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SHORT COMMUNICATION

Charlson Comorbidity Index as a predictor of repeated hospital admission and mortality among older women diagnosed with cardiovascular disease

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Abstract

Background Comorbidity can complicate cardiovascular diseases (CVDs), increasing the risk of adverse events including hospitalisation and death. This study aimed to assess the Charlson Comorbidity Index (CCI) as a predictor of repeated hospital admission and mortality in older CVD patients.

Methods This study linked data from the Australian longitudinal study on women's health (ALSWH) with hospital and National Death Index datasets to identify dates for hospital admission, discharge, and death for women born 1921–26. CCI was calculated using the International Statistical Classification of Diseases, Australia Modification (ICD-10-AM) diagnostic codes.

Results Women with a higher CCI on index admission had increased risk of repeated hospital admission (AHR = 1.29, 95% CI 1.06, 1.58) and mortality (AHR = 3.05, 95% CI 2.15, 4.31). Older age and hypertension were also significantly associated with a higher risk of repeated hospital admission and mortality. Living in a remote area was associated with a higher risk of mortality.

Conclusions The Charlson Comorbidity Index predicts repeated hospital admission and mortality incidences among older women with CVD. Improving management of comorbidities for older CVD patients should be considered as part of a strategy to mitigate subsequent repeated hospitalisation and delay mortality.

Keywords Australia · Survival analysis · Hospital admission · Older women · Charlson Comorbidity Index

Introduction

Cardiovascular diseases (CVDs) continued to be the number one cause of mortality worldwide, responsible for an estimated 17.9 million deaths in 2016 [1]. In Australia, CVDs are the leading contributor to the burden of disease [2], with increasing numbers of people living with CVDs as the population ages and with improved treatment leading to longer survival with the disease. In 2016–2017, more than 1 in 4 (26%) Australians aged 75 years and over had heart disease, stroke or vascular disease [2]. In Australian women, 12% of the total burden of disease is attributable to CVDs, and CVD is a priority within the National Women's Health Strategy 2020–2030. However, comparatively, little is known about the subsequent risk of hospital admission for patients diagnosed with CVDs.

Comorbidity increases the risk of subsequent hospitalisation and death in people with CVDs [3–5]. The most commonly used measure of comorbidity burden is the Charlson Comorbidity Index (CCI) [6]. For instance, CCI predicted the length of hospital stay, mortality and rehospitalisation within 12 months in older patients [7, 8]. However, there is little evidence of CCI as a predictor of repeated hospital admission and mortality among older CVD patients, especially using appropriate statistical methods.

Following CVD diagnosis, frequent hospitalisation is common, especially in older people [9]. Older people

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represent a higher proportion of patients admitted to hospitals with more comorbidities and cognitive and functional impairment, which leads to a high risk of unplanned readmission and post-discharge mortality. For instance, an estimate shows that more than three-fourths of people diagnosed with heart failure will have at least one hospitalisation and almost half will experience four or more hospitalisations during their remaining lifespan [9]. This study aimed to assess the CCI as a predictor of repeated hospital admission and mortality among older women diagnosed with CVD, using a joint frailty model.

Methods

Data

We used data from the Australian Longitudinal Study on Women's Health (ALSWH) 1921–1926 birth cohort [10]. This cohort was followed through postal surveys every 3 years from 1996 until 2011, and every 6 months since 2011. The ALSWH self-reported surveys were linked with data from the New South Wales (NSW) hospital Admitted Patient Data Collection (APDC), National Death Index (NDI) and other administrative datasets. The current study included women who were NSW residents from 2001 to 2011 and who did not opt-out of hospital data linkage ($N = 3739$).

Data linkage with the administrative dataset

Linked data from APDC and NDI [11] were used to identify public and private hospital admissions and date of death (2001–2016). The APDC includes admission and separation dates, principal and secondary diagnosis codes using International Classification of Diseases, Tenth Revision, Australia Modification (ICD-10-AM) diagnostic codes. Admissions are flagged as emergency/unplanned, non-emergency/planned, urgency not assigned, maternity/newborn, or regular same day planned admissions.

Outcome

The primary outcome is time-to-repeated hospital admission, with death taken into account as a competing risk. Repeated hospital admission is defined as subsequent unplanned hospitalisation with an overnight hospital stay due to any cause, which occurred until the end of the study period, 31 December 2016.

Covariates

This study calculated the CCI for the index hospitalisation using ICD-10-AM codes for all secondary diagnoses and applying weights to 17 index conditions [6, 12]. The sum of comorbidity weights was categorised as less than two, and two or more [12]. We also identified other comorbidities, such as hypertension and atrial fibrillation (AF), which were not in the CCI calculation. Age at index admission was in years. Length of hospital stay on the index admission was categorised as less than or equal to 3 days and greater than 3 days. Area of residence, derived from the women's home addresses, was categorised using standard Australian ARIA + classification as metropolitan, inner regional and outer regional/remote/very remote [11]. Duke Social Support Index (DSSI) has been used as a continuous variable.

Ethical clearance

The ALSWH project has ongoing ethical clearance from both the University of Newcastle and the University of Queensland's Human Research Ethics Committees. Linkage of ALSWH survey data to the NSW APDC ethical clearance was obtained from the NSW Population and Health Services Research Ethics Committees.

Statistical analysis

We reported patient's baseline characteristics using descriptive statistics, such as percentage, mean, median and standard deviation (Std).

Time-to-repeated hospital admission data were structured as a discontinuous risk interval, where patients already admitted to hospital are not at risk of another admission until they are discharged alive. A joint frailty survival model [13] was used to assess CCI as a predictor of repeated hospital admission and mortality. Both of these events are common among older people living with CVDs, and in this analysis death was considered as a competing event, precluding further admissions. This allowed for the joint modelling of the evolution of two survival processes (admission and death), applying appropriate statistical methods as required to analyse time-to-repeated hospitalisation by treating the incident of 'death' as a competing event [13]. The survival model was adjusted for covariates significant during the bivariate analysis and with no missing value. A *Frailtypack* package in R software, Vs 3.6.1, was used to conduct the statistical analysis.

Results

This study included 1115 women who had an index admission with a principal diagnosis of CVDs, stayed at least

one night in hospital and were discharged alive. Women's age at the index admission ranged from 75 to 89 years (mean = 81.9 years). In 15 years (2001–2016), 930 women (83.41%) had at least one subsequent unplanned admission after being discharged alive. Overall, 3,307 subsequent unplanned admissions were reported from those women. The number of unplanned admissions per woman ranged from 0 to 21 (mean 3.5; std = 1.87), and the rate of unplanned admissions was 19.5 per 1,000 women per month at risk. Between 2001 and 2016, there were 878 post-discharge deaths, and the cumulative mortality rates were 21.64%, 39.75%, 56.04%, and 78.75% in the 1st year, 3rd years, 5th years, and 15th years post-discharge, respectively (Table 1). One hundred and sixty-nine (15.16%) patients died before having any subsequent unplanned admission. The percentage of deaths following the first, second and fifth subsequent admission was 19.35%, 21.33% and 22.76%, respectively.

The CCI during the index admission ranged from 0 to 9 (mean = 0.80; Std = 1.23). The number of patients with a CCI of one, two, three, four and five were 230 (20.63%), 140 (12.66%), 59 (5.29%), 23 (2.06) and 9 (0.81), respectively. The top three reported comorbidities during the index admission were hemiplegia or paraplegia ($n = 118$, 10.58%), congestive heart failure ($n = 102$, 9.15%) and acute myocardial infarction ($n = 69$, 6.19%) (Table 2). Furthermore, the prevalence of hypertension and atrial fibrillation (AF), which were not incorporated in the CCI calculation, was 189 (43.86%) and 145 (13.0%), respectively.

There was a shortening of the median time between hospital admission incidences (Fig. 1). For instance, the median time decreased from 9.8 months to the index and first hospitalisation to 5.7 months between the fourth and fifth hospitalisation. Marital status, smoking status, and DSSI had missing observations and did not contribute to the model, and, therefore, they were not included in the joint frailty model analysis.

The CCI was significantly associated with a higher risk of repeated hospital admission (AHR = 1.29, 95% CI 1.06, 1.58) and mortality (AHR = 3.05, 95% CI 2.15, 4.31) (Fig. 2). Older age, i.e., women over 80 years, had a higher

Table 1 Patients' characteristics by the number of hospitalisations during the follow-up period (2001–2016)

	Hospitalisation recurrence ($N = 1115$)					
	1st *n* (%)	2nd *n* (%)	3rd *n* (%)	4th *n* (%)	> = 5 *n* (%)	Censored
Age at index admission						
74–80 years	50 (22.00)	59 (31.38)	49 (35.00)	49 (37.98)	92 (37.40)	50 (27.03)
> 80 years	177 (78.0)	129 (68.6)	91 (65.0)	80 (62.02)	154 (62.60)	135 (72.9)
Area						
Metropolitan	92 (40.53)	72 (38.30)	61 (43.57)	49 (37.98)	97 (39.43)	59 (31.89)
Inner regional	94 (41.41)	86 (45.74)	55 (39.29)	53 (41.09)	108 (43.90)	90 (48.65)
Outer regional*	41 (18.06)	30 (15.96)	24 (17.14)	27 (20.93)	41 (16.67)	36 (19.46)
Marital status						
Partnered	68 (30.09)	69 (36.70)	40 (28.57)	45 (34.88)	86 (35.10)	51 (27.72)
Not partnered	158 (69.9)	119 (63.3)	100 (71.4)	84 (65.12)	159 (64.9)	133 (72.28)
LOS index admission						
≤ 3	77 (33.92)	75 (39.89)	58 (41.43)	49 (37.98)	100 (40.65)	82 (44.32)
> 3	150 (66.1)	113 (60.1)	82 (58.57)	80 (60.02)	146 (59.35)	103 (55.68)
Smoking status						
Never smoked	126 (58.6)	111 (61.67)	73 (56.59)	83 (68.0)	148 (65.2)	118 (67.05)
Ex-smoker	70 (32.6)	57 (31.67)	44 (34.11)	32 (26.23)	67 (29.52)	41 (23.30)
Smoker	19 (8.84)	12 (6.67)	12 (9.30)	7 (5.74)	12 (5.29)	17 (9.66)
DSSI	8.66 ± 1.78	8.76 ± 5.79	8.79 ± 1.72	8.98 ± 1.68	1.59 ± 5.8	8.74 ± 1.57
Hypertension						
No	135 (59.5)	107 (56.9)	83 (59.3)	69 (53.5)	133 (54.1)	99 (55.5)
Yes	92 (40.5)	81 (43.1)	57 (40.7)	60 (46.5)	113 (45.9)	86 (46.5)
AF						
No	186 (81.9)	156 (82.3)	118 (84.3)	106 (82.2)	219 (89.0)	154 (83.2)
Yes	41 (18.1)	32 (17.0)	22 (15.7)	23 (17.8)	27 (11.0)	31 (16.7)
CCI						
≤ 1	166 (73.1)	151 (80.3)	123 (87.9)	109 (84.5)	211 (85.8)	114 (61.6)
> 1	61 (26.87)	37 (19.7)	17 (12.1)	20 (15.5)	35 (14.2)	71 (38.4)

*Outer regional includes outer regional, remote and very remote area

Table 2 Comorbidities for index hospitalisation according to the Charlson Comorbidity Index [6] from ICD-10-AM codes

No	Comorbidities	CCI weights	ICD-10-AM	$N=1,115$ n (%)
1	Acute myocardial infarction	1	I21, I22, I252	69 (6.19)
2	Congestive heart failure	1	I50	102 (9.15)
3	Peripheral vascular disease	1	I71, I790, I739, R02, Z958, Z959	15 (1.35)
4	Cerebral vascular accident	1	I60, I61, I62, I63, I65, I66,G450, G451, G452, G458, G459, G46,I64, G454, I670, I671, I672, I674, I675, I676, I677 I678, I679,I681, I682, I688, I69	52 (4.66)
5	Dementia	1	F00, F01, F02, F051	14 (1.26)
6	Pulmonary disease	1	J40, J41, J42, J44, J43, J45, J46, J47, J67, J44, J60, J61, J62, J63, J66, J64, J65	58 (5.2)
7	Connective tissue disorder	1	M32, M34, M332, M053, M058, M059, M060, M063, M069, M050, M052, M051, M353	20 (1.79)
8	Peptic ulcer	1	K25, K26, K27, K28	7 (0.63)
9	Liver disease	1	K702, K703, K73, K717, K740, K742, K746, K743, K744, K745	0 (0.00)
10	Diabetes	1	E109, E119, E139, E149, E101, E111, E131, E141, E105, E115,E135, E145	87 (7.8)
11	Diabetes complications	2	E102, E112, E132, E142 E103, E113, E133, E143 E104, E114,E134, E144	29 (2.60)
12	Hemiplegia or Paraplegia	2	G81 G041, G820, G821, G822	118 (10.58)
13	Renal disease	2	N03, N052, N053, N054, N055, N056, N072, N073, N074, N01, N18, N19, N25	53 (4.75)
14	Cancer	2	C0, C1, C2, C3, C40, C41, C43, C45, C46, C47, C48, C49, C5, C6, C70, C71, C72, C73, C74, C75, C76, C80, C81, C82, C83, C84, C85, C883, C887, C889, C900, C901, C91, C92, C93, C940, C941, C942, C943, C9451, C947, C95, C96	22 (1.97)
15	Metastatic cancer	3	C77, C78, C79, C80	9 (0.81)
16	Severe liver disease	3	K729, K766, K767, K721	0 (0.0)
17	HIV/AIDS	6	B20, B21, B22, B23, B24	0
With no CCI comorbidities				644 (57.76)

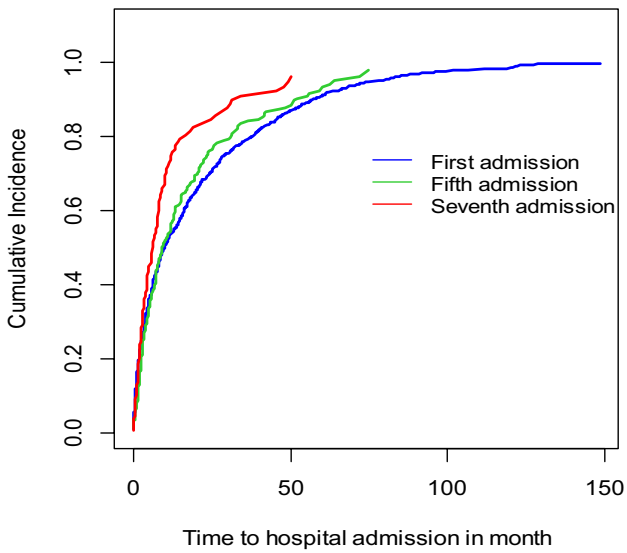

Fig. 1 Cumulative incidence for successive risk of hospital admission (an example is taken for the first, fifth and seventh hospital admission)

risk of repeated admission (AHR = 1.31, 95% CI 1.14, 1.51) and mortality (AHR = 2.15, 95% CI 1.63, 2.82) compared to their younger counterparts. The frailty estimate shows there was considerable variability due to the rate of repeated admission among patients ($\Theta = 0.514$). A significant positive value of alpha ($\alpha = 1.632$), which measures the degree of dependence between the principal event and competing risk, indicates that the risk of death was significantly associated with a history of repeated hospitalisation after adjusting for covariates.

Discussion

This study assessed the CCI as a predictor of repeated hospital admission and mortality in older women hospitalised with CVDs as the principal diagnosis. The ALSWH self-reported survey linkage with APDC and NDI allowed us to capture virtually all hospital admissions and death dates for women in the 1921–26 birth cohort of ALSWH who were resident in New South Wales. Longitudinally recorded

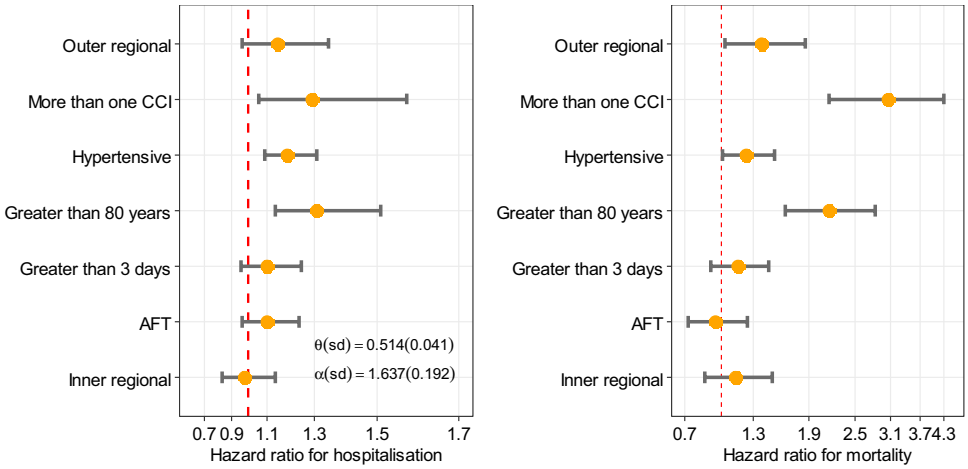

Fig. 2 Estimated covariates hazard ratio using a joint frailty model for repeated hospitalisation and death

hospital admission and death incidence were jointly modelled using a joint frailty model [13].

After index admission (unplanned admission with CVDs as the primary diagnosis), three-quarters of older women experienced two or more unplanned admissions in the 15 years follow-up. The time gap between subsequent hospitalisations showed a progressive shortening. This may indicate the long-term higher risk of repeated hospital admission after contracting CVDs in later life and as disease progresses. A previous study estimated an average of 7.9 hospital admissions per 10 person-years for older people diagnosed with heart failure [14]. Increased in age could contribute to the likelihood of repeated admission with shorting gaps between hospitalisation. In our study, women aged 80 years and over had a 30% higher risk of repeated admission, compared to their counterparts aged below 80 years.

The CCI is the most extensively studied comorbidity index to predict mortality after it was developed and validated by Charlson in 1987 [6]. This study evidenced that higher CCI was significantly associated with repeated hospital admission and mortality in older women aged 75 years and over. Risk of subsequent hospitalisations is nearly 30% higher in patients with a higher CCI (two or more) after controlling for other covariates. Comorbidities in older patients, who halve already diagnosed with CVDs, lead to high health care utilisation and a higher risk of death.

A study that evaluated the CCI as a predictor of all causes of hospitalisation among heart failure patients found that having higher comorbidities had led to an increased risk of being admitted to hospital [15]. Juarez R et al. 2018 found that most of the women had one or more subsequent admission, and women had more admissions compared to men [15]. Another study examined the CCI impact on adverse clinical outcomes among older stroke patients in the Alfred Hospital, Victoria, Australia [12]. This study estimated that older patients with a CCI of two or more spend at least 1 day longer in hospital have 26.1% (AUD 2,481) higher hospital costs, and have an elevated risk of in-hospital death than patients with CCI less than two. A recent study also found that CCI had a significant association with length of hospital stay, rehospitalisation and mortality among older patients aged 68 years and over [7]. Additionally, it has been reported that comorbidities play a negative role in the wellbeing and risk of mortality in older CVD patients [8]. The significant association between the CCI and poorer functional decline and 1-year mortality has also been explored in older stroke patients [16]. Given the negative impact of comorbidity in later life, studies should not be limited to focusing only on the management of a single factor or disease [3]. It is, therefore, important to assess and manage the whole person rather than just a specific or single disease aspect in later life.

One of the limitations of this study is the limited information about the women at the time of index hospitalisation, and the inability to include the change in these factors in relation to subsequent admissions. Other socioeconomic variables were not evaluated in this study, which future studies need to consider [17]. For instance, a recent study suggested that improving educational knowledge through public policy would reduce the burden of heart disease at the population level. Another limitation of this study is that we included patients who had a principal diagnosis with CVDs. Therefore, future studies can further evaluate CCI as a predictor of hospital use in older people with and without a principal diagnosis of CVDs. Furthermore, clustering older people based on their multimorbidity pattern to compare the CCI impact on repeated hospitalisation and mortality would inform interventions to prevent and mitigate the effects of different forms of multimorbidity [18]. The other limitation of this study is that only older women were included. As women live longer than men and have different rates and risks for hospital admission [19], the rate and risk factors of multiple hospitalizations may be different for older men.

Conclusion

The CCI is a significant predictor of repeated hospital admission and death in the older population. This highlights the importance of exploring the burden, impact and outcomes of comorbidities in trajectories of CVD patients, in later life [3]. Measures to control comorbidities in older CVD patients should be considered as part of a strategy to mitigate future hospital admissions and delay mortality.

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Compliance with ethical standards

Conflict of interest The authors have no conflict of interest.

Ethical approval The ALSWH project has ongoing ethical clearance from both the University of Newcastle and the University of Queensland's Human Research Ethics Committees. Linkage of ALSWH survey data to the NSW APDC ethical clearance was obtained from the NSW Population and Health Services Research Ethics Committees.

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