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RESEARCH PAPER

Hospital frailty risk score and adverse health outcomes: evidence from longitudinal record linkage cardiac data

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Abstract

Background: Despite recent evidence on the effect of frailty on health outcomes among those with heart failure, there is a dearth of knowledge on measuring frailty using administrative health data on a wide range of cardiovascular diseases (CVD).
Methods: We conducted a retrospective record-linkage cohort study of patients with diverse CVD in Queensland, Australia. We investigated the relationship between the risk of frailty, defined using the hospital frailty risk score (HFRS), and 30-day mortality, 30-day unplanned readmission, non-home discharge, length of hospital stay (LOS) at an emergency department and inpatient units and costs of hospitalisation. Descriptive analysis, bivariate logistic regression and generalised linear models were used to estimate the association between HFRS and CVD outcomes. Smear adjustment was applied to hospital costs and the LOS for each frailty risk groups.
Results: The proportion of low, medium and high risk of frailty was 24.6%, 34.5% and 40.9%, respectively. The odds of frail patients dying or being readmitted within 30 days of discharge was 1.73 and 1.18, respectively. Frail patients also faced higher odds of LOS, and non-home discharge at 3.1 and 2.25, respectively. Frail patients incurred higher hospital costs (by 42.7–55.3%) and stayed in the hospital longer (by 49%).
Conclusion: Using the HFRS on a large CVD cohort, this study confirms that frailty was associated with worse health outcomes and higher healthcare costs. Administrative data should be more accessible to research such that the HFRS can be applied to healthcare planning and patient care.

Keywords: cardiovascular diseases, linkage data, hospital frailty risk score, Australia, adverse health outcomes, older people

Key Points

- The association of hospital frailty risk score and adverse health outcomes of older cardiovascular disease patients were examined.
- Frail patients were 73% higher the risk of 30-day mortality; 42–55% higher hospital costs; 49% longer LOS.
- Administrative health data can be an effective tool to measure frailty

Introduction

Frailty is a complex health condition, mostly occurring among older people and is characterised by loss of biological reserves and vulnerability to adverse outcomes. It often leads to a higher risk of falls, disability, hospitalisation and mortality [1]. These outcomes are of considerable importance to older people, their families, the health care system and society due to its associated burden. Therefore, frailty is gaining increasing prominence as a key health policy issue, with growing recognition that the health care system needs to adapt to meet the needs of older people living with frailty [2]. More importantly, with the demographic trend in many developed countries moving towards an ageing population, researchers and policy-makers have been interested in the measurement of peoples' vulnerability to adverse health outcomes among the aged. Such measurement and its link with adverse health outcomes are not only important for planning the provision of health services but can also lead to the efficient allocation of scarce resources [3]. However, manually assessed frailty measurement tools (e.g. Fried phenotype) [4] require clinical assessments, which can be expensive and time-consuming, and hence, frailty has not been systematically measured.

Administrative health data have recently been used to develop and validate frailty measurement tools [3, 5–7], which will play a crucial role to achieve mass frailty assessment. A recent systematic review [8] revealed that the automated measurement of frailty using administrative health data has rapidly expanded. The hospital frailty risk score (HFRS) [3] is one of the most popular among such automated frailty measurement tools. To date, the HFRS has been validated in the UK [9], Canada [10], Switzerland [11] and the USA [12, 13]. A recent study [13] has shown that the HFRS can predict adverse health outcomes of patients with heart failure. However, to date, there has been no study that has investigated the impact of frailty on adverse health outcomes among patients across the broad spectrum of cardiovascular diseases (CVD).

This study aims to estimate the HFRS [3] and assess its ability to predict adverse health outcomes using 229,637 multiple-day CVD-related hospitalisations of older patients in Queensland, Australia during the 2010–2015 period. To our best knowledge, this study is the first study to estimate the HFRS in Australia. We also contribute to the literature with the first evidence on the power of the HFRS to predict adverse health outcomes in a cohort of diverse cardiac conditions.

Methods

We conducted a retrospective cohort study of adult patients hospitalised in 2010 for treatments of CVD at any of the 247 hospitals in Queensland, Australia. Any subsequent hospitalisations of these patients were followed until the end of 2015. The hospital admission data set was linked with emergency department (ED) admissions, costs, death registration, and records of health services and pharmaceutical utilisation in the community. Details of the data linkage process are presented in Byrnes et al. [14].

Based on the previous studies [3, 10, 11], we examined the HFRS and its association with adverse health outcomes using admissions of patients aged 75 years and older. We focused on multiple-day admissions because same-day admissions are mostly for routine services or minor health issues. To make our findings comparable to the literature [3], we set admission data to the first 2 years as a 'pre-hospitalisation' period, hence, the HFRS is calculated using diagnosis codes of all admissions in the first 2 years and the current admission. After calculating the HFRS, the analysis was conducted using the data of the last 4 years of the study period (2012–2015). As a result, the number of observations reduced from 229,637 to 115,946 episodes, a sharp fall by 49.5%.

The International Classification of Diseases—10th Revision (ICD-10) diagnosis codes were used to define CVD conditions and to calculate the HFRS. Specifically, CVD was defined as having primary or subsequent ICD-10 diagnosis codes in the range of I00-I99. We adopted the algorithm developed by Gilbert et al. [3] to estimate the HFRS. First, cluster analysis was conducted to classify a list of ICD-10 codes by selecting *a priori* to identify a cluster that has characteristics of frailty. Second, a list of ICD-10 codes determined to be at least twice as likely to present in the frailty cluster was selected to calculate the HFRS. Third, a penalised logistic regression, which shrinks the coefficient of highly correlated variables, was estimated. Fourth, coefficients of the logistic regression were converted to a score, and the HFRS was calculated as the sum of these points. For example, ICD code F00 (Dementia in Alzheimer disease) was assigned the highest score of 7.1, while the lowest score of 0.1 assigned to R50 (fever of unknown origin). The HFRS was then categorised into three frailty risk groups: low risk (HFRS $<$ 5), medium risk (HFRS 5–15), and high risk (HFRS $>$15). Compared with the previous studies [3, 10–13], a binary frailty measure that joins the medium and high risk into one group was also used to represent frail people. A detailed description of the HFRS calculation algorithm is contained in the original HFRS study [3].

Based on the recent literature [3, 10–13, 15], we examined the association between frailty and six outcomes: 30-day mortality; 30-day readmission; non-home discharge (e.g. discharge to nursing homes or other healthcare facilities); long stay at hospitals (defined as staying at hospitals for longer than 10 days [3]); length of hospital stay (LOS) and hospital costs. The effect of frailty measures on adverse health outcomes was estimated using generalised linear models with suitable choices of link functions (e.g. identity, logit, power) and distributions (e.g. Gaussian, Poisson, Bernoulli) depending on the nature of outcomes (whether binary, continuous or counts). Two main outcomes, 30-day mortality and unplanned 30-day readmission, (which we defined as readmission via the ED) were estimated in a bivariate system to consider unobserved patient characteristics that affect both outcomes [16]. If the correlation coefficient between

residuals of the mortality and readmission regressions were significant, applying standard estimators (e.g. logit) to these outcomes will produce biased results. If the residual correlations were not significant, the bivariate analysis provides no added benefit and standard estimators are preferred.

We controlled for demographic characteristics of patients (age, sex, ethnicity, marital status and socio-economic status), whether the admission was covered by private hospital insurance, whether an intensive care unit (ICU) was used during the admission, Charlson comorbidity index (CCI), whether the patient had a long length of stay (LOS) (i.e. stayed longer than 10 days in hospital) [3], whether the patient' LOS at ED belonged to the last quartile of the distribution (i.e. long ED LOS), a linear time trend and hospital fixed effects (i.e. using one binary variable representing each hospital). Since the choice of long LOS by Gilbert et al. [3] (>10 days) falls in the last quartile of the LOS distribution in our data, we chose the last quartile of the LOS ED distribution to define a binary variable long ED LOS. The socio-economic status was proxied by the socio-economic indexes for areas (SEIFA) [17], constructed from various inputs such as income, education and occupation, ranging from 0 to 1,000; a higher SEIFA index indicates a higher socio-economic status. We took the natural logarithm of cost and lengths of stay in hospital in regression analysis to mitigate their skewness distribution. Predictions from log-linear regressions were adjusted using the Duan's smear factor [18]. We used Akaike information criteria (AIC) [19] to select the desired model from possible alternatives (e.g. logit vs survival regressions; log-linear vs Poisson regressions). All analyses were conducted in STATA 15 [20] and R 3.6.1 [21].

Results

Among 115,946 admissions in the 2012–2015 period, Table 1 shows that 24.6% experienced low risk of frailty, followed by medium risk (34.5%) and high risk (40.9%). Males were over-represented in the low-risk group (51.3%) compared to their average proportion of the sample (47.7%). One interesting observation was that the proportion of admissions increased with socio-economic status (i.e. SEIFA quintiles). Also, the rate of increase was fastest in the high-risk group, where the admissions of those in the first SEIFA quintile accounted for only 16.8% while admissions of those in the highest SEIFA quintile accounted for 24.7%. There were also large variations in the risk of frailty by marital status; the probability of being high risk for frailty was substantially higher for those married or widowed. The risk of frailty also increased significantly with the CCI groups: the proportion of those with a CCI of zero or one declined with frailty severity, while the proportion of those with a CCI of 2 and above increased substantially with frailty severity. However, the proportion of those admitted to an ICU reduced with frailty severity, although the magnitudes of the difference were small, ranging from 3.8% for the low-risk group to 3.2% for the high-risk group. The severity of frailty was also positively associated with LOS in both the ED and inpatient units.

HFRS was positively associated with 30-day mortality risk, defined as dying at a hospital or within 30 days from discharge. While only 5.3% of admissions with low-risk frailty died in hospitals or within 30 days of discharge, the respective figures for medium-risk and high-risk groups were 10.0% and 13.9%. The proportion of non-home discharge was also positively associated with frailty risk, increasing from 10.9% for the low-risk group to 21.0% for the intermediate-risk group, and 28.7% for the high-risk group. In contrast, the probability of being readmitted within 30-day of discharged decreases monotonically with frail severity with 20.7%, 19.9% and 18.4% for the low-, medium- and high-risk groups, respectively.

The prevalence of CVD conditions was substantially higher among those with a medium or high risk of frailty, compared with the low-risk group (Table 2). Primary hypertension (I10), heart failure (I50) and atrial fibrillation (I48) were the most common CVD conditions with an average prevalence rate of 23.9%, 16.3% and 15.2%, respectively. The association of frailty with CVD changed considerably with conditions: while the prevalence of hypertension and heart failure increased substantially with the severity of frailty, the probability of atrial fibrillation decreased slightly from 15.4% for the low-risk group to 15.2% for the high-risk group.

Results of regression analysis showed that the residual correlation coefficient in the bivariate analysis was significantly high (0.92, P-value < 0.01). Thus, we present results of the bivariate analysis only as the results of the logistic regression will be biased. Frailty had a strong discriminative power to predict adverse health outcomes with the C-statistics ranging from 0.63 for 30-day readmission to 0.70 for non-home discharge (Table 3). Particularly, frail patients faced a higher risk of 30-day mortality, 30-day unplanned readmission, long LOS and non-home discharge by 73%, 18%, 210% and 125%, respectively.

Among the remaining covariates, sex, age, private insurance status, admission to ED and comorbidities were significant drivers of adverse health outcomes. Particularly, males were 29% more likely to die within 30 days from discharge, but their risk of long hospital stay and non-home discharge was lower by 3% and 5%, respectively. With regards to age, an additional year increase from the mean age (83.5 years) was associated with a 5% increase in the risk of 30-day mortality, while the risk of 30-day unplanned readmission, long LOS and non-home discharge increased by 1–2% per year. Among other covariates, multiple comorbidities, ICU admission and long ED LOS were the most influential. Compare those with no comorbidity (CCI = 0), the risk of dying with 30 days from discharge was 65% and 126% higher among those with one comorbidity (CCI = 1) and multiple comorbidities (CCI $\geq$ 2), respectively. An ICU admission was associated with an increase in 30-day

Table 1. Descriptive statistics by hospital frailty risk groups

Variables	Low risk (HFRS < 5) $N = 28,523$ (24.6%)	Medium risk (HFRS 5–15) $N = 40,045$ (34.5%)	High risk (HFRS > 15) $N = 47,378$ (40.9%)	Whole data $N = 115,946$
Sex (males = 1)	51.3%	47.8%	45.4%	47.7%
Age (years)	82.4 (5.2)	83.7 (5.5)	84.1 (5.5)	83.5 (5.5)
Indigenous ($Y = 1$)	0.7%	0.9%	1.2%	1.0%
SEIFA—Q1	18.6%	18.5%	16.8%	17.8%
SEIFA—Q2	19.2%	19.2%	17.8%	18.6%
SEIFA—Q3	19.6%	20.0%	20.0%	19.9%
SEIFA—Q4	22.1%	21.0%	20.6%	21.1%
SEIFA—Q5	20.5%	21.2%	24.7%	22.5%
Divorce/separated	6.7%	7.9%	8.7%	7.9%
Married	54.1%	45.6%	41.2%	45.9%
Never married	4.8%	5.8%	6.4%	5.8%
Widows	34.2%	40.8%	43.7%	40.3%
Private insurance	62.0%	52.3%	43.9%	51.2%
30-day mortality	5.3%	10.0%	13.9%	10.5%
Non-home discharge	10.9%	21.0%	28.7%	21.7%
30-day readmission	15.9%	16.7%	16.1%	16.3%
ICU usage	3.8%	3.7%	3.2%	3.5%
CCI = 0	20.8%	9.6%	4.3%	10.2%
CCI = 1	16.4%	12.2%	8.9%	11.9%
CCI = 2+	62.9%	78.2%	86.8%	77.9%
Length of stay (days)	5.97 (5.78)	8.86 (11.50)	11.00 (14.49)	9.02 (11.98)
ED LOS (hours)	3.89 (13.41)	4.93 (14.83)	5.66 (6.51)	4.97 (11.75)
Long LOS (>10 days)	12.3%	25.4%	32.9%	25.3%
Hospital costs (A$, 2015 price)	8,130 (8,441)	10,090 (11,757)	12,528 (16,192)	10,741 (13,467)

Note: statistics are presented as mean (SD) for continuous variables and percent for binary variables. *P*-values of tests for differences of all variables by frailty risk groups were <0.001 except the indigenous status; SEIFA = socio-economic indexes for areas; ICU = intensive care unit; CCI=Charlson Comorbidity Index; ED = emergency department; LOS = length of stay.

Table 2. Prevalence of top five CVD conditions by frailty risk groups (%)

ICD-10 codes: CVD conditions	All	Frailty groups		
		Low (HFRS < 5)	Medium (5 ≤ HFRS ≤ 15)	High (HFRS > 15)
1. I10: Primary hypertension	23.9	19.3	23.2	27.2
2. I50: Heart failure	16.3	12.7	16.3	18.3
3. I48: Atrial fibrillation	15.2	15.4	15.2	15.1
4. I95: Hypotension	9.8	4.1	10.2	12.8
5. I25: Chronic ischaemic heart disease	7.4	10.7	7.2	5.6

mortality risk by 68% while the respective figure for those who stayed in ED for more than 10 h was 20%.

Frail patients incurred higher hospital costs and a longer hospital length of stay by 26% and 46%, respectively (Table 4). When compared to females, males incurred higher hospital costs by 2% although their hospital LOS was shorter by 2%. Those who live in the highest socio-economic advantaged areas (SEIFA-Q4 & Q5) also experienced lower hospital costs (by 4% and 7%, respectively) despite having a similar LOS. Likewise, people with private health insurance had 8% lower hospital costs despite staying 2% longer in hospital. Among factors representing the severity of admissions (i.e. comorbidities, ICU use and a long stay at ED), the admission to ICU was most influential; with a 294% increase in hospital costs and a 64% longer length of stay. The smear-adjusted predicted hospital costs for those with low frailty risk was $5,242 per admission while the respective figure for those with medium-risk and high risk of frailty were $7,481 (42.7% higher) and $8,139 (55.3% higher). Similarly, the predicted LOS for the low-risk group was 6.3 days, and 9.4 days (49% higher) for both the medium and high-risk groups.

Discussion

To our knowledge, this is the first study to estimate the HFRS in Australia and assess its ability to predict adverse health outcomes. Our key findings were mostly in line with the literature. Frailty is a common issue among multiple-day CVD hospitalisations; about three in four admissions were classified as medium or high risk. The rates of the

Table 3. Hospital frailty risk score and selected outcomes

	30-day mortality	30-day readmission	Long hospital stay	Non-home discharge
Frail (HFRS ≥ 5)	1.73 (<0.01)	1.18 (<0.01)	3.10 (<0.01)	2.25 (<0.01)
Sex (Males = 1)	1.29 (<0.01)	1.19 (<0.01)	0.97 (0.02)	0.95 (<0.01)
Indigenous (*Y* = 1)	1.05 (0.62)	1.07 (0.38)	0.95 (0.52)	0.75 (<0.01)
Age	1.05 (<0.01)	1.01 (<0.01)	1.01 (<0.01)	1.02 (<0.01)
SEIFA (Q1 = base)				
Q2	1.08 (0.02)	1.01 (0.81)	1.05 (0.08)	0.92 (<0.01)
Q3	1.06 (0.11)	0.98 (0.45)	1.04 (0.12)	0.96 (0.19)
Q4	1.14 (<0.01)	0.99 (0.95)	1.02 (0.52)	0.96 (0.16)
Q5	1.18 (<0.01)	0.96 (0.18)	1.01 (0.70)	0.97 (0.23)
Marital status (divorce = base)				
Married	1.08 (0.02)	1.02 (0.92)	0.90 (<0.01)	0.88 (<0.01)
Never married	1.05 (0.33)	0.93 (0.05)	1.04 (0.36)	1.20 (<0.01)
Widowed	0.98 (0.60)	0.97 (0.26)	0.99 (0.65)	0.94 (0.05)
Private insurance	1.10 (<0.01)	1.09 (<0.01)	1.07 (<0.01)	1.20 (<0.01)
Charlson comorbidity groups (no comorbidity = 1)				
Comorbidity = 1	1.65 (<0.01)	1.35 (<0.01)	1.19 (<0.01)	1.20 (<0.01)
Comorbidity = 2+	2.26 (<0.01)	1.89 (<0.01)	1.35 (<0.01)	1.18 (<0.01)
ICU usage (*Y* = 1)	1.68 (<0.01)	1.13 (<0.01)	3.08 (<0.01)	2.10 (<0.01)
Long ED (>10 h = 1)	1.20 (<0.01)	1.18 (<0.01)	1.11 (<0.01)	1.08 (<0.01)
Time trend	1.02 (0.01)	1.03 (<0.01)	1.02 (<0.01)	1.04 (<0.01)
C-statistics	0.67	0.63	0.68	0.70
Residual correlation	0.92 (<0.01)			

Note: Parameters are odds ratios. *P*-values are in parentheses. Parameters of hospital fixed effects are not reported for brevity; HFRS = hospital frailty risk score; SEIFA; socio-economic indexes for areas; ICU = intensive care unit; ED = emergency department.

Table 4. Hospital frailty risk score and costs

Variables	Hospital costs		Length of stay	
	$e^{\text{Coef.}}$	*P*-value	$e^{\text{Coef.}}$	*P*-value
Frail (HFRS ≥ 5)	1.26	<0.01	1.46	<0.01
Sex (Males = 1)	1.02	<0.01	0.98	<0.01
Indigenous (*Y* = 1)	1.02	0.48	0.99	0.97
Age	0.99	<0.01	1.005	<0.01
SEIFA (Q1 = base)				
Q2	0.99	0.93	1.03	<0.01
Q3	0.99	<0.01	1.02	0.01
Q4	0.96	<0.01	1.01	0.10
Q5	0.93	<0.01	1.01	0.19
Marital status (divorce = base)				
Married	1.01	0.45	0.96	<0.01
Never married	1.05	0.01	1.02	0.07
Widowed	1.02	0.16	0.99	0.45
Private insurance	0.92	<0.01	1.02	<0.01
Charlson comorbidity groups (no comorbidity = 1)				
Comorbidity = 1	1.04	0.01	1.09	<0.01
Comorbidity = 2+	1.06	<0.01	1.13	<0.01
ICU usage (*Y* = 1)	3.94	<0.01	1.64	<0.01
Long ED (>10 h = 1)	1.003	0.69	1.04	<0.01
Time trend	1.03	<0.01	1.003	0.13
Predicted value [CI]				
Low risk	$5,242 [5,193, 5,290]		6.34 [6.32, 6.36]	
Medium risk	$7,481 [7,425, 7,537]		9.41 [9.39, 9.44]	
High risk	$8,139 [8,087, 8,190]		9.37 [9.35, 9.40]	

HFRS = hospital frailty risk score; SEIFA = socio-economic indexes for areas; ICU = intensive care unit; ED = emergency department; CI = confidence interval.

medium risk (34.5%) and high risk (40.9%) of frailty in our cohort were substantially higher than the risk reported in the original study [3] and previous validation studies (36%) [10, 11, 13]. Population differences could contribute to the variations: our study focused on patients of CVD while the cohorts in Canada, Switzerland and the UK covered all types of admissions. The US study [13] focused on heart failure patients, but they included all patients from the age of 18 and

Table 5. Frailty and outcomes by top five CVD conditions

CVD conditions	30-day mortality (OR)	30-day readmission (OR)	Long hospital stay (OR)	Non-home discharge (OR)	Hospital costs ($e^{coef.}$)	Length of stay ($e^{coef.}$)
I10: Primary hypertension	2.15	1.19	3.63	2.59	1.34	1.56
I50: Heart failure	2.31	1.05 (0.78)	2.97	2.57	1.40	1.48
I48: Atrial fibrillation	2.52	1.09 (0.44)	3.86	2.64	1.40	1.59
I95: Hypotension	2.64	1.26	3.33	2.51	1.44	1.62
I25: Chronic ischaemic heart disease	2.56	1.01 (0.91)	3.25	2.20	1.29	1.48

Note: Bivariate analysis was applied for 30-day mortality and 30-day unplanned readmissions. Residual correlation coefficients of all five conditions were significant. The remaining parameters are not reported for brevity, *P*-values were all <0.01 unless reported in parentheses; OR = odds ratio.

above while we focused on those aged 75 years and above, a common age threshold in frailty studies [8].

The effects of HFRS on 30-day mortality and hospital costs were higher in a sub-sample analysis of the top five CVD conditions (Table 5). Regarding heart failure, our finding that frail patients faced higher odds (2.31) of 30-day mortality was comparable with that of the US study [13] (2.28–3.05). However, the selected outcome was slightly different: we focused on 30-day mortality while they focused on in-hospital deaths only. Also, our analysis focused on multiple-day admissions of patients aged 75 while they included all admissions of patients aged 18 and above.

We also confirmed a significant association between HFRS and adverse health outcomes found in the original study [3] and validation studies [9–13]. Particularly, frail patients, defined as those having a HFRS of 5 or higher, had a two times higher risk of 30-day mortality, were three times more likely to stay in hospital for more than 10 days, and twice more likely to be discharged to other facilities rather than their homes. The C-statistics for 30-day mortality, 30-day readmission and long LOS in our study were 0.67, 0.63 and 0.7, with the respective figures in the previous studies also ranging from 0.6 to 0.7 [3, 10, 11].

The positive association between frailty severity and SEIFA seems counter-intuitive. Two factors may contribute to this phenomenon. First, people in low SEIFA areas would have poorer health (e.g. having lower life expectancy) because of lower quality health inputs (e.g. healthy food, exercises, rest) [22]. Second, those who survived old age (e.g. more than 75 years) in low SEIFA areas may have significant survival bias [23]. Thus, compared to those of similar age, older people in high SEIFA areas may have higher rates of frailty than those in low SEIFA areas.

Our finding that the risk of non-home discharge increases with frailty is consistent with the literature [12]. It is possible that frail people need special care (e.g. 24/7 nurse support) that is only available in facilities outside of homes (e.g. residential aged care facilities).

The insignificance of the indigenous health gap is in contrast with the literature [24]. One factor that may explain the difference is our focus on people aged 75 and above. Given the life expectancy of indigenous Australians is around 60–65 [25], indigenous patients who survive in this cohort could be healthier.

Our finding that the HFRS is a significant predictor of adverse health outcomes is in contrast with Bruno et al. [15], who found that the HFRS was no longer a significant predictor of adverse health outcomes when severity measures such as the Charlson comorbidity index was controlled for. A possible explanation for their insignificant finding could be due to multicollinearity since both the HFRS and Charlson index are proxied for true health status and hence could be highly correlated with each other. We found minimal effects of a time trend, which may represent technological progress in health care. One possible explanation is that the effects of technological progress could be offset by the age effects of our cohort of senior patients.

We made the choice of combining intermediate-risk and high-risk of frailty into one group to enable comparison with the original study [3]. For a sensitivity test, we also examined the effects of medium-risk and high-risk of frailty on health outcomes, compared with the low-risk group. We found expected results that more severe frailty was associated with worse health outcomes while other parameters were almost unchanged (see Supplementary materials for details).

The main limitation of this study is the shortage of data on risk factors such as lifestyle (e.g. smoking status), clinical details (e.g. blood pressure) and traditional frailty measures (e.g. Fried frailty phenotype). These limitations will be mitigated in future studies as we are in the process of updating the new cohort through linking admission data with additional data sources.

Conclusions

This study has provided new evidence from Australia using a large cohort of CVD hospitalisations. Our findings are consistent with the original study and previous validation studies that the HFRS score is strongly associated with adverse health outcomes. The prevalence of all CVD conditions was substantially higher among those with a medium or high risk of frailty. The ability to automate a frailty measure using administrative health data has major benefits through identifying those at medium and high risk enabling the provision of targeted interventions for this group. This should reduce health care costs and prevent adverse health outcomes. Thus, a desirable policy application should aim to

encourage using administrative data for research, particularly to measure frailty for better healthcare planning among the older population.

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

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