating the dementia-categorical FI associations with each outcome are presented in **S2 Figure [A-C]**. The latter figures illustrate the magnitude of absolute risk (percentage estimates) for each of our three outcomes across comparison groups that vary in dementia and (categorical) frailty status.

DISCUSSION

In this population-based study of primarily urban-dwelling older home care clients in Ontario, just over one quarter had dementia with a similar proportion categorized as frail. Clients with dementia (vs without) were older and more likely to be frail (30% vs 24%) but showed lower levels of multimorbidity. Both groups showed meaningful variation in frailty status with close to a third being robust. In adjusted analyses accounting for relevant competing risks, the impact of dementia on LTC admission and mortality over 1 year was significantly modified by frailty status**.** Specifically, the higher incidence of LTC admission and lower mortality rate evident among those with (vs without) dementia, observed overall, was attenuated with

increasing frailty. There was less compelling evidence of a significant modification by client frailty for the impact of dementia on urgent hospitalization.

Past research has shown higher healthcare utilization (including hospitalization and emergency department visits)[6-10] for community-dwelling persons with dementia relative to controls. We found that the incidence of urgent hospitalization, though high overall, was significantly lower among those with (vs without) dementia across all frailty levels. This may be explained by several factors. Our cohort included long-stay home care clients who were generally older and more impaired relative to other community-based samples. The coordination, monitoring and support available through home care may have contributed to the lower incidence of hospitalization observed for clients with dementia.[32] Differences in the number, type or severity of chronic conditions between the two groups may have had an effect on hospitalization, though we adjusted for multimorbidity (and frailty) and observed no meaningful variation in incidence across frailty status. Relative to others,[5] we found more similarities in the distribution of prevalent chronic conditions among clients with and without dementia. Finally, our findings may reflect a decision not to pursue hospitalization in more vulnerable persons with dementia.[7]

Consistent with the literature, both dementia and greater frailty were associated with a significantly higher incidence of LTC admission.[11,12,16,20] The attenuation of the association between dementia and incidence of LTC admission (lower sHR) with increasing frailty may initially seem counterintuitive. However, this largely reflects the important contribution of higher levels of frailty to LTC admission among clients *without* dementia (**S1 Figure B**). Others have similarly shown an attenuation of relative risk estimates for various health outcomes associated with dementia with increasing clinical complexity and level of comorbidity in the population

under investigation.[15] Our findings highlight two other important issues relevant to healthcare planning. First, dementia is a significant predictor of LTC admission among home care clients who are relatively robust (representing 34% of clients in our cohort). Second, when compared to those at lowest risk (i.e., robust clients without dementia), the co-occurrence of being frail and having dementia resulted in the highest (7-fold higher) incidence of LTC admission.

Contrary to expectations,[12,17] we observed a lower mortality rate among clients with dementia, though this association was less evident with higher levels of frailty and reversed in direction for the most frail (FI scores ≥ 0.5). Though we adjusted for many factors associated with mortality, including multimorbidity and a comprehensive frailty measure derived from physical and psychosocial items, important differences may have persisted between these two client groups. As noted earlier, it is also possible that aspects of the home care provided to clients may have resulted in better outcomes overall for those with dementia.

Strengths of our study include the population-based sample of clients, timeliness of data, availability of comprehensive clinical and functional measures derived from the RAI-HC and linked administrative databases, and adjustment for competing risks. This allowed for a more sophisticated exploration of the joint impact of dementia and frailty on healthcare outcomes of interest to clients, healthcare practitioners and policy makers. Our analyses also employed previously validated algorithms for both dementia[28] and frailty.[19,20]

Limitations include the absence of data for some covariates of interest (e.g., presence of advance directives, extent/type of supportive services), focus on all-cause outcomes, and inability to incorporate frailty as a time-varying measure. The latter issue is less of a concern given our 1-year follow-up. Our findings may not be generalizable to community-residing persons with dementia or frailty not currently receiving home care. We are unable to comment

on the appropriateness of patterns observed for urgent hospitalization and LTC admission among clients with dementia and/or frailty vs without, or on possible barriers to needed healthcare resources (e.g., in rural settings). All should be areas for future dementia and frailty research.

Conclusions

Our findings support the notion that dementia and frailty, though related, represent distinct clinical considerations in our understanding of the potential impact of population aging on healthcare utilization and costs.[16,17] For older adults receiving home care, a population at high risk of potentially inappropriate care transitions and associated adverse outcomes,[2,3] we showed that the likelihood for LTC admission and death (but not urgent hospitalization) for clients with compared to those without dementia was significantly modified by their frailty status. Given projected increases in the prevalence of both dementia and frailty,[1,16] future work should examine the extent to which the quality, appropriateness and outcomes of health and social care services vary for persons with dementia[33] *and* with varying degrees of frailty.

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Authors' contributions: All co-authors fulfill the criteria required for authorship. CJM, LM, DBH and WPW conceived and designed the study. LM carried out the statistical analyses with assistance from MAC and CJM. LM, WPW and SEB contributed to the acquisition of relevant data. CJM wrote the manuscript and all authors (LM, DBH, MAC, SEB, DPS, WPW) contributed substantially to the critical appraisal, review and interpretation of findings and the final preparation of the manuscript. All authors claim responsibility for the integrity of the data and analyses and have approved the submitted version of the manuscript.

Competing interests: Dr. Seitz has participated as a site investigator for a clinical trial sponsored by Hoffman La Roche. All other authors declare that no competing interests exist.

Data availability: The data from this study are held securely in coded form at ICES. While data sharing agreements prohibit ICES from making the data publicly available, access may be granted to those who meet pre-specified criteria for confidential access, available at www.ices.on.ca/DAS

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Table 1. Baseline characteristics and 1-year health outcomes of long-stay home care clients aged 50+ years in Ontario (April 2014 to March 2015), by presence of dementia.

		Dementia Diagnosis		
	Overall Sample	**No**	**Yes**	***p-value***
	N=153,125	**N=112,169**	**N=40,956**	
Age (years)				
Mean ± SD	80.08 ± 10.65	78.92 ± 11.28	83.27 ± 7.85	<.001
Median (IQR)	82 (74-88)	81 (71-88)	84 (79-89)	<.001
Female Sex	99,040 (64.7%)	73,133 (65.2%)	25,907 (63.3%)	<.001
Marital Status				
Married	58,389 (38.1%)	41,127 (36.7%)	17,262 (42.1%)	<.001
Widowed	68,353 (44.6%)	49,151 (43.8%)	19,202 (46.9%)	
Separated/ Divorced	14,771 (9.6%)	12,131 (10.8%)	2,640 (6.4%)	
Never married/ Other	11,612 (7.6%)	9,760 (8.7%)	1,852 (4.5%)	
Rural-Urban Residence[a]				
Urban	133,619 (87.3%)	97,160 (86.6%)	36,459 (89.0%)	<.001
Rural	19,502 (12.7%)	15,007 (13.4%)	4,495 (11.0%)	
Income Quintile[a]				
1 (low)	36,889 (24.1%)	28,642 (25.5%)	8,247 (20.1%)	<.001
2	32,812 (21.4%)	24,444 (21.8%)	8,368 (20.4%)	
3	29,656 (19.4%)	21,503 (19.2%)	8,153 (19.9%)	
4	28,217 (18.4%)	19,943 (17.8%)	8,274 (20.2%)	
5 (high)	24,963 (16.3%)	17,193 (15.3%)	7,770 (19.0%)	
Number of Chronic Conditions (excl. dementia)				
0-1	12,437 (8.1%)	8,312 (7.4%)	4,125 (10.1%)	<.001
2	20,112 (13.1%)	13,805 (12.3%)	6,307 (15.4%)	
3	28,867 (18.9%)	20,560 (18.3%)	8,307 (20.3%)	
4	29,459 (19.2%)	21,660 (19.3%)	7,799 (19.0%)	
5	24,422 (15.9%)	18,485 (16.5%)	5,937 (14.5%)	
6+	37,828 (24.7%)	29,347 (26.2%)	8,481 (20.7%)	
Frailty Index (Modified)				
Mean ± SD	0.24 ± 0.09	0.24 ± 0.09	0.25 ± 0.10	<.001
Median (IQR)	0.23 (0.18-0.30)	0.23 (0.17-0.30)	0.25 (0.18-0.32)	<.001
Robust	52,113 (34.0%)	39,214 (35.0%)	12,899 (31.5%)	<0.001
Pre-Frail	61,450 (40.1%)	45,788 (40.8%)	15,662 (38.2%)	
Frail	39,562 (25.8%)	27,167 (24.2%)	12,395 (30.3%)	
Outcomes Over Follow-Up				
Died	22,439 (14.7%)	16,334 (14.6%)	6,105 (14.9%)	0.092
Admitted to LTC	24,704 (16.1%)	12,413 (11.1%)	12,291 (30.0%)	<.001
Urgent Hospital Admission	58,551 (38.2%)	43,504 (38.8%)	15,047 (36.7%)	<.001

[a] Less than 0.4% of the cohort with missing data for one or both of these covariates.

Table 2. Estimated associations† between dementia, frailty (and dementia-frailty interaction) and 1-year health outcomes, among long-stay home care clients aged 50+ years in Ontario.

Outcome	Age-Sex Adj. s/HR	Age-Sex Adj. s/HR	Fully Adj. s/HR‡ Model 1	Fully Adj. s/HR‡ Model 2
Urgent Hospitalization				
Dementia	0.815* (0.800,0.832)	--	0.843* (0.827,0.860)	0.891* (0.844,0.941)
Frailty (FI continuous)	--	1.209* (1.199,1.220)	1.159* (1.149,1.169)	1.165* (1.153,1.177)
Dementia-Frailty term	--	--	--	0.979* (0.960,0.999)
p for interaction	--	--	--	0.036
LTC Admission				
Dementia	2.749* (2.679,2.821)	--	2.598* (2.530,2.668)	5.814* (5.413,6.245)
Frailty (FI continuous)	--	1.472* (1.454,1.490)	1.490* (1.471,1.509)	1.727* (1.697,1.757)
Dementia-Frailty term	--	--	--	0.748* (0.730,0.767)
p for interaction	--	--	--	<0.001
Mortality				
Dementia	0.901* (0.874,0.928)	--	0.869* (0.843,0.895)	0.677* (0.619,0.740)
Frailty (FI continuous)		1.507* (1.488,1.527)	1.478* (1.459,1.498)	1.442* (1.419,1.465)
Dementia-Frailty term	--	--	--	1.090* (1.059,1.122)
p for interaction	--	--	--	<0.001

† For urgent hospitalization and LTC admission, estimates are subdistribution hazard ratios (sHRs) and corresponding 95% confidence intervals from Fine-Gray model; for mortality, estimates are hazard ratios (HRs) and corresponding 95% confidence intervals from Cox proportional hazards regression model.

‡ Models adjusted for age, sex, marital status, rurality, income quintile and multimorbidity count; Model 2 additionally includes dementia-frailty interaction term

* p<0.05

FIGURES

Figure 1. Distribution of baseline frailty (FI) by dementia status

Figure 2. Plots of dementia-frailty (FI) interaction for 1-year health outcomes, illustrating the impact of dementia (yes vs no) on outcomes across frailty (FI) level

SUPPORTING INFORMATION - TABLES & FIGURES

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S2 Table. Description and coding of multimorbidity

S3 Table. Distribution of 16 chronic conditions among long-stay home care clients aged 50+ years in Ontario, by dementia status

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S5 Table. Sensitivity analysis showing estimated associations† between dementia, frailty (categorical FI), and dementia-frailty interaction, and 1-year health outcomes among long-stay home care clients aged 50+ years in Ontario

S1 Figure. Plots of dementia-frailty (categorical FI) interaction for 1-year health outcomes

S2 Figure. Plots of cumulative incidence (Urgent hospitalization, LTC admission), and cumulative hazard (Mortality), based on multivariable regression models that include dementia-frailty (categorical FI) interaction

Fig 1. Distribution of baseline frailty (FI) by dementia status

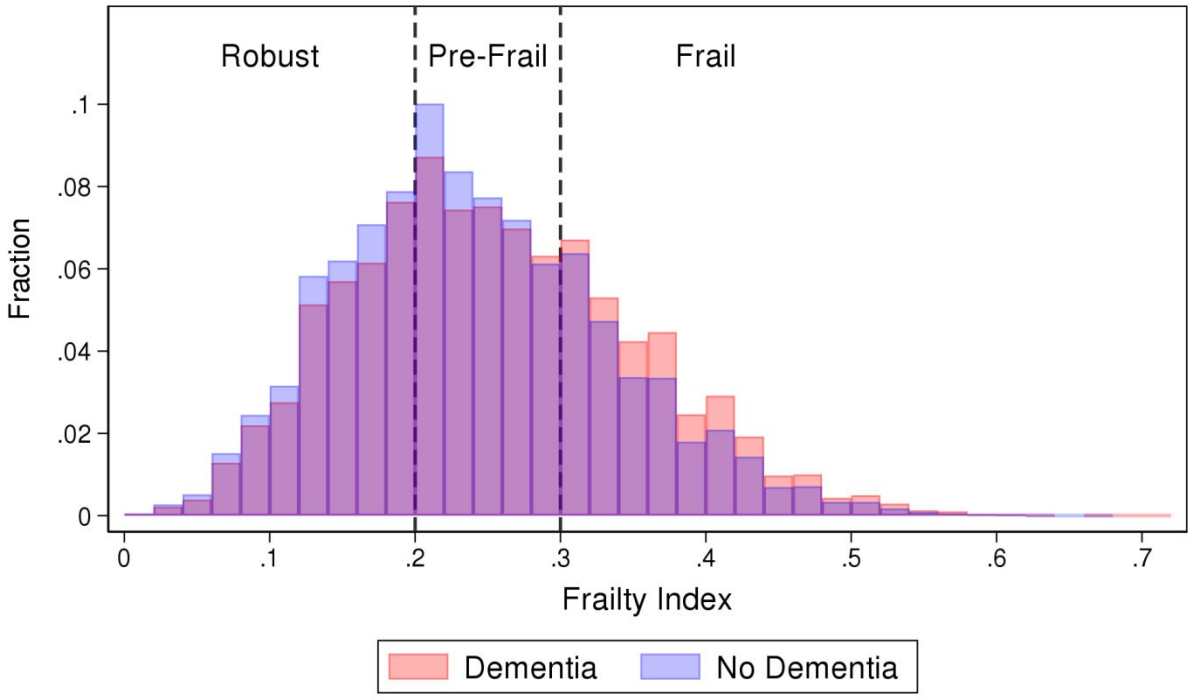
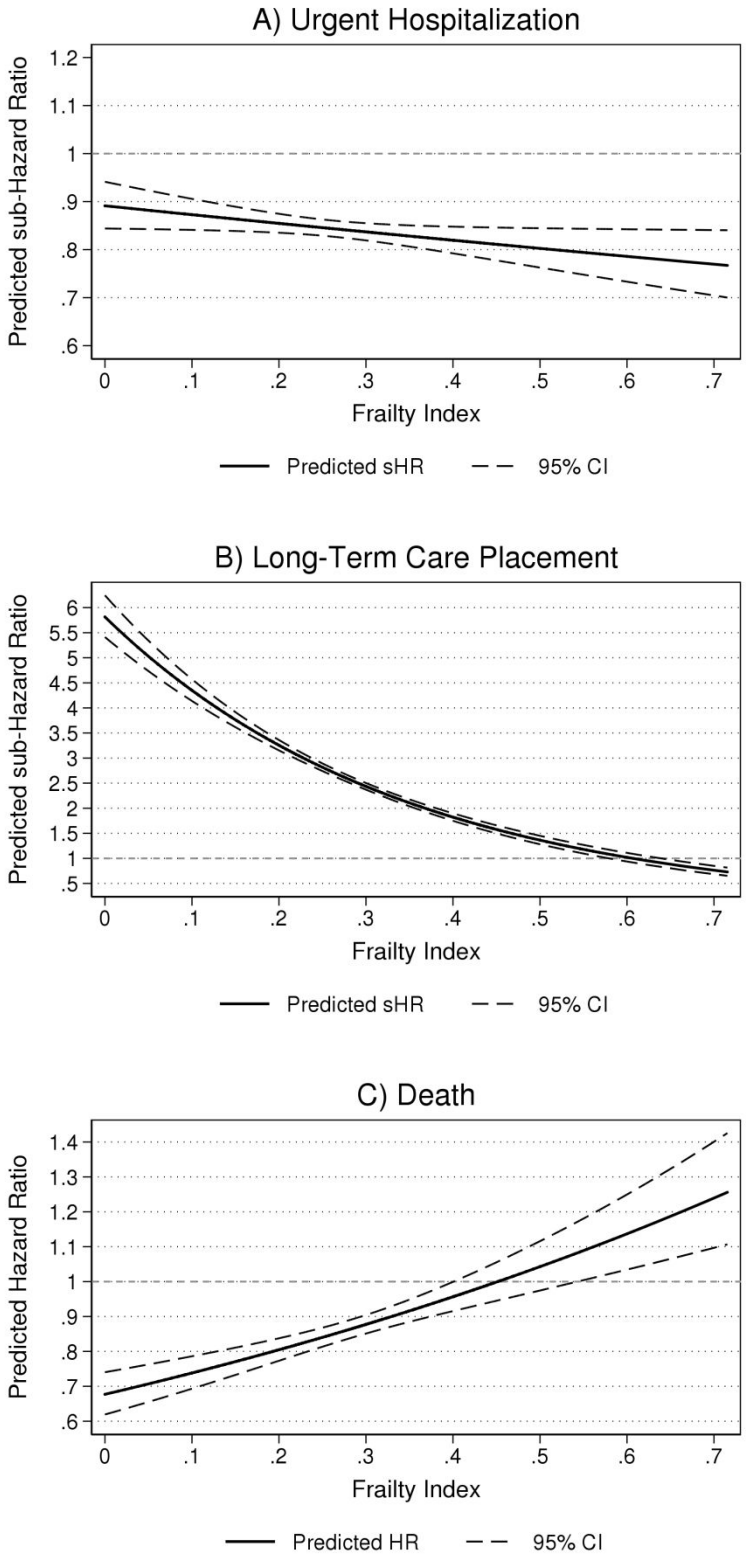


Fig 2. Plots of dementia-frailty (FI) interaction for 1-year health outcomes, illustrating the impact of dementia (yes vs no) on outcomes across frailty (FI) level.



Maxwell et al. Joint impact of dementia and frailty on healthcare utilization and outcomes: a population-based, retrospective cohort study of home care recipients

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S1 Table. RECORD Statement

Joint impact of dementia and frailty on healthcare utilization and outcomes: a population-based, retrospective cohort study of home care recipients.

Authors: Colleen J. Maxwell; Luke Mondor; David B. Hogan; Michael A. Campitelli; Susan E. Bronskill; Dallas P Seitz; Walter P Wodchis

	No.	STROBE items	RECORD items	Location in manuscript where items are reported
Title and abstract				
	1	(a) Indicate the study's design with a commonly used term in the title or the abstract (b) Provide in the abstract an informative and balanced summary of what was done and what was found	RECORD 1.1: The type of data used should be specified in the title or abstract. When possible, the name of the databases used should be included. RECORD 1.2: If applicable, the geographic region and timeframe within which the study took place should be reported in the title or abstract. RECORD 1.3: If linkage between databases was conducted for the study, this should be clearly stated in the title or abstract.	1.1 Included in abstract (*Methods*). 1.2 Included in abstract (*Methods*). 1.3 Included in abstract (*Methods*).
Introduction				
Background rationale	2	Explain the scientific background and rationale for the investigation being reported		2. Included, Introduction (pp. 4-5).
Objectives	3	State specific objectives, including any pre-specified hypotheses		3. Included, Introduction (pg. 5).
Methods				
Study Design	4	Present key elements of study design early in the paper		4. Included, *Study Design and Setting* (pg. 5).
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection		5. Included, *Study Design and Setting* (pp. 5-6).
Participants	6	*(a) Cohort study* - Give the eligibility criteria, and the sources and methods	RECORD 6.1: The methods of study population selection (such as codes or algorithms used to identify subjects)	6.1 Included, *Study Cohort* (pp. 6-7).

		of selection of participants. Describe methods of follow-up *Case-control study* - Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study* - Give the eligibility criteria, and the sources and methods of selection of participants *(b) Cohort study* - For matched studies, give matching criteria and number of exposed and unexposed *Case-control study* - For matched studies, give matching criteria and the number of controls per case	should be listed in detail. If this is not possible, an explanation should be provided. RECORD 6.2: Any validation studies of the codes or algorithms used to select the population should be referenced. If validation was conducted for this study and not published elsewhere, detailed methods and results should be provided. RECORD 6.3: If the study involved linkage of databases, consider use of a flow diagram or other graphical display to demonstrate the data linkage process, including the number of individuals with linked data at each stage.	6.2 Included, *Dementia and Frailty* (pg. 6) and *Covariates* (pg. 7). 6.3 *Study Design and Setting* and *Study Cohort* (pp. 5-6), includes detailed information on linked data sources and number of clients included.
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable.	RECORD 7.1: A complete list of codes and algorithms used to classify exposures, outcomes, confounders, and effect modifiers should be provided. If these cannot be reported, an explanation should be provided.	7.1 Included, exposure (*Dementia and Frailty, pp. 6-7*), outcomes (*Outcomes, pg. 7*), confounders (*Covariates, pg. 7*) and effect modifiers (*Frailty, pg. 7*). See also *Supplemental Material: Table S1*.
Data sources/ measurement	8	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group		Included, *Methods,* pp. 6-7.
Bias	9	Describe any efforts to address potential sources of bias		Included, *Statistical Analyses*, pg. 8.
Study size	10	Explain how the study size was arrived at		Included, *Study Cohort*, pg. 6.
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why		Included, *Dementia and Frailty* (pp. 6-7), *Covariates* (pg. 7), *Outcomes* (pg. 7) and *Statistical Analyses* (pg. 8).

Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) *Cohort study* - If applicable, explain how loss to follow-up was addressed *Case-control study* - If applicable, explain how matching of cases and controls was addressed *Cross-sectional study* - If applicable, describe analytical methods taking account of sampling strategy (e) Describe any sensitivity analyses		a) Included, *Statistical Analyses* (pg. 8). b) Included, *Statistical Analyses* (pg. 8). c) Included, *Statistical Analyses* (pg. 9). d) Included, *Statistical Analyses* (pg. 8). e) Included, *Statistical Analyses* (pg. 8).
Data access and cleaning methods		..	RECORD 12.1: Authors should describe the extent to which the investigators had access to the database population used to create the study population. RECORD 12.2: Authors should provide information on the data cleaning methods used in the study.	12.1 Included, *Study Design and Setting* (pp. 5-6). 12.2 Included, *Study Design and Setting* and *Study Cohort* (pp. 5-6).
Linkage		..	RECORD 12.3: State whether the study included person-level, institutional-level, or other data linkage across two or more databases. The methods of linkage and methods of linkage quality evaluation should be provided.	12.3 Included, *Study Design and Setting* (pp. 5-6).
Results				
Participants	13	(a) Report the numbers of individuals at each stage of the study (*e.g.*, numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed) (b) Give reasons for non-participation at each stage.	RECORD 13.1: Describe in detail the selection of the persons included in the study (*i.e.,* study population selection) including filtering based on data quality, data availability and linkage. The selection of included persons can be described in the text and/or by means of the study flow diagram.	13.1 Included, *Study Design and Setting* and *Study Cohort* (pp. 5-6).

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		(c) Consider use of a flow diagram		
Descriptive data	14	(a) Give characteristics of study participants (*e.g.*, demographic, clinical, social) and information on exposures and potential confounders (b) Indicate the number of participants with missing data for each variable of interest (c) *Cohort study* - summarise follow-up time (*e.g.*, average and total amount)		14. Included, *Results* (pg. 9, Table 1, Figure 1 and Table S2).
Outcome data	15	*Cohort study* - Report numbers of outcome events or summary measures over time *Case-control study* - Report numbers in each exposure category, or summary measures of exposure *Cross-sectional study* - Report numbers of outcome events or summary measures		15. Included, *Results* (pg. 9 and Table 1).
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval). Make clear which confounders were adjusted for and why they were included (b) Report category boundaries when continuous variables were categorized (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period		16. Included, *Results* (pp. 9-10 and Table 2 & Figure 2).
Other analyses	17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses		17. Included, *Results* (pg. 10 and Table S4 and Figures S1 & S2).
Discussion				
Key results	18	Summarise key results with reference to study objectives		18. Included, *Interpretation* (pp. 10-11).

Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	RECORD 19.1: Discuss the implications of using data that were not created or collected to answer the specific research question(s). Include discussion of misclassification bias, unmeasured confounding, missing data, and changing eligibility over time, as they pertain to the study being reported.	19.1 Included, *Interpretation* (pp. 12-13).
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence		20. Included, *Interpretation* and *Conclusions* (pp. 11-13).
Generalisability	21	Discuss the generalisability (external validity) of the study results		21. Included, *Interpretation* (pg. 13).
Other Information				
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based		22. Included, *Title Page* (pp. 1-2) and *Acknowledgements / Disclaimer* (pg. 14).
Accessibility of protocol, raw data, and programming code		..	RECORD 22.1: Authors should provide information on how to access any supplemental information such as the study protocol, raw data, or programming code.	22.1 Included, *Data Availability* (pg. 14).

*Reference: Benchimol EI, Smeeth L, Guttmann A, Harron K, Moher D, Petersen I, Sørensen HT, von Elm E, Langan SM, the RECORD Working Committee. The REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) Statement. 2015 Oct 6;12(10):e1001885. doi: 10.1371/journal.pmed.1001885

Completed January 28, 2019 (CJM).

S2 Table. Description and coding of multimorbidity

In addition to dementia, we identified the presence of 16 chronic conditions, prevalent as of each home care clients' RAI-HC assessment date, based on data from hospital discharges (Discharge Abstract Database, DAD), physician billings (Ontario Health Insurance Plan, OHIP) and prescription drugs dispensed (Ontario Drug Benefits, ODB). Conditions included: acute myocardial infarction (AMI), asthma, (any) cancer, cardiac arrhythmia, chronic obstructive pulmonary disease (COPD), congestive heart failure (CHF), chronic coronary syndrome, dementia, diabetes, hypertension, non-psychotic mood and anxiety disorders, other mental illnesses (including schizophrenia, delusions, and other psychoses; personality disorders; and substance abuse), osteoarthritis, osteoporosis, renal failure, rheumatoid arthritis, and stroke (excluding transient ischemic attack). These conditions were selected based on their system burden, in terms of population and economic burden, and have been used in multiple research studies of multimorbidity in Ontario.[3,29] Where applicable we used validated algorithms to ascertain cases (AMI, asthma, CHF, COPD, dementia, diabetes, hypertension and rheumatoid arthritis). All other conditions were defined based on the presence of any one inpatient hospital diagnostic code (DAD data) or two or more outpatient physician billing codes (OHIP data) within a 2 year period using relevant ICD-9 and ICD-10 codes (below). The earliest hospital or billing date was used to identify incident cases.

From these data we defined level of multimorbidity (i.e., chronic disease burden) based on a simple count of prevalent chronic conditions, which was coded as zero/one (reference), two, three, four, five, or six-plus conditions.

Condition [reference for validated algorithm]	ICD 9 / OHIP	ICD 10	ODB*
Acute Myocardial Infarction (AMI) [1]	410	I21, I22	
Osteoarthritis and other Arthritis:			
(A) Osteoarthritis	715	M15-M19	
(B) Other Arthritis (includes Synovitis, Fibrositis, Connective tissue disorders, Ankylosing spondylitis, Gout Traumatic arthritis, pyogenic arthritis, Joint derangement, Dupuytren's contracture, Other MSK disorders)	727, 729, 710, 720, 274, 716, 711, 718, 728, 739	M00-M03, M07, M10, M11-M14, M20-M25, M30-M36, M65-M79	
Arthritis - Rheumatoid arthritis [2]	714	M05-M06	
Asthma [3]	493	J45	
(all) Cancers	140-239	C00-C26, C30-C44, C45-C97	
Cardiac Arrhythmia	427 (OHIP) / 427.3 (DAD)	I48.0, I48.1	
Congestive Heart Failure [4]	428	I500, I501, I509	
Chronic Obstructive Pulmonary Disease [5]	491, 492, 496	J41, J43, J44	
Coronary syndrome (excluding AMI)	411-414	I20, I22-I25	
Dementia [6]	290, 331 (OHIP) / 046.1, 290.0, 290.1, 290.2, 290.3, 290.4, 294, 331.0, 331.1, 331.5, F331.82 (DAD)	F00, F01, F02, F03, G30	Cholinesterase Inhibitors
Diabetes [7]	250	E08 - E13	
Hypertension [8]	401, 402, 403, 404, 405	I10, I11, I12, I13, I15	
(Other) Mental Illnesses	291, 292, 295, 297, 298, 299, 301, 302, 303, 304, 305, 306, 307, 313, 314, 315, 319	F04, F050, F058, F059, F060, F061, F062, F063, F064, F07, F08, F10, F11, F12, F13, F14, F15, F16, F17, F18, F19, F20, F21, F22, F23, F24, F25, F26, F27, F28, F29, F340, F35, F36, F37, F430, F439, F453, F454, F458, F46, F47, F49, F50, F51, F52, F531, F538, F539, F54, F55, F56, F57, F58, F59, F60, F61, F62, F63, F64, F65, F66, F67, F681, F688, F69, F70, F71, F72, F73, F74, F75, F76, F77, F78, F79, F80, F81, F82, F83, F84, F85, F86, F87, F88, F89, F90, F91, F92, F931, F932, F933, F938, F939, F94, F95, F96, F97, F98	

Mood, anxiety, depression and other nonpsychotic disorders	296, 300, 309, 311	F30, F31, F32, F33, F34 (excl. F34.0), F38, F39, F40, F41, F42, F43.1, F43.2, F43.8, F44, F45.0, F45.1, F45.2, F48, F53.0, F68.0, F93.0, F99
Osteoporosis	733	M81, M82
Renal failure	403, 404, 584, 585, 586, v451	N17, N18, N19, T82.4, Z49.2, Z99.2
Stroke (excluding transient ischemic attack)	430, 431, 432, 434, 436	I60-I64

NOTES:

Abbreviations: ICD = International Classification of Disease; ODB = Ontario Drug Benefit program database; OHIP = Ontario Health Insurance Plan, physician billings database;

All case definitions look back to 2001 to ascertain disease status, with the exception of AMI (1 year prior to index), Cancer (2 years), Mood Disorder (2 years) and Other Mental Illnesses (2 years)

AMI, Asthma, COPD, CHF, Dementia, Diabetes Hypertension and Rheumatoid Arthritis are based on validated case algorithms (see Sources 1-8 below, respectively). All other conditions required at least one diagnosis recorded in acute care (CIHI) or two diagnoses recorded in physician billings within a two-year period.

*ODB prescription drug records are not available for the majority of persons under the age of 65

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S3 Table. Distribution of 16 chronic conditions among long-stay home care clients aged 50+ years in Ontario, by dementia status

Chronic Condition	Overall Sample % (n)	No Dementia* % (n)	Dementia* % (n)
	N=153,125	N=112,169	N=40,956
Hypertension	83.6 (128,017)	83.6 (93,828)	83.5 (34,189)
Osteoarthritis	66.3 (101,447)	66.9 (75,046)	64.5 (26,401)
Diabetes	40.8 (62,462)	42.5 (47,631)	36.2 (14,831)
Coronary Syndrome (excl. AMI)	33.9 (51,858)	34.2 (38,378)	32.9 (13,480)
Congestive Heart Failure	26.8 (41,103)	28.8 (32,254)	21.6 (8,849)
Cancer	22.5 (34,477)	24.1 (27,033)	18.2 (7,444)
Arrhythmia	22.0 (33,744)	22.3 (25,060)	21.2 (8,684)
Chronic Obstructive Pulmonary Dis.	20.6 (31,543)	22.4 (25,107)	15.7 (6,436)
Mood & Anxiety Disorders (nonpsychotic)	20.1 (30,773)	19.1 (21,409)	22.9 (9,364)
Asthma	18.6 (28,496)	19.8 (22,191)	15.4 (6,305)
Renal failure	17.7 (27,065)	18.8 (21,070)	14.6 (5,995)
Stroke	15.0 (22,985)	15.2 (17,046)	14.5 (5,939)
Osteoporosis	14.0 (21,412)	13.3 (14,962)	15.7 (6,450)
Other Mental Health Conditions	8.4 (12,920)	8.1 (9,110)	9.3 (3,810)
Rheumatoid Arthritis	4.4 (6,746)	4.9 (5,443)	3.2 (1,303)
Acute Myocardial Infarction	1.4 (2,193)	1.6 (1,847)	0.8 (346)

* Estimates for those without vs with dementia were significantly different ($p<0.001$), except for hypertension ($p=0.423$)

S4 Table. Distribution of the most frequent causes of hospitalization among all urgent admissions† during 1-year follow-up, by ICD-10 chapter

ICD-10 Chapter	Overall Sample	No Dementia	Dementia
	N=94,057	N=71,845	N=22,212
Diseases of the circulatory system	16352 (17.4)	13,166 (18.3)	3,186 (14.3)
Diseases of the respiratory system	16097 (17.1)	12,612 (17.6)	3,485 (15.7)
Symptoms, signs and abnormal clinical and lab findings not elsewhere classified	9350 (9.9)	6,943 (9.7)	2,407 (10.8)
Injury, poisoning and other external causes	9311 (9.9)	6,693 (9.3)	2,618 (11.8)
Diseases of the digestive system	7693 (8.2)	6,266 (8.7)	1,427 (6.4)
Diseases of the genitourinary system	7000 (7.4)	5,131 (7.1)	1,869 (8.4)
Certain infectious and parasitic diseases	4944 (5.3)	3,845 (5.4)	1,099 (4.9)
Mental and behavioural disorders	4462 (4.7)	2,460 (3.4)	2,002 (9.0)
Factors influencing health status and contact with health services	3837 (4.1)	2,887 (4.0)	950 (4.3)
Endocrine, nutritional and metabolic diseases	3681 (3.9)	2,984 (4.2)	697 (3.1)
Diseases of the musculoskeletal system and connective tissue	3071 (3.3)	2,556 (3.6)	515 (2.3)
Diseases of the nervous system	2845 (3.0)	1,684 (2.3)	1,161 (5.2)
Neoplasms	2364 (2.5)	2,012 (2.8)	352 (1.6)
Diseases of the skin and subcutaneous tissue	1730 (1.8)	1,499 (2.1)	231 (1.0)
Diseases of the blood and blood-forming mechanisms	1125 (1.2)	944 (1.3)	181 (0.8)

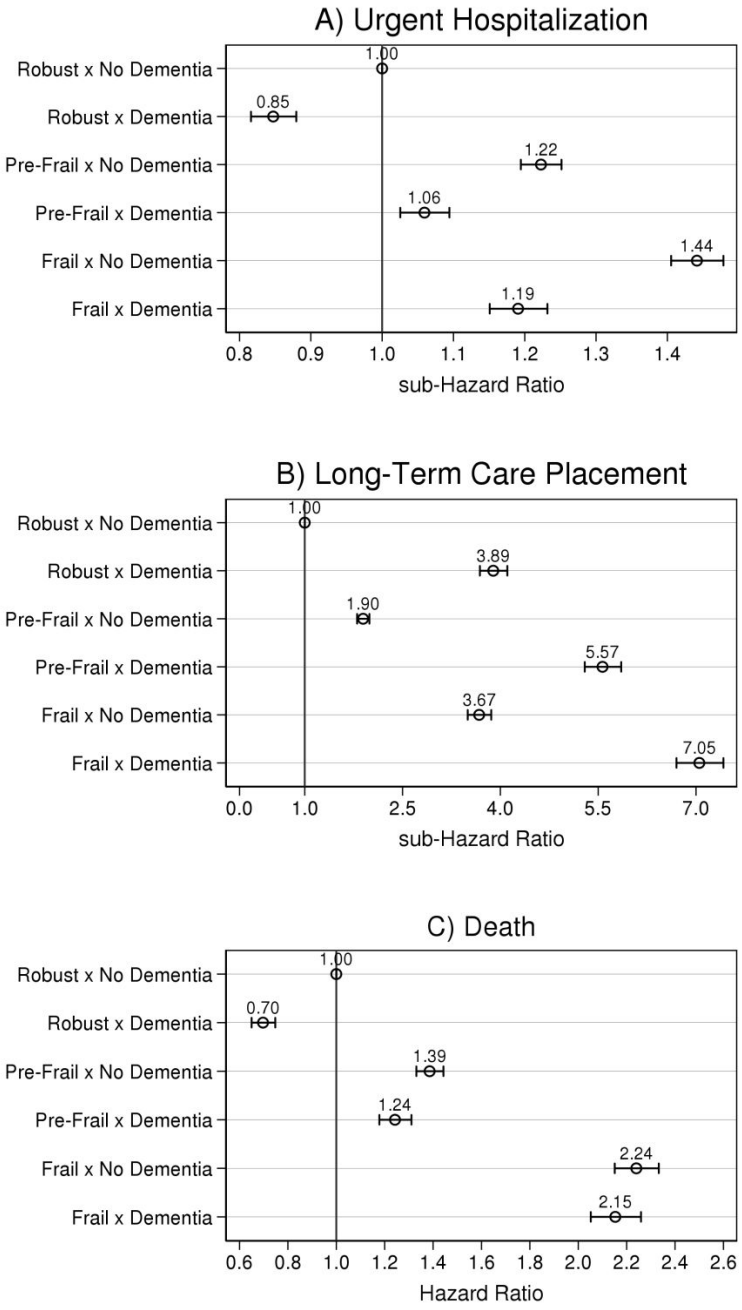
†N=94,057 urgent admissions among 58,551 home care clients (38.2% with at least one urgent hospitalization); Of those with an admission, 63.7% had 1 admission over the follow-up, 22.5% had 2 admissions, and 13.8% had 2+

S5 Table. Sensitivity analysis showing estimated associations† between dementia, frailty (categorical FI), and dementia-frailty interaction, and 1-year health outcomes among long-stay home care clients aged 50+ years in Ontario

Outcome	Age-Sex Adj. s/HR	Age-Sex Adj. s/HR	Fully Adj. s/HR‡ Model 1	Fully Adj. s/HR‡ Model 2
Urgent Hospitalization				
Dementia	0.815* (0.800,0.832)	--	0.847* (0.830,0.864)	0.847* (0.816,0.880)
Frailty – Robust		1 [Ref gp]	1 [Ref gp]	1 [Ref gp]
Pre-frail		1.318* (1.292,1.345)	1.229* (1.204,1.255)	1.223* (1.195,1.252)
Frail		1.580* (1.546,1.614)	1.431* (1.400,1.463)	1.441* (1.405,1.479)
Dementia-Pre-frail	--	--	--	1.023 (0.974,1.073)
Dementia-Frail	--	--	--	0.975 (0.927,1.025)
p for interaction (Wald test)	--	--	--	0.124
LTC Admission				
Dementia	2.749* (2.679,2.821)	--	2.632* (2.563,2.703)	3.891* (3.687,4.107)
Frailty – Robust		1 [Ref gp]	1 [Ref gp]	1 [Ref gp]
Pre-frail		1.544* (1.494,1.596)	1.634* (1.580,1.690)	1.895* (1.804,1.992)
Frail		2.476* (2.395,2.559)	2.563* (2.478,2.652)	3.675* (3.499,3.860)
Dementia-Pre-frail	--	--	--	0.755* (0.706,0.807)
Dementia-Frail	--	--	--	0.493* (0.461,0.527)
p for interaction (Wald test)	--	--	--	<0.001
Mortality				
Dementia	0.901* (0.874,0.928)	--	0.882* (0.856,0.909)	0.697* (0.650,0.748)
Frailty – Robust		1 [Ref gp]	1 [Ref gp]	1 [Ref gp]
Pre-frail		1.524* (1.471,1.579)	1.466* (1.414,1.519)	1.386* (1.331,1.443)
Frail		2.565* (2.477,2.655)	2.425* (2.340,2.512)	2.240* (2.151,2.333)
Dementia-Pre-frail	--	--	--	1.286* (1.181,1.401)
Dementia-Frail	--	--	--	1.379* (1.270,1.497)
p for interaction (Wald test)	--	--	--	<0.001

† For urgent hospitalization and LTC admission, estimates are sub-distribution hazard ratios (sHRs) and corresponding 95% confidence intervals from Fine-Gray model; for mortality, estimates are hazard ratios (HRs) and corresponding 95% confidence intervals from Cox proportional hazards regression model.
‡ Models adjusted for age, sex, marital status, rurality, income quintile and multimorbidity count; Model 2 additionally includes dementia-frailty interaction term.
* p<0.05

S1 Figure. Plots of dementia-frailty (categorical FI) interaction for 1-year health outcomes

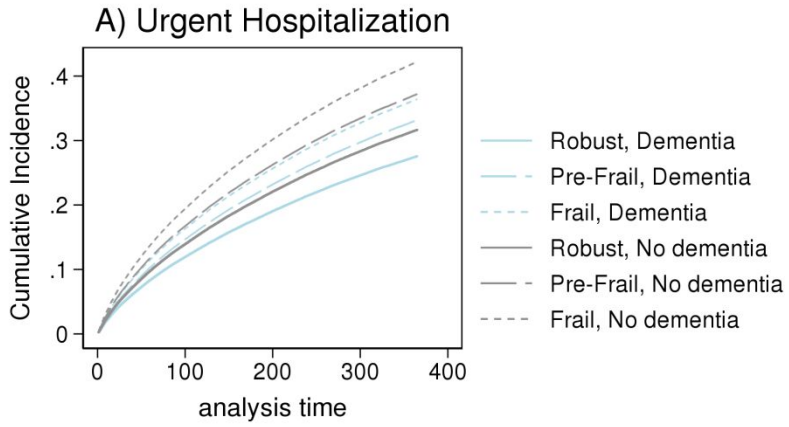


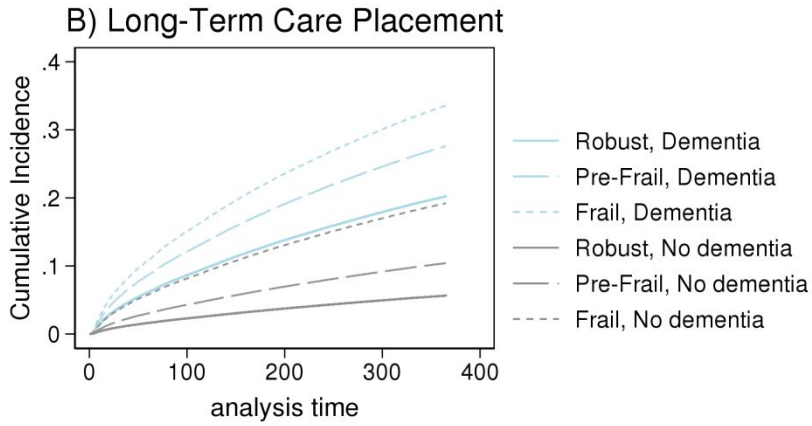
Ratio [Dementia vs No Dementia] for urgent hospitalization among:
Robust=0.85; Pre-frail=[1.06/1.22]=0.87; Frail=[1.19/1.44]=0.83

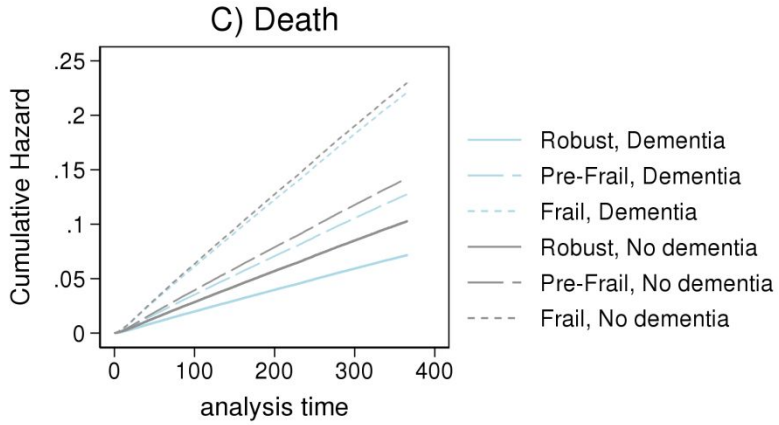
Ratio [Dementia vs No Dementia] for LTC admission among:
Robust=3.89; Pre-frail=[5.57/1.90]=2.93; Frail=[7.05/3.67]=1.92

Ratio [Dementia vs. No Dementia] for mortality among:
Robust=0.70; Pre-frail=[1.24/1.39]=0.89; Frail=[2.15/2.24]=0.96

S2 Figure. Plots of cumulative incidence (Urgent hospitalization, LTC admission), and cumulative hazard (Mortality), based on multivariable regression models that include dementia-frailty (categorical FI) interaction







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Joint impact of dementia and frailty on healthcare utilization and outcomes: A retrospective cohort study of long-stay home care recipients.

(Short Title: Dementia, frailty and healthcare utilization)

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ABSTRACT

Objectives: To examine the associations between dementia and 1-year health outcomes (urgent hospitalization, long-term care [LTC] admission, mortality) among long-stay home care recipients and the extent to which these associations vary by clients' frailty level.

Design: A retrospective cohort study using linked clinical and health administrative databases.

Setting: Home care in Ontario, Canada.

Participants: Long-stay (≥60 days) care clients (n=153,125) aged ≥50 years assessed between April 2014 and March 2015.

Main outcome measures: Dementia was ascertained with a validated administrative data algorithm and frailty with a 66-item frailty index (FI) based on a previously validated FI derived from the clinical assessment. We examined associations between dementia, FI, and their interactions, with 1-year outcomes using multivariable Fine-Gray competing risk (urgent hospitalization and LTC admission) and Cox proportional hazards (mortality) models.

Results: Clients with dementia (vs without) were older (mean ± SD, 83.3±7.9 vs 78.9±11.3 years, p<0.001) and more likely to be frail (30.3% vs 24.2%, p<0.001). In models adjusted for FI (as a continuous variable) and other confounders, clients with dementia showed a lower incidence of urgent hospitalization (adjusted sub-distribution hazard ratio (sHR) = 0.84, 95%CI: 0.83-0.86) and mortality rate (adjusted hazard ratio (HR) = 0.87, 95%CI: 0.84-0.89) but higher incidence of LTC admission (adjusted sHR = 2.60, 95%CI: 2.53-2.67). The impact of dementia on LTC admission and mortality was significantly modified by clients' FI (p<0.001 interaction terms), showing a lower magnitude of association (i.e., attenuated positive [for LTC admission] and negative [for mortality] association) with increasing frailty.

Conclusions: The strength of associations between dementia and LTC admission and death (but not urgent hospitalization) among home care recipients was significantly modified by their frailty status. Understanding the public health impact of dementia requires consideration of frailty levels among older populations, including those with and without dementia and varying degrees of multimorbidity.

Strengths and limitations of this study

- This population-based long-stay home care study included a large sample size and employed robust statistical modeling techniques to explore relevant interactions and to account for competing risks over follow-up.
- Both exposures of interest (dementia and frailty) were based on previously validated measures for older care recipients in Ontario.
- The availability of linked clinical and health administrative databases allowed for an investigation of the impact of a comprehensive, multi-domain frailty index (FI) on dementia – outcome associations of interest.
- Findings from this study may not be generalizable to community-residing older adults not currently receiving home care services on a long-stay basis.
- Data regarding other covariates (e.g., support services received) and health outcomes (e.g., functional and/or cognitive decline, quality of life) of interest to home care clients, were not available for this cohort and should be explored in future research.

BACKGROUND

An estimated 500,000 Canadians currently live with dementia and this number is expected to double over the next 10-15 years.[1] Though increasing functional impairment and behavioural challenges often lead to institutionalization, many with dementia reside in the community with substantial support provided by family, friends, and formal home care services.[2,3] Beyond the implications for the health and well-being of those living with or affected by dementia, projected increases in dementia prevalence raise concerns about the ability of the healthcare system to deal with anticipated demand and costs.[1,4]

Previous work, largely from the U.S., has demonstrated elevated healthcare utilization and expenditures for community-dwelling older adults with dementia relative to matched comparison groups.[5,6] This includes an increased likelihood for hospitalization,[7-10] emergency department visits,[7,9] and long-term care (LTC) placement.[11,12] These utilization patterns are important from a public payer perspective but may also highlight possible inadequacies in the availability and/or effectiveness of community-based care for persons with dementia.[12] Many of the resultant transitions in care, especially hospitalizations, are associated with worse outcomes for those with dementia,[13] and may be potentially avoidable with timely and adequate care in the community setting.[6-8,14] Recent healthcare reforms in Canada and elsewhere have called for an expansion of publicly funded home and community-based care[15,16] with the aim of potentially reducing costly acute and LTC admissions among vulnerable older adults. Consequently, there is considerable value in understanding patterns of healthcare utilization among older home care recipients, especially for persons with dementia and/or other indices of heightened risk or vulnerability.[2,3,17-19]

Population-based reports on the impact of dementia on health outcomes and healthcare use among vulnerable older adults are relatively scarce in Canada,[4] with the exception of a few recent studies on dementia in the context of multimorbidity only,[3,20] including previous work by our team.[3] Notably absent are studies examining the joint impact of dementia *and* frailty on healthcare outcomes in community-dwelling older adults,[21,22] including those receiving care in the home. Frailty, defined as an increased vulnerability to stressors arising from multi-system dysfunction and subsequent loss of homeostatic reserve and resiliency,[23] is an important predictor of care transitions among older populations,[24,25] though its predictive value in dementia is less clear.[26,27] Emerging data support a bidirectional relationship between frailty and dementia[28,29] with both becoming more common with increasing age.[4,21,24] As frailty level may reflect dementia severity or stage as well as overall vulnerability, it is an important consideration in understanding the health system implications of dementia prevalence trends.

To inform current and future regional and national dementia strategies[30] and related policy and resource planning decisions regarding home and community-based services for this vulnerable population, we sought to: 1) investigate the relative effect of dementia on the incidence of urgent (non-elective) hospitalization and LTC admission and rate of death over 1-year among a current cohort of community-dwelling home care recipients in Ontario, and 2) explore variation in these associations by client frailty. In doing so, we provide important baseline empirical data to assist with the prioritization and evaluation of novel client and system level interventions to improve the healthcare and outcomes of vulnerable persons with and without dementia.

METHODS

Study Design and Setting

We conducted a retrospective cohort study of long-stay home care clients in Ontario from April 2014 to March 2016 using linked health administrative and clinical databases. During this period, Ontario's population included over 13.5 million residents with approximately 5 million aged 50 years and older. Most are covered by a universal, publicly funded health insurance program for all necessary medical and emergency care services. Included are costs for hospital and physician services and prescription drugs for those aged 65 years and older or on social assistance or receiving services under the home care program. Referrals for publicly funded home care may be made by healthcare providers, institutions, clients and/or their family and potential clients are assessed for eligibility and level of care by regional case managers. Services may include homemaking, transportation, personal care, nursing care, end-of-life care, physiotherapy, occupational and speech-language therapy and can vary by type and amount across health regions.[15] Home care is provided on either a short- (i.e., services provided for <60 days [e.g., to aid in recovery post-surgery or injury]) or long-stay (i.e., clients requiring services in the home for ≥60 days in a single episode) basis. For all long-stay clients (approximately 40% of all home care clients),[31] the province has mandated the administration of the Resident Assessment Instrument for Home Care (RAI-HC) on admission and at regular (~6-month) intervals. The RAI-HC is completed by trained staff and provides standardized data on clients' sociodemographic characteristics, health conditions, physical and cognitive status, behaviours and service use.[32]

RAI-HC data were linked with several provincial administrative databases using unique encoded identifiers and analyzed at ICES. These included the Continuing Care Reporting System for Long-Term Care (CCRS-LTC), Canadian Institute for Health Information's Discharge

Abstract database (DAD), Ontario Health Insurance Plan database (OHIP), Ontario Drug Benefit database (ODB), and Registered Persons Database (RPDB).

The use of data in this project was authorized under section 45 of Ontario's Personal Health Information Protection Act, which does not require review by a Research Ethics Board. Informed consent from participants was not required because we used health information routinely collected in Ontario and held in health administrative databases. The study is reported as per RECORD guidelines (**S1 Table**).

Study Cohort

All RAI-HC assessments dated between April 1, 2014 and March 31, 2015 among clients aged 50-105 years (n=250,987) were identified. Records were excluded for data quality issues (n=609) and for those ineligible to receive health care services or who resided outside the province (n=230). Given our interest in community-based home care clients, we excluded records for those who had resided in LTC (n=8,816) or had received designated palliative care (n=14,003), or only case management (n=5,775) in the year prior to RAI-HC assessment. We excluded clients receiving palliative home care as they represent a unique subgroup with different objectives of care and drivers of healthcare utilization with their own policy and practice implications.[33] For those with multiple RAI-HC assessments, only the first assessment in the study period was examined (*index* assessment, n=160,209). We excluded those in hospital at the time of this assessment (n=7,084), resulting in a final sample of 153,125 clients.

Patient and Public Involvement

Patients were not involved in the design or conduct of this study.

Dementia and Frailty

Presence of a dementia diagnosis prior to the index assessment was ascertained using a validated algorithm based on the presence of: a dementia-related hospitalization code (DAD), or three physician claims for dementia within a 2-year period each separated by 30-days (OHIP), or a prescription filled for a cholinesterase inhibitor (ODB).[34]

Baseline frailty was defined using a validated frailty index (FI), calculated as the proportion of accumulated to potential health deficits based on 72 variables derived from the index RAI-HC.[24,25] Given our focus on both dementia and frailty as predictors, we excluded dementia diagnoses and cognitive items from the original FI, an approach consistent with that employed by other researchers,[35] resulting in a 66-item FI. This FI was examined as a continuous variable, with higher values indicative of greater frailty. In sensitivity analyses, a categorical FI was examined with robust (FI<0.2), pre-frail (FI 0.2-0.3) and frail (FI>0.3) clients identified based on previously defined thresholds.[24]

Covariates

Client age (at index assessment) and sex were identified from the RPDB, and neighbourhood-level income quintile and rural residence (i.e., community with <10,000 individuals) from the 2006 Statistics Canada census. Marital status was derived from the index RAI-HC. Multimorbidity was based on a count of 16 high-impact chronic conditions (exclusive of dementia) using common case ascertainment algorithms for DAD and OHIP databases. Additional details regarding these conditions and codes are provided in **S2 Table** and elsewhere.[3,36] Multimorbidity was coded as zero or one, two, three, four, five, or six-plus conditions.

Outcomes

We determined the time (in days) to first urgent hospitalization (DAD data), first LTC admission (CCRS-LTC data) and death (RPDB data) during the 1-year period following clients' index assessment. Of note, 92% of first hospital admissions were urgent (i.e., non-elective or unplanned).

Statistical Analyses

Descriptive statistics were calculated for baseline characteristics (including frailty) and key outcomes by dementia status, using chi-squared tests for categorical variables and one-way analysis of variance for continuous variables.

We modeled associations between dementia, frailty and 1-year outcomes using Fine-Gray competing risk models for urgent hospitalization (accounting for death and LTC admission)[3] and LTC admission (accounting for death) and Cox proportional hazards models for mortality.[37] Associations are reported as either subdistribution-hazard ratios (sHR, Fine-Gray models) or hazard ratios (HR, Cox models) with corresponding 95% confidence intervals (CI). For clients where no event was observed, follow-up time was censored at 1-year after the index assessment. For interpretation, continuous FI estimates are expressed per 0.1-unit increase, which equates to 6-7 additional deficits.

Initial models assessed the separate associations of dementia and frailty with outcomes, adjusting for age and sex. Full multivariable models included dementia and frailty adjusting for age, sex, marital status, income quintile, rural/urban residence and multimorbidity, consistent with previous work.[3,24] A 2-way dementia-frailty interaction was then added to this model and statistical significance of the regression term assessed. From these models, we estimated the sHR or HR and corresponding CI for dementia (yes vs no) across the FI continuum. To assist with

interpretation, we report the estimated associations of dementia with outcomes at the 25th and 75th percentiles of the FI distribution in the study population (FI = 0.177 and 0.303, respectively).

In sensitivity analyses (i.e., categorical FI variable), the significance of dementia-frailty interaction terms for all outcomes were examined with Wald tests, with resulting coefficients plotted for visual representation. Coefficients represent sHR or HR for each dementia-frailty group relative to a reference group of robust clients without dementia (considered the lowest risk group for comparative purposes).

Observations with missing data (<0.4% of cohort) were excluded from all analyses. All statistical analyses were conducted using Stata/MP v15 (StataCorp, College Station, TX).

RESULTS

The mean age of the sample was 80.1 (±10.7) years, 65% were women, almost half were widowed and the majority (87%) resided in an urban setting (**Table 1**). Twenty-seven percent (n=40,956) had a dementia diagnosis. High levels of multimorbidity were evident. The most prevalent were hypertension (83.6%), osteoarthritis (66.3%), diabetes (40.8%), coronary syndrome (33.9%) and congestive heart failure (26.8%) (**S3 Table**). Clients' mean FI was 0.24 (±0.09) and 26% were categorized as frail (with 40% pre-frail and 34% robust). Clients with dementia (vs without) were significantly more likely to be older, male, and to have lower levels of multimorbidity but a higher mean FI, with a greater proportion categorized as frail (30.3% vs 24.2%) (**S1 Figure**).

Over the 1-year, a greater proportion of clients with dementia were admitted to LTC (30.0% vs. 11.1%), while slightly fewer had an urgent hospitalization (36.7% vs 38.8%). The distribution of the most common causes of all urgent hospitalizations by dementia status are

shown in **S4 Table**. Crude mortality did not vary significantly by dementia status (~ 15% for both groups).

In age-sex and fully adjusted models, the incidence of urgent hospitalization was significantly lower among clients with dementia and higher for those with greater frailty (**Table 2**). The dementia-FI interaction term was modestly significant (p=0.036) and suggested that the lower incidence of urgent hospitalization for dementia was slightly more pronounced with increasing frailty (**Figure 1A**). For example, the estimated sHR for urgent hospitalization associated with dementia at the 25th and 75th percentile of FI was 0.86 (CI: 0.84-0.88) and 0.84 (CI: 0.82-0.86), respectively.

In age-sex and fully adjusted models, both dementia and higher frailty levels were significantly associated with a higher incidence of LTC admission. The dementia-FI interaction term was significant (p<0.001, **Table 2**), and showed that the relative magnitude of the increased incidence of LTC admission associated with dementia was lower with increasing frailty (**Figure 1B**). The estimated sHR for LTC admission among those with dementia (vs without) at the 25th and 75th percentile of FI was 3.48 (3.36-3.61) and 2.42 (2.35-2.48), respectively.

The rate of mortality was significantly lower for clients with dementia and higher for those with greater frailty in both age-sex and fully adjusted models. The dementia-FI interaction term was significant (p<0.001, **Table 2**) and indicated that the lower mortality rate associated with dementia was attenuated with increasing frailty (**Figure 1C**). The estimated HR for death among clients with dementia (vs without) at the 25th and 75th percentile of FI was 0.79 (0.76-0.83) and 0.88 (0.85-0.91), respectively. At FI levels beyond 0.5 (i.e., the most frail 1%), clients with dementia showed an increased mortality rate.

Sensitivity Analyses

Incorporating a 3-level categorical FI variable (to define robust, pre-frail and frail groups) into the models for each outcome produced comparable findings, except that the dementia-FI interaction term was no longer statistically significant for urgent hospitalization (p=0.124; see **S5 Table** and **Figure 2 [A-C]**). Cumulative incidence plots illustrating the dementia-categorical FI associations with each outcome are presented in **Figure 3 [A-C]** (with 1-year estimates shown in **S6 Table)**. The latter figures illustrate the magnitude of absolute risk (percentage estimates) for each of our three outcomes across comparison groups that vary in dementia and (categorical) frailty status.

DISCUSSION

In this population-based study of primarily urban-dwelling older long-stay home care clients in Ontario, just over one quarter had dementia with a similar proportion categorized as frail. Clients with dementia (vs without) were older and more likely to be frail (30% vs 24%) but showed lower levels of multimorbidity. Both groups showed meaningful variation in frailty status with close to a third being robust. In adjusted analyses accounting for relevant competing risks, the impact of dementia on LTC admission and mortality over 1 year was significantly modified by frailty status**.** Specifically, the higher incidence of LTC admission and lower mortality rate evident among those with (vs without) dementia, observed overall, was attenuated with increasing frailty. There was less compelling evidence of a significant modification by client frailty for the impact of dementia on urgent hospitalization.

Past research has shown higher healthcare utilization (including hospitalization and emergency department visits)[6-10] for community-dwelling persons with dementia relative to controls. We found that the incidence of urgent hospitalization, though high overall, was significantly lower among those with (vs without) dementia across all frailty levels. Our findings

regarding the substantial burden of unplanned hospitalization among community-residing older adults receiving home care, but lower incidence of hospitalization among clients with (vs without) dementia are consistent with earlier studies of older home care recipients from North America and Europe.[17,18] The lower incidence observed for clients with dementia may be explained by several factors. Our cohort included long-stay home care clients who were generally older and more impaired relative to other community-based samples. Given our primary focus on community-residing, long-stay home care clients, we also excluded clients who had received LTC or palliative care in the year prior to their index assessment. These clients would be expected to have more severe or late-stage dementia and thus, potentially different health outcomes (and drivers) compared to our study population. The coordination, monitoring and support available through home care may have contributed to the lower incidence of hospitalization observed for clients with dementia.[38] For example, persons with an explicit diagnosis of dementia receiving formal home care services may be more likely to have their unique care needs (and those of their family caregivers) identified and appropriately addressed by home care staff and other members of the interprofessional team.[17] This could include a greater likelihood for such clients to have a do-not-hospitalize directive discussed and noted in their care plan. Differences in the number, type or severity of chronic conditions between the two groups may have had an effect on hospitalization, though we adjusted for multimorbidity (and frailty) and observed no meaningful variation in incidence across frailty status. Relative to others,[5] we found more similarities in the distribution of prevalent chronic conditions among clients with and without dementia. However, we also observed a significantly higher likelihood for several chronic conditions, previously shown to be important predictors of hospitalization,[17,18] among clients without (vs with) dementia, including congestive heart failure,

cancer, chronic obstructive pulmonary disease and renal failure. Finally, our findings may reflect a decision not to pursue hospitalization in more vulnerable persons with dementia.[7]

Consistent with the literature, both dementia and greater frailty were associated with a significantly higher incidence of LTC admission.[11,12,21,25] The attenuation of the association between dementia and incidence of LTC admission (lower sHR) with increasing frailty may initially seem counterintuitive. However, this largely reflects the important contribution of higher levels of frailty to LTC admission among clients *without* dementia (Figure 2B). Others have similarly shown an attenuation of relative risk estimates for various health outcomes associated with dementia with increasing clinical complexity and level of comorbidity in the population under investigation.[20] Our findings highlight two other important issues relevant to healthcare planning. First, dementia is a significant predictor of LTC admission among home care clients who are relatively robust (representing 34% of clients in our cohort). Second, when compared to those at lowest risk (i.e., robust clients without dementia), the co-occurrence of being frail and having dementia resulted in the highest (7-fold higher) incidence of LTC admission.

Contrary to expectations,[12,22] we observed a lower mortality rate among clients with dementia, though this association was less evident with higher levels of frailty and reversed in direction for the most frail (FI scores ≥ 0.5). Though we adjusted for many factors associated with mortality, including multimorbidity and a comprehensive frailty measure derived from physical and psychosocial items, important differences may have persisted between these two client groups, as discussed above for our hospitalization finding. As noted earlier, it is also possible that aspects of the home care provided to clients may have resulted in better outcomes overall for those with dementia.

Strengths of our study include the population-based sample of long-stay, non-palliative clients, timeliness of data, availability of comprehensive clinical and functional measures derived from the RAI-HC and linked administrative databases, and adjustment for competing risks. This allowed for a more sophisticated exploration of the joint impact of dementia and frailty on healthcare outcomes of interest to clients, healthcare practitioners and policy makers. Our analyses also employed previously validated algorithms for both dementia[34] and frailty.[24,25]

Limitations include the absence of data for some covariates of interest (e.g., presence of advance directives, extent/type of supportive services), focus on all-cause outcomes, and inability to incorporate frailty as a time-varying measure. The latter issue is less of a concern given our 1-year follow-up. Our administrative data derived algorithm for dementia, though validated,[34] does not allow us to comment on the relevance of dementia sub-type to risk of our key outcomes, including mortality. Our findings may not be generalizable to community-residing persons with dementia or frailty not currently receiving long-stay home care or those residing in other care settings (e.g., assisted living, residential or long-term care) or regions with different healthcare systems. Approximately half of community-residing persons with dementia in Ontario received home care during our study period.[39] Our long-stay home care population (including those with and without dementia) would be expected to be more impaired with higher multimorbidity and acuity levels than their counter-parts in the community not receiving home care,[40] but less functionally or cognitively impaired than similarly aged persons residing in residential or long-term care facilities.[1,41] These baseline health differences across care settings would be expected to alter the likelihood for healthcare use and outcomes among persons with and without dementia or frailty.[17,41] We are unable to comment on the appropriateness of patterns observed for urgent hospitalization and LTC admission among clients with dementia and/or

frailty vs without, or on possible barriers to needed healthcare resources (e.g., in rural settings). All should be areas for future dementia and frailty research.

Conclusions

Our findings support the notion that dementia and frailty, though related, represent distinct clinical considerations in our understanding of the potential impact of population aging on healthcare utilization and costs.[21,22,42] For older adults receiving home care on a long-stay basis, a population at high risk of potentially inappropriate care transitions and associated adverse outcomes,[2,3] we showed that the likelihood for LTC admission and death (but not urgent hospitalization) for clients with compared to those without dementia was significantly modified by their frailty status. Given projected increases in the prevalence of both dementia and frailty,[1,21] future work should examine the extent to which the quality, appropriateness and outcomes of health and social care services vary for persons with dementia[43] *and* with varying degrees of frailty.

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Authors' contributions: All co-authors fulfill the criteria required for authorship. CJM, LM, DBH and WPW conceived and designed the study. LM carried out the statistical analyses with assistance from MAC and CJM. LM, WPW and SEB contributed to the acquisition of relevant data. CJM wrote the manuscript and all authors (LM, DBH, MAC, SEB, DPS, WPW) contributed substantially to the critical appraisal, review and interpretation of findings and the final preparation of the manuscript. All authors claim responsibility for the integrity of the data and analyses and have approved the submitted version of the manuscript.

Competing interests: Dr. Seitz has participated as a site investigator for a clinical trial sponsored by Hoffman La Roche. All other authors declare that no competing interests exist.

Data availability: The data from this study are held securely in coded form at ICES. While data sharing agreements prohibit ICES from making the data publicly available, access may be granted to those who meet pre-specified criteria for confidential access, available at www.ices.on.ca/DAS

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Table 1. Baseline characteristics and 1-year health outcomes of long-stay home care clients aged 50+ years in Ontario (April 2014 to March 2015), by presence of dementia.

	Overall Sample	Dementia Diagnosis[b]	
		No	Yes
	N=153,125	N=112,169	N=40,956
Age (years)			
Mean ± SD	80.08 ± 10.65	78.92 ± 11.28	83.27 ± 7.85
Median (IQR)	82 (74-88)	81 (71-88)	84 (79-89)
Female Sex	99,040 (64.7%)	73,133 (65.2%)	25,907 (63.3%)
Marital Status			
Married	58,389 (38.1%)	41,127 (36.7%)	17,262 (42.1%)
Widowed	68,353 (44.6%)	49,151 (43.8%)	19,202 (46.9%)
Separated/ Divorced	14,771 (9.6%)	12,131 (10.8%)	2,640 (6.4%)
Never married/ Other	11,612 (7.6%)	9,760 (8.7%)	1,852 (4.5%)
Rural-Urban Residence[a]			
Urban	133,619 (87.3%)	97,160 (86.6%)	36,459 (89.0%)
Rural	19,502 (12.7%)	15,007 (13.4%)	4,495 (11.0%)
Income Quintile[a]			
1 (low)	36,889 (24.1%)	28,642 (25.5%)	8,247 (20.1%)
2	32,812 (21.4%)	24,444 (21.8%)	8,368 (20.4%)
3	29,656 (19.4%)	21,503 (19.2%)	8,153 (19.9%)
4	28,217 (18.4%)	19,943 (17.8%)	8,274 (20.2%)
5 (high)	24,963 (16.3%)	17,193 (15.3%)	7,770 (19.0%)
Number of Chronic Conditions (excl. dementia)			
0-1	12,437 (8.1%)	8,312 (7.4%)	4,125 (10.1%)
2	20,112 (13.1%)	13,805 (12.3%)	6,307 (15.4%)
3	28,867 (18.9%)	20,560 (18.3%)	8,307 (20.3%)
4	29,459 (19.2%)	21,660 (19.3%)	7,799 (19.0%)
5	24,422 (15.9%)	18,485 (16.5%)	5,937 (14.5%)
6+	37,828 (24.7%)	29,347 (26.2%)	8,481 (20.7%)
Frailty Index (Modified)			
Mean ± SD	0.24 ± 0.09	0.24 ± 0.09	0.25 ± 0.10
Median (IQR)	0.23 (0.18-0.30)	0.23 (0.17-0.30)	0.25 (0.18-0.32)
Robust	52,113 (34.0%)	39,214 (35.0%)	12,899 (31.5%)
Pre-Frail	61,450 (40.1%)	45,788 (40.8%)	15,662 (38.2%)
Frail	39,562 (25.8%)	27,167 (24.2%)	12,395 (30.3%)
Outcomes Over Follow-Up			
Died	22,439 (14.7%)	16,334 (14.6%)	6,105 (14.9%)
Admitted to LTC	24,704 (16.1%)	12,413 (11.1%)	12,291 (30.0%)
Urgent Hospital Admission	58,551 (38.2%)	43,504 (38.8%)	15,047 (36.7%)

[a] Less than 0.4% of the cohort with missing data for one or both of these covariates. [b] All differences are statistically significant at p<0.001 except for mortality outcome (p=0.092).

Table 2. Estimated associations† between dementia, frailty (and dementia-frailty interaction) and 1-year health outcomes, among long-stay home care clients aged 50+ years in Ontario.

Outcome	Age-Sex Adj. s/HR	Age-Sex Adj. s/HR	Fully Adj. s/HR‡ Model 1	Fully Adj. s/HR‡ Model 2
Urgent Hospitalization				
Dementia	0.815* (0.800,0.832)	--	0.843* (0.827,0.860)	0.891* (0.844,0.941)
Frailty (FI continuous)	--	1.209* (1.199,1.220)	1.159* (1.149,1.169)	1.165* (1.153,1.177)
Dementia-Frailty term	--	--	--	0.979* (0.960,0.999)
p for interaction	--	--	--	0.036
LTC Admission				
Dementia	2.749* (2.679,2.821)	--	2.598* (2.530,2.668)	5.814* (5.413,6.245)
Frailty (FI continuous)	--	1.472* (1.454,1.490)	1.490* (1.471,1.509)	1.727* (1.697,1.757)
Dementia-Frailty term	--	--	--	0.748* (0.730,0.767)
p for interaction	--	--	--	<0.001
Mortality				
Dementia	0.901* (0.874,0.928)	--	0.869* (0.843,0.895)	0.677* (0.619,0.740)
Frailty (FI continuous)		1.507* (1.488,1.527)	1.478* (1.459,1.498)	1.442* (1.419,1.465)
Dementia-Frailty term	--	--	--	1.090* (1.059,1.122)
p for interaction	--	--	--	<0.001

† For urgent hospitalization and LTC admission, estimates are subdistribution hazard ratios (sHRs) and corresponding 95% confidence intervals from Fine-Gray model; for mortality, estimates are hazard ratios (HRs) and corresponding 95% confidence intervals from Cox proportional hazards regression model.

‡ Models adjusted for age, sex, marital status, rurality, income quintile and multimorbidity count; Model 2 additionally includes dementia-frailty interaction term

* p<0.05

FIGURES

Figure 1. Plots of dementia-frailty (FI) interaction for 1-year health outcomes [A) Urgent hospitalization; B) LTC placement; C) Death], illustrating the impact of dementia (yes vs no) on outcomes across frailty (FI) level

Figure 2. Plots of dementia-frailty (categorical FI) interaction for 1-year health outcomes [A) Urgent hospitalization; B) LTC placement; C) Death]

Notes for below Figure 2.

Ratio [Dementia vs No Dementia] for urgent hospitalization among:
Robust=0.85; Pre-frail=[1.06/1.22]=0.87; Frail=[1.19/1.44]=0.83

Ratio [Dementia vs No Dementia] for LTC admission among:
Robust=3.89; Pre-frail=[5.57/1.90]=2.93; Frail=[7.05/3.67]=1.92

Ratio [Dementia vs. No Dementia] for mortality among:
Robust=0.70; Pre-frail=[1.24/1.39]=0.89; Frail=[2.15/2.24]=0.96

Figure 3. Plots of cumulative incidence [A) Urgent hospitalization, B) LTC placement], and cumulative hazard [C) Death], based on multivariable regression models that include dementia-frailty (categorical FI) interaction

SUPPORTING INFORMATION - TABLES & FIGURES

S1 Table. RECORD Statement

S2 Table. Description and coding of multimorbidity

S3 Table. Distribution of 16 chronic conditions among long-stay home care clients aged 50+ years in Ontario, by dementia status

S4 Table. Distribution of the most frequent causes of hospitalization among all urgent admissions† during 1-year follow-up, by ICD-10 chapter and dementia status

S5 Table. Sensitivity analysis showing estimated associations† between dementia, frailty (categorical FI), and dementia-frailty interaction, and 1-year health outcomes among long-stay home care clients aged 50+ years in Ontario

S6 Table. Estimated cumulative incidence (urgent hospitalization, LTC admission) and cumulative hazard (mortality) at 1-year, based on multivariable regression models that include dementia-frailty (categorical FI) interaction

S1 Figure. Distribution of baseline frailty (FI) by dementia status

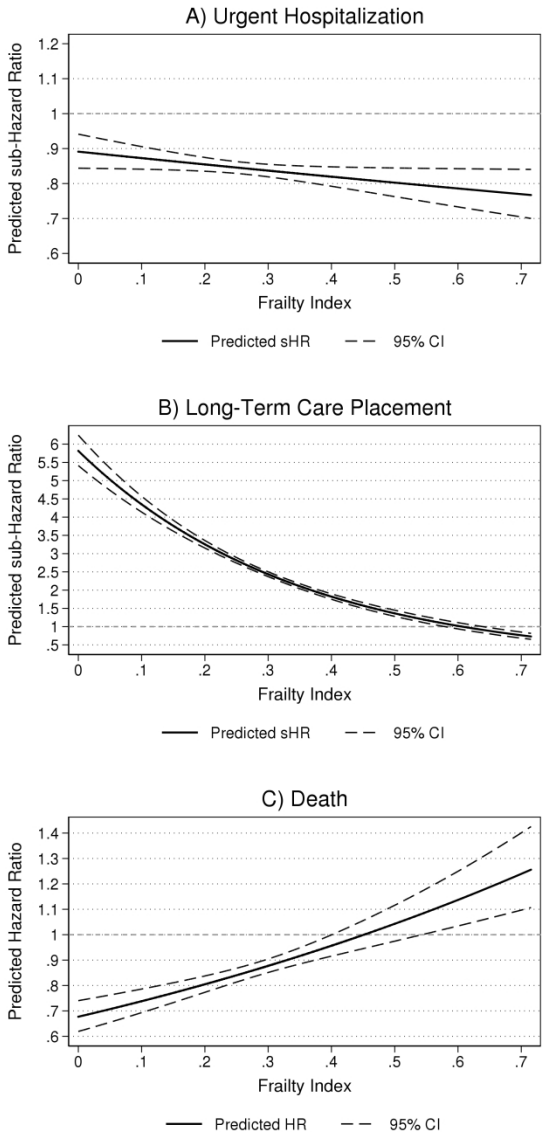

Figure 1. Plots of dementia-frailty (FI) interaction for 1-year health outcomes [A) Urgent hospitalization; B) LTC placement; C) Death], illustrating the impact of dementia (yes vs no) on outcomes across frailty (FI) level

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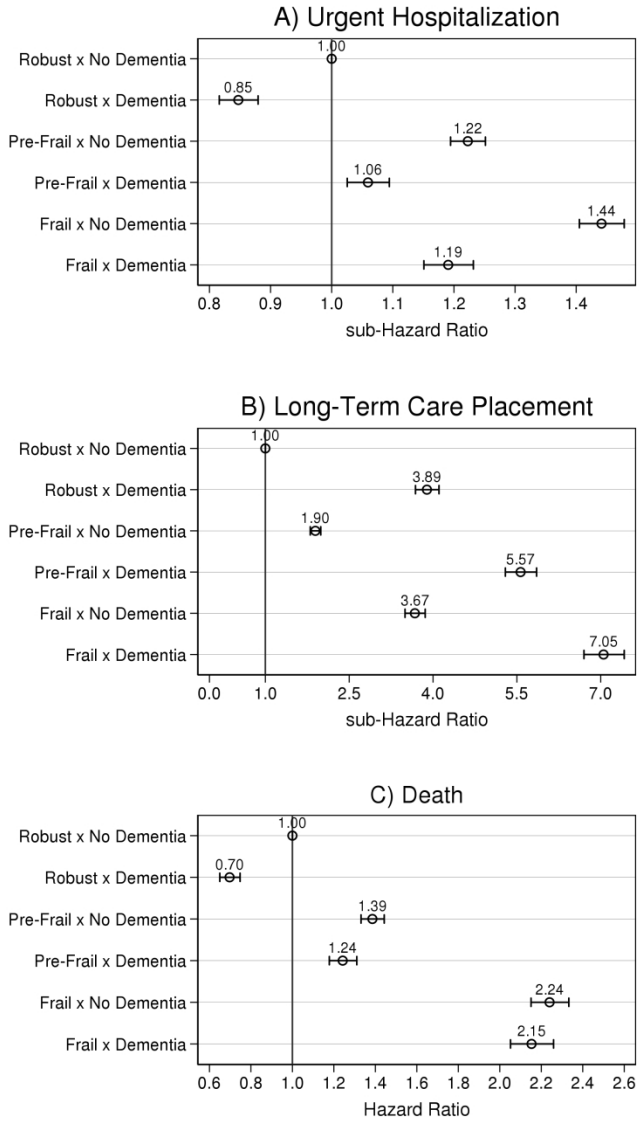

Figure 2. Plots of dementia-frailty (categorical FI) interaction for 1-year health outcomes [A) Urgent hospitalization; B) LTC placement; C) Death]

Legend:

Ratio [Dementia vs No Dementia] for urgent hospitalization among:
Robust=0.85; Pre-frail=[1.06/1.22]=0.87; Frail=[1.19/1.44]=0.83

Ratio [Dementia vs No Dementia] for LTC admission among:
Robust=3.89; Pre-frail=[5.57/1.90]=2.93; Frail=[7.05/3.67]=1.92

Ratio [Dementia vs. No Dementia] for mortality among:
Robust=0.70; Pre-frail=[1.24/1.39]=0.89; Frail=[2.15/2.24]=0.96

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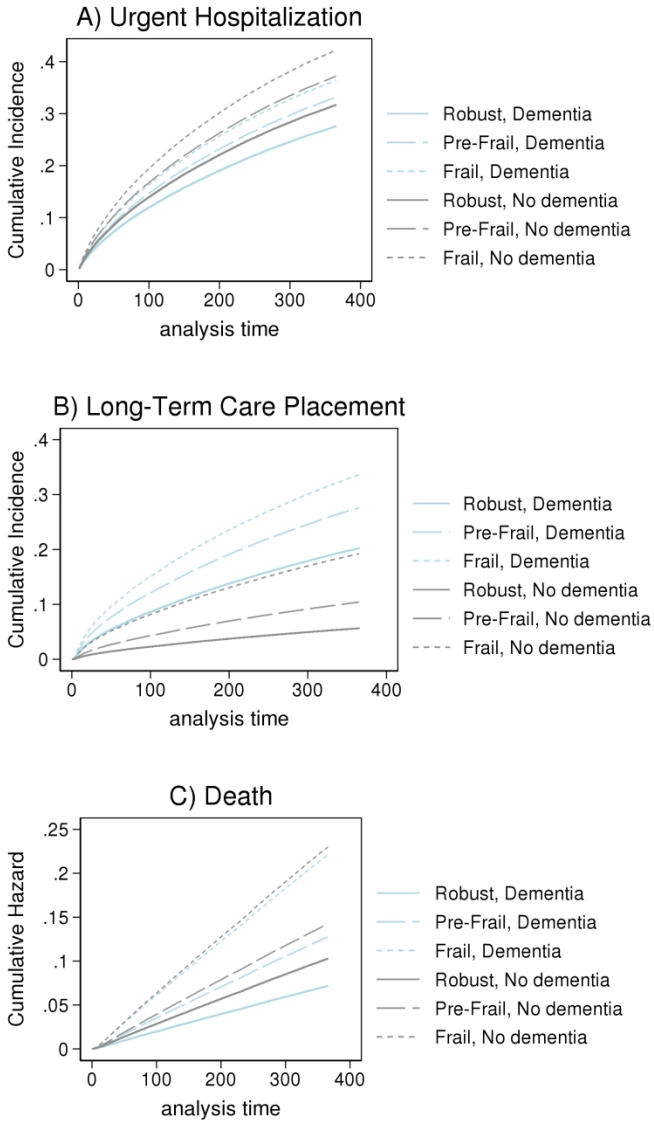

Figure 3. Plots of cumulative incidence [A) Urgent hospitalization, B) LTC placement], and cumulative hazard [C) Death], based on multivariable regression models that include dementia-frailty (categorical FI) interaction

705x1175mm (72 x 72 DPI)

Maxwell et al. Joint impact of dementia and frailty on healthcare utilization and outcomes: a retrospective cohort study of long-stay home care recipients

SUPPORTING INFORMATION - TABLES & FIGURES

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S1 Table. RECORD Statement

Joint impact of dementia and frailty on healthcare utilization and outcomes: a retrospective cohort study of long-stay home care recipients.

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	No.	STROBE items	RECORD items	Location in manuscript where items are reported
Title and abstract				
	1	(a) Indicate the study's design with a commonly used term in the title or the abstract (b) Provide in the abstract an informative and balanced summary of what was done and what was found	RECORD 1.1: The type of data used should be specified in the title or abstract. When possible, the name of the databases used should be included. RECORD 1.2: If applicable, the geographic region and timeframe within which the study took place should be reported in the title or abstract. RECORD 1.3: If linkage between databases was conducted for the study, this should be clearly stated in the title or abstract.	1.1 Included in abstract (*Methods*). 1.2 Included in abstract (*Methods*). 1.3 Included in abstract (*Methods*).
Introduction				
Background rationale	2	Explain the scientific background and rationale for the investigation being reported		2. Included, Introduction (pp. 4-5).
Objectives	3	State specific objectives, including any pre-specified hypotheses		3. Included, Introduction (pg. 5).
Methods				
Study Design	4	Present key elements of study design early in the paper		4. Included, *Study Design and Setting* (pp. 5-6).
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection		5. Included, *Study Design and Setting* (pp. 5-6).
Participants	6	*(a) Cohort study* - Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	RECORD 6.1: The methods of study population selection (such as codes or algorithms used to identify subjects) should be listed in detail. If this is not	6.1 Included, *Study Cohort* (pg. 7).

		Case-control study - Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study* - Give the eligibility criteria, and the sources and methods of selection of participants *(b) Cohort study* - For matched studies, give matching criteria and number of exposed and unexposed *Case-control study* - For matched studies, give matching criteria and the number of controls per case	possible, an explanation should be provided. RECORD 6.2: Any validation studies of the codes or algorithms used to select the population should be referenced. If validation was conducted for this study and not published elsewhere, detailed methods and results should be provided. RECORD 6.3: If the study involved linkage of databases, consider use of a flow diagram or other graphical display to demonstrate the data linkage process, including the number of individuals with linked data at each stage.	6.2 Included, *Dementia and Frailty* (pp. 7-8) and *Covariates* (pg. 8). 6.3 *Study Design and Setting* and *Study Cohort* (pp. 5-6, 7, includes detailed information on linked data sources and number of clients included.
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable.	RECORD 7.1: A complete list of codes and algorithms used to classify exposures, outcomes, confounders, and effect modifiers should be provided. If these cannot be reported, an explanation should be provided.	7.1 Included, exposure (*Dementia and Frailty, pp. 7-8*), outcomes (*Outcomes, pg. 9*), confounders (*Covariates, pg. 8*) and effect modifiers (*Frailty, pg. 8*). See also *Supplemental Material: Table S2.*
Data sources/ measurement	8	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group		Included, *Methods*, pp. 6-9.
Bias	9	Describe any efforts to address potential sources of bias		Included, *Statistical Analyses*, pp. 9-10.
Study size	10	Explain how the study size was arrived at		Included, *Study Cohort*, pg. 7.
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why		Included, *Dementia and Frailty* (pp. 7-8), *Covariates* (pg. 8), *Outcomes* (pg. 9) and *Statistical Analyses* (pp. 9-10).

Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) *Cohort study* - If applicable, explain how loss to follow-up was addressed *Case-control study* - If applicable, explain how matching of cases and controls was addressed *Cross-sectional study* - If applicable, describe analytical methods taking account of sampling strategy (e) Describe any sensitivity analyses		a) Included, *Statistical Analyses* (pg. 9). b) Included, *Statistical Analyses* (pg. 9). c) Included, *Statistical Analyses* (pg. 10). d) Included, *Statistical Analyses* (pg. 9). e) Included, *Statistical Analyses* (pg. 10).
Data access and cleaning methods		..	RECORD 12.1: Authors should describe the extent to which the investigators had access to the database population used to create the study population. RECORD 12.2: Authors should provide information on the data cleaning methods used in the study.	12.1 Included, *Study Design and Setting* (pp. 5-6). 12.2 Included, *Study Design and Setting* and *Study Cohort* (pp. 5-6).
Linkage		..	RECORD 12.3: State whether the study included person-level, institutional-level, or other data linkage across two or more databases. The methods of linkage and methods of linkage quality evaluation should be provided.	12.3 Included, *Study Design and Setting* (pp. 5-6).
Results				
Participants	13	(a) Report the numbers of individuals at each stage of the study (*e.g.*, numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed) (b) Give reasons for non-participation at each stage.	RECORD 13.1: Describe in detail the selection of the persons included in the study (*i.e.*, study population selection) including filtering based on data quality, data availability and linkage. The selection of included persons can be described in the text and/or by means of the study flow diagram.	13.1 Included, *Study Design and Setting* and *Study Cohort* (pp. 5-7).

		(c) Consider use of a flow diagram		
Descriptive data	14	(a) Give characteristics of study participants (*e.g.*, demographic, clinical, social) and information on exposures and potential confounders (b) Indicate the number of participants with missing data for each variable of interest (c) *Cohort study* - summarise follow-up time (*e.g.*, average and total amount)		14. Included, *Results* (pg. 10, Table 1, S1 Figure and S3 Table).
Outcome data	15	*Cohort study* - Report numbers of outcome events or summary measures over time *Case-control study* - Report numbers in each exposure category, or summary measures of exposure *Cross-sectional study* - Report numbers of outcome events or summary measures		15. Included, *Results* (pp. 10-11, Table 1 and S4 Table).
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval). Make clear which confounders were adjusted for and why they were included (b) Report category boundaries when continuous variables were categorized (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period		16. Included, *Results* (pp. 10-11, Table 2, and Figure 1A-C).
Other analyses	17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses		17. Included, *Results* (pp. 11-12, S5 & S6 Tables and Figures 2 & 3).
Discussion				
Key results	18	Summarise key results with reference to study objectives		18. Included, *Discussion* (pg. 12).

Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	RECORD 19.1: Discuss the implications of using data that were not created or collected to answer the specific research question(s). Include discussion of misclassification bias, unmeasured confounding, missing data, and changing eligibility over time, as they pertain to the study being reported.	19.1 Included, *Discussion* (pp. 15-16).
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence		20. Included, *Discussion* (pp. 12-14) and *Conclusions* (pg. 16).
Generalisability	21	Discuss the generalisability (external validity) of the study results		21. Included, *Discussion* (pg. 15).
Other Information				
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based		22. Included, *Acknowledgements / Disclaimer* (pg. 17).
Accessibility of protocol, raw data, and programming code		..	RECORD 22.1: Authors should provide information on how to access any supplemental information such as the study protocol, raw data, or programming code.	22.1 Included, *Data Availability* (pg. 18).

*Reference: Benchimol EI, Smeeth L, Guttmann A, Harron K, Moher D, Petersen I, Sørensen HT, von Elm E, Langan SM, the RECORD Working Committee. The REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) Statement. 2015 Oct 6;12(10):e1001885. doi: 10.1371/journal.pmed.1001885

Completed April 14, 2019 (CJM).

S2 Table. Description and coding of multimorbidity

In addition to dementia, we identified the presence of 16 chronic conditions, prevalent as of each home care clients' RAI-HC assessment date, based on data from hospital discharges (Discharge Abstract Database, DAD), physician billings (Ontario Health Insurance Plan, OHIP) and prescription drugs dispensed (Ontario Drug Benefits, ODB). Conditions included: acute myocardial infarction (AMI), asthma, (any) cancer, cardiac arrhythmia, chronic obstructive pulmonary disease (COPD), congestive heart failure (CHF), chronic coronary syndrome, dementia, diabetes, hypertension, non-psychotic mood and anxiety disorders, other mental illnesses (including schizophrenia, delusions, and other psychoses; personality disorders; and substance abuse), osteoarthritis, osteoporosis, renal failure, rheumatoid arthritis, and stroke (excluding transient ischemic attack). These conditions were selected based on their system burden, in terms of population and economic burden, and have been used in multiple research studies of multimorbidity in Ontario.[3,36] Where applicable we used validated algorithms to ascertain cases (AMI, asthma, CHF, COPD, dementia, diabetes, hypertension and rheumatoid arthritis). All other conditions were defined based on the presence of any one inpatient hospital diagnostic code (DAD data) or two or more outpatient physician billing codes (OHIP data) within a 2 year period using relevant ICD-9 and ICD-10 codes (below). The earliest hospital or billing date was used to identify incident cases.

From these data we defined level of multimorbidity (i.e., chronic disease burden) based on a simple count of prevalent chronic conditions, which was coded as zero/one (reference), two, three, four, five, or six-plus conditions.

Condition [reference for validated algorithm]	ICD 9 / OHIP	ICD 10	ODB*
Acute Myocardial Infarction (AMI) [1]	410	I21, I22	
Osteoarthritis and other Arthritis:			
(A) Osteoarthritis	715	M15-M19	
(B) Other Arthritis (includes Synovitis, Fibrositis, Connective tissue disorders, Ankylosing spondylitis, Gout Traumatic arthritis, pyogenic arthritis, Joint derangement, Dupuytren's contracture, Other MSK disorders)	727, 729, 710, 720, 274, 716, 711, 718, 728, 739	M00-M03, M07, M10, M11-M14, M20-M25, M30-M36, M65-M79	
Arthritis - Rheumatoid arthritis [2]	714	M05-M06	
Asthma [3]	493	J45	
(all) Cancers	140-239	C00-C26, C30-C44, C45-C97	
Cardiac Arrhythmia	427 (OHIP) / 427.3 (DAD)	I48.0, I48.1	
Congestive Heart Failure [4]	428	I500, I501, I509	
Chronic Obstructive Pulmonary Disease [5]	491, 492, 496	J41, J43, J44	
Coronary syndrome (excluding AMI)	411-414	I20, I22-I25	
Dementia [6]	290, 331 (OHIP) / 046.1, 290.0, 290.1, 290.2, 290.3, 290.4, 294, 331.0, 331.1, 331.5, F331.82 (DAD)	F00, F01, F02, F03, G30	Cholinesterase Inhibitors
Diabetes [7]	250	E08 - E13	
Hypertension [8]	401, 402, 403, 404, 405	I10, I11, I12, I13, I15	
(Other) Mental Illnesses	291, 292, 295, 297, 298, 299, 301, 302, 303, 304, 305, 306, 307, 313, 314, 315, 319	F04, F050, F058, F059, F060, F061, F062, F063, F064, F07, F08, F10, F11, F12, F13, F14, F15, F16, F17, F18, F19, F20, F21, F22, F23, F24, F25, F26, F27, F28, F29, F340, F35, F36, F37, F430, F439, F453, F454, F458, F46, F47, F49, F50, F51, F52, F531, F538, F539, F54, F55, F56, F57, F58, F59, F60, F61, F62, F63, F64, F65, F66, F67, F681, F688, F69, F70, F71, F72, F73, F74, F75, F76, F77, F78, F79, F80, F81, F82, F83, F84, F85, F86, F87, F88, F89, F90, F91, F92, F931, F932, F933, F938, F939, F94, F95, F96, F97, F98	

Mood, anxiety, depression and other nonpsychotic disorders	296, 300, 309, 311	F30, F31, F32, F33, F34 (excl. F34.0), F38, F39, F40, F41, F42, F43.1, F43.2, F43.8, F44, F45.0, F45.1, F45.2, F48, F53.0, F68.0, F93.0, F99
Osteoporosis	733	M81, M82
Renal failure	403, 404, 584, 585, 586, v451	N17, N18, N19, T82.4, Z49.2, Z99.2
Stroke (excluding transient ischemic attack)	430, 431, 432, 434, 436	I60-I64

NOTES:

Abbreviations: ICD = International Classification of Disease; ODB = Ontario Drug Benefit program database; OHIP = Ontario Health Insurance Plan, physician billings database;

All case definitions look back to 2001 to ascertain disease status, with the exception of AMI (1 year prior to index), Cancer (2 years), Mood Disorder (2 years) and Other Mental Illnesses (2 years)

AMI, Asthma, COPD, CHF, Dementia, Diabetes Hypertension and Rheumatoid Arthritis are based on validated case algorithms (see Sources 1-8 below, respectively). All other conditions required at least one diagnosis recorded in acute care (CIHI) or two diagnoses recorded in physician billings within a two-year period.

*ODB prescription drug records are not available for the majority of persons under the age of 65

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2. Widdifield J, Bernatsky S, Paterson JM, Tu K, Ng R, Thorne JC, Pope JE, Bombardier C. Accuracy of Canadian health administrative databases in identifying patients with rheumatoid arthritis: a validation study using the medical records of rheumatologists. Arthritis Care Res 2013; 65(10): 1582-1591.
3. Gershon AS, Wang C, Guan J, Vasilevska-Ristovska J, Cicutto L, To T. Identifying patients with physician-diagnosed asthma in health administrative databases. Can Respir J 2009;16:183–8.
4. Schultz SE, Rothwell DM, Chen Z, Tu K. Identifying cases of congestive heart failure from administrative data: a validation study using primary care patient records. Chronic Diseases and Injuries in Canada 2013;33:160–6.
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6. Jaakkimainen RL, Bronskill SE, Tierney MC, Herrmann N, Green D, Young J, et al. Identification of Physician-Diagnosed Alzheimer's Disease and Related Dementias in Population-Based Administrative Data: A Validation Study Using Family Physicians' Electronic Medical Records. J Alzheimers Dis. IOS Press; 2016 Aug 10;54(1):337–49
7. Hux JE, Ivis F, Flintoft V, Bica A. Diabetes in Ontario: Determination of prevalence and incidence using a validated administrative data algorithm. Diabetes Care 2002;25:512–6.
8. Tu K, Campbell NR, Chen Z-L, Cauch-Dudek KJ, McAlister FA. Accuracy of administrative databases in identifying patients with hypertension. Open Med 2007;1:e18–26.

S3 Table. Distribution of 16 chronic conditions among long-stay home care clients aged 50+ years in Ontario, by dementia status

Chronic Condition	Overall Sample % (n)	No Dementia* % (n)	Dementia* % (n)
	N=153,125	N=112,169	N=40,956
Hypertension	83.6 (128,017)	83.6 (93,828)	83.5 (34,189)
Osteoarthritis	66.3 (101,447)	66.9 (75,046)	64.5 (26,401)
Diabetes	40.8 (62,462)	42.5 (47,631)	36.2 (14,831)
Coronary Syndrome (excl. AMI)	33.9 (51,858)	34.2 (38,378)	32.9 (13,480)
Congestive Heart Failure	26.8 (41,103)	28.8 (32,254)	21.6 (8,849)
Cancer	22.5 (34,477)	24.1 (27,033)	18.2 (7,444)
Arrhythmia	22.0 (33,744)	22.3 (25,060)	21.2 (8,684)
Chronic Obstructive Pulmonary Dis.	20.6 (31,543)	22.4 (25,107)	15.7 (6,436)
Mood & Anxiety Disorders (nonpsychotic)	20.1 (30,773)	19.1 (21,409)	22.9 (9,364)
Asthma	18.6 (28,496)	19.8 (22,191)	15.4 (6,305)
Renal failure	17.7 (27,065)	18.8 (21,070)	14.6 (5,995)
Stroke	15.0 (22,985)	15.2 (17,046)	14.5 (5,939)
Osteoporosis	14.0 (21,412)	13.3 (14,962)	15.7 (6,450)
Other Mental Health Conditions	8.4 (12,920)	8.1 (9,110)	9.3 (3,810)
Rheumatoid Arthritis	4.4 (6,746)	4.9 (5,443)	3.2 (1,303)
Acute Myocardial Infarction	1.4 (2,193)	1.6 (1,847)	0.8 (346)

***** Estimates for those without vs with dementia were significantly different ($p<0.001$), except for hypertension ($p=0.423$)

S4 Table. Distribution of the most frequent causes of hospitalization among all urgent admissions† during 1-year follow-up, by ICD-10 chapter and dementia status

ICD-10 Chapter	Overall Sample	No Dementia	Dementia
	N=94,057	N=71,845	N=22,212
Diseases of the circulatory system	16352 (17.4)	13,166 (18.3)	3,186 (14.3)
Diseases of the respiratory system	16097 (17.1)	12,612 (17.6)	3,485 (15.7)
Symptoms, signs and abnormal clinical and lab findings not elsewhere classified	9350 (9.9)	6,943 (9.7)	2,407 (10.8)
Injury, poisoning and other external causes	9311 (9.9)	6,693 (9.3)	2,618 (11.8)
Diseases of the digestive system	7693 (8.2)	6,266 (8.7)	1,427 (6.4)
Diseases of the genitourinary system	7000 (7.4)	5,131 (7.1)	1,869 (8.4)
Certain infectious and parasitic diseases	4944 (5.3)	3,845 (5.4)	1,099 (4.9)
Mental and behavioural disorders	4462 (4.7)	2,460 (3.4)	2,002 (9.0)
Factors influencing health status and contact with health services	3837 (4.1)	2,887 (4.0)	950 (4.3)
Endocrine, nutritional and metabolic diseases	3681 (3.9)	2,984 (4.2)	697 (3.1)
Diseases of the musculoskeletal system and connective tissue	3071 (3.3)	2,556 (3.6)	515 (2.3)
Diseases of the nervous system	2845 (3.0)	1,684 (2.3)	1,161 (5.2)
Neoplasms	2364 (2.5)	2,012 (2.8)	352 (1.6)
Diseases of the skin and subcutaneous tissue	1730 (1.8)	1,499 (2.1)	231 (1.0)
Diseases of the blood and blood-forming mechanisms	1125 (1.2)	944 (1.3)	181 (0.8)

†N=94,057 urgent admissions among 58,551 home care clients (38.2% with at least one urgent hospitalization); Of those with an admission, 63.7% had 1 admission over the follow-up, 22.5% had 2 admissions, and 13.8% had 2+

S5 Table. Sensitivity analysis showing estimated associations† between dementia, frailty (categorical FI), and dementia-frailty interaction, and 1-year health outcomes among long-stay home care clients aged 50+ years in Ontario

Outcome	Age-Sex Adj. s/HR	Age-Sex Adj. s/HR	Fully Adj. s/HR‡ Model 1	Fully Adj. s/HR‡ Model 2
Urgent Hospitalization				
Dementia	0.815* (0.800,0.832)	--	0.847* (0.830,0.864)	0.847* (0.816,0.880)
Frailty – Robust		1 [Ref gp]	1 [Ref gp]	1 [Ref gp]
Pre-frail		1.318* (1.292,1.345)	1.229* (1.204,1.255)	1.223* (1.195,1.252)
Frail		1.580* (1.546,1.614)	1.431* (1.400,1.463)	1.441* (1.405,1.479)
Dementia-Pre-frail	--	--	--	1.023 (0.974,1.073)
Dementia-Frail	--	--	--	0.975 (0.927,1.025)
p for interaction (Wald test)	--	--	--	0.124
LTC Admission				
Dementia	2.749* (2.679,2.821)	--	2.632* (2.563,2.703)	3.891* (3.687,4.107)
Frailty – Robust		1 [Ref gp]	1 [Ref gp]	1 [Ref gp]
Pre-frail		1.544* (1.494,1.596)	1.634* (1.580,1.690)	1.895* (1.804,1.992)
Frail		2.476* (2.395,2.559)	2.563* (2.478,2.652)	3.675* (3.499,3.860)
Dementia-Pre-frail	--	--	--	0.755* (0.706,0.807)
Dementia-Frail	--	--	--	0.493* (0.461,0.527)
p for interaction (Wald test)	--	--	--	<0.001
Mortality				
Dementia	0.901* (0.874,0.928)	--	0.882* (0.856,0.909)	0.697* (0.650,0.748)
Frailty – Robust		1 [Ref gp]	1 [Ref gp]	1 [Ref gp]
Pre-frail		1.524* (1.471,1.579)	1.466* (1.414,1.519)	1.386* (1.331,1.443)
Frail		2.565* (2.477,2.655)	2.425* (2.340,2.512)	2.240* (2.151,2.333)
Dementia-Pre-frail	--	--	--	1.286* (1.181,1.401)
Dementia-Frail	--	--	--	1.379* (1.270,1.497)
p for interaction (Wald test)	--	--	--	<0.001

† For urgent hospitalization and LTC admission, estimates are sub-distribution hazard ratios (sHRs) and corresponding 95% confidence intervals from Fine-Gray model; for mortality, estimates are hazard ratios (HRs) and corresponding 95% confidence intervals from Cox proportional hazards regression model.
‡ Models adjusted for age, sex, marital status, rurality, income quintile and multimorbidity count; Model 2 additionally includes dementia-frailty interaction term.
* p<0.05

S6 Table. Estimated cumulative incidence (urgent hospitalization, LTC admission) and cumulative hazard (mortality) at 1-year, based on multivariable regression models that include dementia-frailty (categorical FI) interaction

	Urgent Hospitalization (cumulative incidence)	LTC Placement (cumulative incidence)	Death (cumulative hazard)
Dementia, Robust	.28	.20	.07
Dementia, Pre-Frail	.33	.28	.13
Dementia, Frail	.36	.34	.22
No Dementia, Robust	.32	.06	.10
No Dementia, Pre-Frail	.37	.10	.14
No Dementia, Frail	.42	.19	.23

S1 Figure. Distribution of baseline frailty (FI) by dementia status