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RESEARCH PAPER

Predictors of mortality shortly after entering a long-term care facility

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Abstract

Objective: Moving into a long-term care facility (LTCF) requires substantial personal, societal and financial investment. Identifying those at high risk of short-term mortality after LTCF entry can help with care planning and risk factor management. This study aimed to: (i) examine individual-, facility-, medication-, system- and healthcare-related predictors for 90-day mortality at entry into an LTCF and (ii) create risk profiles for this outcome.
Design: Retrospective cohort study using data from the Registry of Senior Australians.
Subjects: Individuals aged ≥ 65 years old with first-time permanent entry into an LTCF in three Australian states between 01 January 2013 and 31 December 2016.
Methods: A prediction model for 90-day mortality was developed using Cox regression with the purposeful variable selection approach. Individual-, medication-, system- and healthcare-related factors known at entry into an LTCF were examined as predictors. Harrell's C-index assessed the predictive ability of our risk models.
Results: 116,192 individuals who entered 1,967 facilities, of which 9.4% ($N = 10{,}910$) died within 90 days, were studied. We identified 51 predictors of mortality, five of which were effect modifiers. The strongest predictors included activities of daily living category (hazard ratio [HR] = 5.41, 95% confidence interval [CI] = 4.99–5.88 for high vs low), high level of complex health conditions (HR = 1.67, 95% CI = 1.58–1.77 for high vs low), several medication classes and male sex (HR = 1.59, 95% CI = 1.53–1.65). The model out-of-sample Harrell's C-index was 0.773.
Conclusions: Our mortality prediction model, which includes several strongly associated factors, can moderately well identify individuals at high risk of mortality upon LTCF entry.

Keywords: mortality, predictors, long-term care, older people, nursing homes

Key Points

- Identification of new residents of a long-term care facility at high risk of mortality shortly after care entry can assist with their care planning.

- A prediction model for mortality within 90 days of entering long-term care, with good performance (Harrell C-index = 0.773, 95% confidence interval = 0.765–0.781), was created using existing integrated aged care and healthcare data at the point of care entry.
- The strongest predictors of mortality identified included activities of daily living category, high level of complex health conditions, several medication classes and male sex.
- This prediction tool can aid individualised care planning.

Introduction

In 33 Organisation for Economic Co-operation and Development countries, over 4% of people over the age of 65 lived in long-term care facilities (LTCFs, also known as nursing homes, or residential aged care facilities) in 2019 [1]. While the number of older people living in LTCFs has been decreasing globally, as countries respond to older people's preference to stay at home as long as possible, there is still a significant need for care for older people in this setting [1]. The need for LTCF care typically arises when a person can no longer care for themselves and live in the community, usually due to deteriorating health, frailty, cognitive or functional decline or lack of local appropriate home care support [2, 3]. In Australia, dying in an LTCF is still common, with 29.5% of older Australians dying in an LTCF in 2019 [4].

Transitioning to an LTCF is a vulnerable time [5]. Pre-LTCF entry, individuals' health conditions and care needs typically change, leading, for example, to dramatic increases in hospitalisations [6–8]. Immediately post-LTCF entry, several changes occur in the care and management of individuals, including well-documented access to usual general practitioners and increased use of psychotropic medicines, which may make the older person vulnerable to subsequent poor health events [9, 10]. A systematic review of 11 studies found a median 20% 6-month mortality rate for first time LTCF entrants [5]. In Australia, 35% of first-time LTCF entrants died within a year—10 times the age- and sex-standardised mortality rate of the general population [11].

Placement of an individual into an LTCF requires infrastructure, policies, formal and informal support and financial investment. In Australia, this includes identification of a suitable aged care provider plus allocation of a place, eligibility assessment for government care subsidies (approximately AUD$70,000/year per resident), approvals for services, individual and family-level financial assessments and formal agreements between individuals and the LTCF [12]. In 2018–19, the median time from initial eligibility assessment for the government care subsidy to LTCF entry was 152 days [13], a period when an older person could deteriorate significantly.

Identifying older people at risk of short-term mortality after LTCF entry as other studies have done [14–17] could be of significant interest to care providers who could use this information to identify those at need of end-of-life care (who are not already flagged as such), decide on the best care setting for individuals and assist with care planning for individuals' stay in LTCF. In Australia, specific data are collected on LTCF entrants [18] and, together with regularly collected data on government-subsidised pharmaceutical and medical services, use and also hospital usage data, can provide useful information about the care needs and health status of these individuals. This study aimed to: (i) examine individual-, facility-, medication-, system- and healthcare-related predictors for 90-day mortality at entry into a LTCF; and (ii) create risk profiles for this outcome.

Methods

Study design, setting and data source

A retrospective cohort study using the National Historical Cohort of the Registry of Senior Australians (ROSA) was conducted [19]. This cross-sectoral dataset contains linked de-identified aged care and healthcare data from individuals who accessed aged care services between 2002 and 2017 for which an eligibility assessment is required: respite, transition and permanent long-term (residential) aged care and home care packages. The data sources integrated in ROSA include part of the Australian Institute of Health and Welfare's (AIHW) National Aged Care Data Clearinghouse (NACDC) (includes the National Death Index), the Australian Government Medicare Benefits Schedule (MBS) and Pharmaceutical Benefits Scheme (PBS) datasets and Emergency Department and Inpatient Hospitalisations data collections from several Australian states (New South Wales, Victoria and South Australia).

Study cohort

All non-indigenous individuals aged 65 years or older with initial entry as a permanent resident in an LTCF in New South Wales, Victoria and South Australia (capturing 68% of Australian LTCF residents) between 01 January 2013 and 31 December 2016, who were not indicated as requiring palliative care (excluded N = 6,610), according to their entry into care assessment (using the Aged Care Funding Instrument) and who did not receive Department of Veterans' Affairs subsidised services were included [20]. Individuals who lacked data from the entry into care assessment (N = 4,029, 3%) were not included. The final cohort studied was N = 116,192.

Outcome of interest

The outcome of interest was mortality from any cause within 90 days of first-time entry into an LTCF. The follow-up period was 01 January 2013–31 March 2017.

Predictors of interest

Variables selected for consideration consisted of individual-level factors, LTCF-level factors, medication history and health (hospital and medical practitioner) services utilisation [20].

Individual factors (Table 1 and Supplementary Table S1) ascertained from assessments performed for service eligibility determination [21] or entry into permanent care [18] included: age, sex, partner status, ROSA Frailty Index score [22], health conditions, access to respite care services in the year prior to entry plus levels of need for each of activities of daily living (ADL), cognition and behaviour and complex healthcare (composite variables described in detail in [18]). While information for some geriatric health conditions was determined from the union of data from both assessments, others (e.g. diagnoses of dementia [9], depression) used additional data from the medication-based co-morbidity measure RxRisk-V [23]. Counts of individuals' co-morbid conditions used RxRisk-V, in which medication use is used to infer co-morbidities.

The facility characteristics, ascertained from the aged care episode within the NACDC, assessed included: location of facility (state, geographical remoteness) [24] and funding type (non-profit, for-profit or governmental).

Medication variables (Table 1 and Supplementary Table S2), ascertained from the PBS medication-dispensing records, were constructed as binary indicators for medication class usage (i.e. Anatomical, Therapeutic and Chemical (ATC) 4th level) in the 90 days prior to LTCF entry or the number of medications supplied (ATC 5th level) and sedative load rating (i.e. cumulative effect of medications with sedative properties) [25].

Healthcare-related factors (Table 2, Supplementary Table S3) ascertained from hospitalisation records included numbers and lengths of stay of unplanned public hospital admissions (total and potentially preventable) in the year prior to LTCF entry, number of previous year ED presentations and whether hospitalisation or ED presentation occurred within 30 days prior to LTCF entry. Other healthcare factors ascertained from the MBS-subsidised health services records examined were primary, specialist and allied health service utilisation in the previous year with at least 5% prevalence, such as general practice attendances, health assessments and specialist geriatric services (Supplementary Table S4).

Statistical analysis

The characteristics of the cohort were summarised using means, standard deviation, medians, interquartile ranges (IQRs), frequencies and proportions. Cox regression modelling, using a modified Hosmer and Lemeshow's purposeful variable selection approach, was employed to identify predictors of mortality within 90 days of LTCF entry [26]. Covariate terms for effect modification with age, sex or state were added if considered statistically significant upon application of the likelihood ratio test. Functional forms were selected for (quasi-) continuous covariates using discretised covariate plots and evaluation of likelihoods over alternative choices. Functional forms were restricted to linear functions potentially with truncation or step functions, to facilitate interpretation. Hazard ratios (HRs) and 95% confidence intervals (CIs) for the final model were presented. Model discrimination was quantified using Harrell's C-index within sample (10-fold cross-validation) and out-of-sample using an external cohort of individuals not included in the study cohort. The external validation cohort (subject to the same inclusion criteria as the training cohort, but excluding SA non-city due to incomplete ED data) included $N = 26{,}314$ individuals who entered an LTCF in 2012 in the same states included in this study. All calculations used complete-case analysis. The variable with the greatest missing records (0.07%) was facility remoteness. In a sensitivity analysis, we constructed and assessed a prediction model excluding LTCF entry year and Australian state, to improve potential generalisability of the proposed model.

Ethics

This study received ethics approval from: University of South Australia's (Ref: 200487), Australian Institute of Health and Welfare (AIHW Ref: EO2018/1/418), South Australian Department for Health & Wellbeing (Ref: HREC/18/SAH/90) and New South Wales Population & Health Services (Ref: 2019/ETH12028).

Results

Cohort description and incidence of mortality

Of the 116,192 individuals entering 1,967 LTCFs examined, 61.8% ($N = 71{,}861$) were women, 50.5% ($N = 31{,}841$) had dementia and the median age was 85 years (IQR = 80–89) (Tables 1 and 2, Supplementary Tables S1–S4). Within 90 days of entry, the mortality incidence was 9.4% ($N = 10{,}910$; Supplementary Figure S1).

Causes of death within 90 days

The most common groups of death causes were diseases of the circulatory system (34.2%, $N = 3{,}689$), neoplasms (21.3%, $N = 2{,}294$), diseases of the respiratory system (11.7%, $N = 1{,}257$) and mental and behavioural disorders (7.5%, $N = 806$) (Supplementary Table S5).

Predictors of 90-day mortality post-LTCF entry

Our model (Table 3) identified 51 predictors of 90-day mortality, including five effect modifiers. The model's

Table 1. Study cohort description, highlights of individual-, medication- and facility-related factors by mortality status at 90 days after entry into a long-term care facility

	Total *N*	Alive at 90 days	Died within 90 days
No. of participants	116,192	105,282 (90.6)	10,910 (9.4)
Age, years, median (IQR)	85 (80–89)	85 (80–89)	85 (80–89)
Women	71,861	66,330 (92.3)	5,531 (7.7)
Select geriatric syndrome health conditions[a]			
Dementia	58,714	53,784 (91.6)	4,930 (8.4)
Incontinence	41,126	37,094 (90.2)	4,032 (9.8)
History of falls	15,659	14,473 (92.4)	1,186 (7.6)
Malnutrition	6,542	5,912 (90.4)	630 (9.6)
Activities of daily living needs level			
None	1,431	1,420 (99.2)	11 (0.8)
Low	28,577	27,809 (97.3)	768 (2.7)
Medium	38,689	36,645 (94.7)	2,044 (5.3)
High	47,495	39,408 (83.0)	8,087 (17.0)
Behavioural needs level			
None	9,784	9,135 (93.4)	649 (6.6)
Low	25,262	23,368 (92.5)	1,894 (7.5)
Medium	30,030	27,331 (91.0)	2,699 (9.0)
High	51,116	45,448 (88.9)	5,668 (11.1)
Complex healthcare needs level			
None	7,400	7,205 (97.4)	195 (2.6)
Low	30,934	29,463 (95.2)	1,471 (4.8)
Medium	30,900	28,900 (93.5)	2,000 (6.5)
High	46,958	39,714 (84.6)	7,244 (15.4)
Received respite care (1 year before)	62,106	57,159 (92.0)	4,947 (8.0)
Number of medications			
0–2	11,490	10,713 (93.2)	777 (6.8)
3–5	24,953	23,264 (93.2)	1,689 (6.8)
6–9	40,624	37,254 (91.7)	3,370 (8.3)
10–19	37,251	32,523 (87.3)	4,728 (12.7)
20+	1,874	1,528 (81.5)	346 (18.5)
Facility state			
New South Wales	55,455	49,962 (90.1)	5,493 (9.9)
Victoria	45,069	41,186 (91.4)	3,883 (8.6)
South Australia	15,668	14,134 (90.2)	1,534 (9.8)
ARIA facility remoteness[b]			
Major cities	82,971	75,153 (90.6)	7,818 (9.4)
Inner regional	26,065	23,634 (90.7)	2,431 (9.3)
Outer regional	6,822	6,186 (90.7)	636 (9.3)
(Very) remote	249	231 (92.8)	18 (7.2)
Provider type			
Non-profit	59,124	54,361 (91.9)	4,763 (8.1)
For-profit	51,007	45,455 (89.1)	5,552 (10.9)
Government	6,061	5,466 (90.2)	595 (9.8)
Year of entry into facility			
2013	27,943	25,238 (90.3)	2,705 (9.7)
2014	29,224	26,463 (90.6)	2,761 (9.4)
2015	31,277	28,403 (90.8)	2,874 (9.2)
2016	27,748	25,178 (90.7)	2,570 (9.3)

IQR, interquartile range; ROSA, Registry of Senior Australians; ARIA, Accessibility/Remoteness Index of Australia. [a]All, except dementia, were ascertained from the aged care eligibility and entry into care assessments. Dementia was ascertained from the aged care eligibility assessment, entry into care assessment and the RxRisk-V medication-based co-morbidity condition indicator for dementia. [b]Missing data: ARIA remoteness $n = 85$ (0.1%).

out-of-sample Harrell's C-index was 0.773 (95% CI 0.765–0.781) (Figure 1; Supplementary Figure S2 for the receiver operator characteristic curve; and Supplementary Table S6 for model coefficients).

Being older (HR = 1.34, 95% CI = 1.26–1.43) and male (HR = 1.59, 95% CI = 1.53–1.65) were predictive of higher risk of 90-day mortality. Increasing level of ADL limitations (HR = 0.27, 95% CI = 0.15–0.49; HR = 1.90, 95% CI = 1.74–2.07; HR = 5.41, 95% CI = 4.99–5.88 for none, medium and high limitations, respectively, compared to low level), high level of complex healthcare needs (vs low level; HR = 1.67, 95% CI = 1.58–1.77) and medium level of behavioural care needs (vs low level; HR = 0.90, 95% CI = 0.85–0.95) were predictors of mortality. Malnutrition

Table 2. Study cohort description, highlights of hospital and healthcare related factors accessed prior to entry into care by mortality status at 90 days after entry into a long-term care facility

	Total *N*	Alive at 90 days	Died within 90 days
No. of participants	116,192	105,282 (90.6)	10,910 (9.4)
Unplanned hospitalisations (30 days prior)	42,400	36,475 (86.0)	5,925 (14.0)
No. of unplanned hospitalisations			
0	36,053	34,097 (94.6)	1,956 (5.4)
1	41,383	37,585 (90.8)	3,798 (9.2)
2–4	34,321	29,962 (87.3)	4,359 (12.7)
5+	4,435	3,638 (82.0)	797 (18.0)
ED presentation (30 days prior)	23,473	20,033 (85.3)	3,440 (14.7)
No. of ED presentations			
0	32,296	30,410 (94.2)	1,886 (5.8)
1	34,475	31,501 (91.4)	2,974 (8.6)
2–4	40,278	35,656 (88.5)	4,622 (11.5)
5+	9,143	7,715 (84.4)	1,428 (15.6)
No. of general practitioner attendances (1 year prior)			
0–4	23,827	21,891 (91.9)	1,936 (8.1)
5–10	38,948	35,563 (91.3)	3,385 (8.7)
11+	53,417	47,828 (89.5)	5,589 (10.5)
No. of medical practitioner attendances in LTCFs (1 year prior)[a]			
0–4	97,056	87,939 (90.6)	9,117 (9.4)
5–10	15,197	13,805 (90.8)	1,392 (9.2)
11+	3,939	3,538 (89.8)	401 (10.2)

ED, emergency department; No., number. [a]This class includes services provided by both GPs and non-GP medical practitioners and included people in respite and transition care in an LTCF prior to their permanent residence.

(HR = 1.17, 95% CI = 1.08–1.27) was associated with a higher risk of mortality, while dementia (HR = 0.88, 95% CI = 0.84–0.92), incontinence (HR = 0.83, 95% CI = 0.80–0.86), history of falls (HR = 0.81, 95% CI = 0.77–0.87) and past year's use of respite care (HR = 0.88, 95% CI = 0.83–0.92) were associated with lower mortality risk (Table 3).

Being in the state of Victoria compared to New South Wales (HR = 0.90, 95% CI = 0.84–0.96), being located in a major city compared to inner regional areas (HR = 0.87, 95% CI = 0.83–0.91) and residing in a for-profit (HR = 1.13, 95% CI = 1.08–1.17) or government-funded (HR = 1.23, 95% CI = 1.12–1.34) facility compared to a non-profit facility were associated with higher mortality risk. The association of high vs low complex healthcare needs of residents for LTCFs in Victoria was lower than for New South Wales or South Australia (effect modification HR = 0.80, 95% CI = 0.74–0.87).

A higher number of medications (HR = 1.05, 95% CI = 1.04–1.05 per 1 increase) was predictive of mortality as were eight medication classes including: natural opium alkaloids (HR = 1.12, 95% CI = 1.07–1.18), organic nitrate (cardiac) vasodilators (HR = 1.11, 95% CI = 1.05–1.18), potassium supplementation (HR = 1.12, 95% CI = 1.05–1.20), anticholinergics (HR = 1.16, 95% CI = 1.10–1.23), sulfonamide high-ceiling diuretics (HR = 1.24, 95% CI = 1.19–1.30), aldosterone antagonist diuretics (HR = 1.24, 95% CI = 1.16–1.32), glucocorticoids–corticosteroids for systemic use (HR = 1.40, 95% CI = 1.33–1.48) and propulsives (for functional gastrointestinal disorders) (HR = 1.46, 95% CI = 1.38–1.55). The higher risk of mortality of natural opium alkaloids and propulsives were attenuated in older people (effect modification HR = 0.88, 95% CI = 0.83–0.94 and HR = 0.84, 95% CI = 0.78–0.90).

Thirteen medication classes were associated with a lower risk of mortality: dopa and dopa derivative anti-Parkinson drugs (HR = 0.64, 95% CI = 0.58–0.69), selective serotonin reuptake inhibitor antidepressants (HR = 0.79, 95% CI = 0.75–0.83), other analgesics and antipyretics (HR = 0.82, 95% CI = 0.76–0.88), bisphosphonates (HR = 0.81, 95% CI = 0.74–0.88), other ophthalmologicals (HR = 0.82, 95% CI = 0.77–0.88), biguanide blood glucose-lowering drugs (HR = 0.82, 95% CI = 0.77–0.88), anilide analgesics (HR = 0.83, 95% CI = 0.80–0.87), angiotensin II receptor blockers (ARBs) plain (HR = 0.84, 95% CI = 0.79–0.88), other antidepressants (HR = 0.85, 95% CI = 0.80–0.90), HMG CoA reductase inhibitors ('statins') (HR = 0.84, 95% CI = 0.81–0.88, but with effect modification by age HR = 1.15, 95% CI = 1.08–1.22), anticholinesterase anti-dementia drugs (HR = 0.87, 95% CI = 0.80–0.94), ACE inhibitors and plain (HR = 0.87, 95% CI = 0.83–0.92) and dihydropyridine calcium channel blockers (HR = 0.89, 95% CI = 0.84–0.94).

The number of unplanned hospitalisations in the year prior to entering care (HR = 1.06, 95% CI = 1.03–1.06 per 1 increase), whether hospitalisation (HR = 1.27, 95% CI = 1.21–1.33) and ED presentation (HR = 1.18, 95% CI = 1.13–1.24) occurred in the 30 days prior to LTCF entry and the number of GP attendances in the previous year (HR = 1.01, 95% CI = 1.01–1.02 per 1 increase) were predictors of mortality. The association of GP attendances was stronger in younger residents than in older residents (effect modification HR = 0.99, 95% CI = 0.98–0.99). Having at

Table 3. Prediction model factors associated with mortality within 90 days of entry into a long-term care facility. Hazard ratios and 95% confidence intervals

Factors[a]	Mortality within 90 days	
	HR	95% CI
Individual factors		
Men vs women	1.59	1.53–1.65
Age in decades	1.34	1.26–1.43
Dementia	0.88	0.84–0.92
Incontinence	0.83	0.80–0.86
History of falls	0.81	0.77–0.87
History of malnutrition	1.17	1.08–1.27
ADL needs: none vs low	0.27	0.15–0.49
ADL needs: medium vs low	1.90	1.74–2.07
ADL needs: high vs low	5.41	4.99–5.88
Behavioural needs: medium vs low	0.90	0.85–0.95
Behavioural needs: high vs low	1.04	0.98–1.09
Complex healthcare needs: high vs low	1.67	1.58–1.77
Respite care (1 year prior)	0.88	0.83–0.92
Facility factors		
State: Victoria vs New South Wales	0.90	0.84–0.96
Major city vs inner regional areas	0.87	0.83–0.91
For-profit vs non-profit facility	1.13	1.08–1.17
Government funded vs non-profit facility	1.23	1.12–1.34
System factors		
Year: 2013 vs 2015	1.35	1.29–1.42
Year: 2014 vs 2015	1.20	1.14–1.26
Medication factors[b]		
Number of medications, truncated to 13	1.05	1.04–1.05
Propulsives (for functional gastrointestinal disorders)	1.46	1.38–1.55
Biguanide blood glucose-lowering drugs (e.g. metformin)	0.82	0.77–0.88
Potassium supplement	1.12	1.05–1.20
Organic nitrate (cardiac) vasodilators	1.11	1.05–1.18
Sulfonamides, plain	1.24	1.19–1.30
Aldosterone antagonist diuretics	1.24	1.16–1.32
Dihydropyridine calcium channel blockers	0.89	0.84–0.94
ACE inhibitors, plain	0.87	0.83–0.92
Angiotensin II receptor blockers (ARBs), plain	0.84	0.79–0.88
HMG CoA reductase inhibitors (statins)	0.84	0.81–0.88
Glucocorticoids–corticosteroids for systemic use	1.40	1.33–1.48
Bisphosphonates	0.81	0.74–0.88
Natural opium alkaloids	1.12	1.07–1.18
Anilide analgesics	0.83	0.80–0.87
Other analgesics and antipyretics	0.82	0.76–0.88
Dopa and dopa derivative anti-Parkinson drugs	0.64	0.58–0.69
Selective serotonin reuptake inhibitor antidepressants	0.79	0.75–0.83
Other antidepressants	0.85	0.80–0.90
Anticholinesterase anti-dementia drugs	0.87	0.80–0.94
Anticholinergics—inhaled drugs for obstructive airway diseases	1.16	1.10–1.23
Other ophthalmologicals	0.82	0.77–0.88
Healthcare factors[c]		
No. of unplanned hospitalisations, truncated to 6	1.04	1.03–1.06
Unplanned hospitalisations (30 days prior)	1.27	1.21–1.33
Unplanned ED presentation (30 days prior)	1.18	1.13–1.24
Number of GP attendances, truncated to 15	1.01	1.01–1.02
Three or more services for patients in LTCFs	0.90	0.86–0.95
Effect modification terms		
Complex healthcare needs: high vs low × facility in Victoria	0.80	0.74–0.87
HMG CoA reductase inhibitors × age in decades	1.15	1.08–1.22
Natural opium alkaloids × age in decades	0.88	0.83–0.94
Propulsives × age in decades	0.84	0.78–0.90
Number of GP attendances, truncated to 15 (A01) × age in decades	0.99	0.98–0.99

HR, hazard ratio; CI, confidence interval; ED, emergency department; ATC, Anatomical, Therapeutic and Chemical classification codes; GP, general practitioners; ADL, activities of daily living; No., number. [a]These factors are all from a single, multivariable model. All factors are either binary (yes vs no) or linear (per 1 increment) unless otherwise specified in the table. [b]See Supplementary Table S3 for specific medications' Anatomical, Therapeutic and Chemical classification codes. Medication usage assessed for 90 days prior to LTCF entry. [c]Unless specified look back period for variable ascertainment is for the year prior to entry into permanent LTCF entry, except for medications that use 90-day look back.

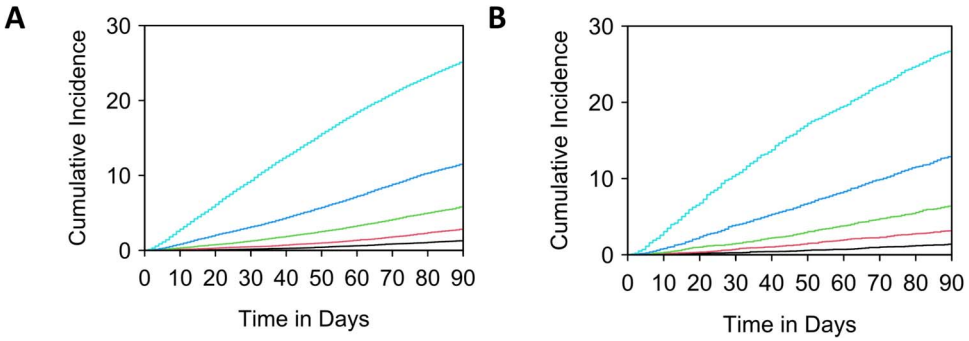

Figure 1. Cumulative mortality using quintiles of predictions from (A) in-sample 10-fold cross-validation, Harrell's C-index 0.757 (95% CI = 0.753–0.761) and (B) out-of-sample validation, Harrell's C-index = 0.773 (95% CI = 0.765–0.781).

least three professional attendances by a medical practitioner in an LCTF in the year prior to permanent LTCF residence was associated with a lower risk of mortality (HR = 0.90, 95% CI = 0.86–0.95).

Sensitivity analysis

A prediction model without calendar year or Australian variables had similar performance as the full proposed model (C index = 0.773, 95% CI = 0.765–0.781, Supplementary Table S6).

Discussion

In our cohort of 116,192 individuals, 9.4% died within 90 days of entry and 51 factors known at LTCF entry can help predict the likelihood of someone's short-term mortality. In Australia, almost 70,000 people enter LTCFs each year and our prediction model, which has good discrimination ability, could potentially identify and help improve care of those at high risk of dying within a short period but not adequately flagged as such. This is potentially valuable information for care providers to discuss with residents and family members on whether different solutions should be considered for their last few months, like at-home palliative care. Additionally, it may also help identify groups that may benefit from risk mitigation and/or appropriate end-of-life care if they decide to enter LTCFs.

Our predictive model included a number of established factors associated with a risk of mortality in those in the aged care setting, particularly male sex, increasing age, malnutrition and high level of ADL limitations [5, 11, 27–32]. The model includes factors known to contribute to LTCF entry for individuals that may not necessarily have more life-limiting, including those with dementia, incontinence and history of falls [9, 33–35]. Additionally, we found 13 medication classes that contribute to mortality predictions, including some that were associated with lower mortality, which are proxies for health conditions (e.g. dopa and dopa derivatives used to treat Parkinson's disease, bisphosphonates used to treat osteoporosis) less life-limiting than other conditions some may enter LTCF (e.g. for cancer). Other factors that we found to contribute to mortality prediction in our datasets were recent hospitalisations [36], recent ED presentations and GP attendances, which are likely indications of the poorer health status of these individuals. Finally, some of the associations found between geographic factors and facility ownership and mortality were consistent with broader Australian population trends during the study period [37] and other reports that for-profit LTCFs have been found to deliver inferior care compared to other facilities [38, 39].

Our final model, developed using Australian data, and variant model (Supplementary Table S6), perform on par with several mortality prediction models developed for other datasets. For example, the Mortality Risk Score (MRS3), trained on 30-day mortality data from newly admitted Medicare beneficiaries, had Harrell C-index values of 0.744 and 0.709 for 30- and 60-day mortality [40]. Similarly, the MDS-CHESS 3.0 score predicted death in newly admitted residents with C-indices of 0.759 and 0.716 at 30 and 60 days post-entry, respectively [14]. Another model using MDS data from newly admitted residents of Veterans' Affairs nursing homes yielded predictions with C-indices of 0.85 and 0.80 for 30- and 60-day mortality [15]. Mortality models for older people such as the RiskOP (C = 0.843 for 3 months) [41], QMortality (C = 0.80 for 1 year) [42] have higher discrimination than our model, but apply to a broader set of individuals than in our cohort, such as home care users (RiskOP) or the general older population (QMortality). The higher discrimination likely results from greater diversity of individuals' profiles, including less impairment and better health, given that these cohorts include people not yet in need of long-term care.

This study used integrated cross-sectoral health and aged care data on the Australian aged care population to identify individuals at risk of mortality and predictors of mortality in the short term after entering care. Data were from LTCF residents from three Australian states covering 68% of the national population over a 4-year period, and the findings inferred from the mortality prediction model are likely applicable to other parts of Australia and also other Western counties with similarly ageing populations and aged care systems. However, there are limitations to note, including a lack of potentially important mortality risk variables such as psychosocial and wellbeing variables, in-depth clinical

information, other environmental and facility characteristics, workforce data and private hospitalisation data. For example, individuals likely to receive palliative care (and thus excluded from our cohort) were identified only from the entry-into-care assessments data, which has been reported to under-ascertain palliative care, due to the lack of incentive on providers to record this if the maximum funding for individual care (due to complex healthcare needs) has been reached. Our prediction model did not use data from indigenous Australians, who make up approximately 2% of the LTCF population [43], as this requires specific indigenous leadership, governance and ethics approvals that are not in place for this study. To improve the interpretation of factors, we chose a prediction approach whose results are readily interpretable, intentionally using simple functional forms but potentially sacrificing some predictive ability. Also, we must emphasise that causation cannot be inferred from the prediction model, and some of the rationalisations of the associations between predictors and mortality risk assume selection bias with respect to the individuals who enter LTCFs.

Conclusions

This work presents a model for predicting risk of short-term risk of mortality after entry into an LTCF and insights to the factors influencing mortality risk. This model can be used by clinicians and aged care providers to assist with individuals' decisions for appropriate care planning and risk mitigation, particularly those at highest likelihood of ill health and death.

Supplementary Data: Supplementary data mentioned in the text are available to subscribers in *Age and Ageing* online.

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