Original Article

Multimorbidity in middle age predicts more subsequent hospital admissions than in older age: A nine-year retrospective cohort study of 121,188 discharged in-patients

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ABSTRACT

Background: Previous research has suggested a differential short-term effect of multimorbidity on hospitalization by age, with younger groups affected more. This study compares the nine-year hospitalization pattern by age and multimorbidity status in a retrospective cohort of discharged in-patients, who represent a high-need portion of the population.
Methods: We examined routine clinical records of all patients aged 45+ years with chronic conditions discharged from public general hospitals in 2005 in Hong Kong. Patterns of annual frequencies of hospital admissions and number of hospitalized days over nine years (2005–2014) were compared by multimorbidity status (1, 2, 3+ conditions) and age group (45–64, 65–74, 75+).
Results: Among 121,188 included patients, 33.9% had 2+ conditions and 12.3% had 3+. Hospitalization patterns varied by age and multimorbidity status. For those having only 1 condition, annual number of admissions was similar by age, but older patients had more hospitalized days (4.40 days per person-year for the 45–64 group versus 10.29 for the 75+ group in the 5th year). For those with 3+ conditions, younger patients had more admissions (4.39 admissions per person-year for the 45–64 group versus 1.87 for the 75+ group in the 5th year) but similar number of hospitalized days with older patients. Interaction analysis showed effect of multimorbidity on hospitalization was stronger in younger groups ($P < 0.05$).
Conclusion: Middle-aged discharged in-patients with multimorbidity are admitted more often than their older counterparts and have similar total hospitalized days per year. Further research is needed to investigate chronic care needs of younger people with multimorbidity.

1. Introduction

Multimorbidity, defined as the co-occurrence of two or more chronic health conditions [1–3], is increasingly common due to population ageing [4,5]. Established risk factors include older age, female sex, lower socioeconomic status, smoking, dietary habit, and obesity [6–10]. Consistently associated with poorer quality of life, more healthcare utilization, and higher risk of mortality [11–17], multimorbidity is now one of the top priorities in the public health agenda worldwide [18].

Across age groups, multimorbidity may have differing effects on hospitalization [14], which is generally indicative of major adverse events or acute health problems. Gruneir et al. [14] examined 5,958,514 Canadian adults with chronic conditions and found that although older patients had higher baseline risk of hospitalization, the additional risk associated with increasing number of conditions was larger in younger and middle-aged adults. Also, the absolute number of non-older multimorbid adults is consistently larger than that of older

multimorbid adults in various populations [14,19,20]. For example, the Catalonian primary care health records showed that 62.5% of the multimorbid adult population was under the age of 65 [21]. Similar findings were obtained in a Scottish population, where multimorbidity tend to occur 10 to 15 years earlier in deprived areas [6]. Hence, despite the common conception of multimorbidity as mainly a problem of older populations [22], multimorbidity in younger or middle-aged adults is also important to examine [23]. Based on these findings, together with evidence demonstrating an earlier onset of prevalent chronic conditions in recent decades [24], a stronger research and health-service focus on multimorbidity in younger populations such as middle-aged adults is needed.

Existing research on multimorbidity in middle age is limited. Previous studies seldom followed up participants long enough to investigate the medium- or long-term impact of multimorbidity on adverse health outcomes and burden [13,25–29]. Even fewer studies stratified by age group to study the moderating effect of age [14]. Without this information, it is difficult to examine the independent effect of multimorbidity on hospitalization which may be moderated by age and survival over time.

This study describes and compares the nine-year hospitalization pattern by age group (45–64, 65–74, and 75 +) and multimorbidity status (one, two, and three or more conditions) among 121,188 adults who were discharged home from public general hospitals, with one or more diagnosed chronic conditions, in Hong Kong. Since the patients were already admitted to hospitals to be included in this study, this cohort was not based on the general population but would likely represent a vulnerable portion of the population with existing acute problems. Based on previous evidence on short-term effects of multimorbidity on hospitalization (i.e. one year), we hypothesized that baseline multimorbidity status had a sustained effect on subsequent hospitalization over the nine-year follow-up period and had a stronger effect on younger patients than on older ones.

2. Methods

2.1. Study design

We adopted a retrospective cohort study design, following up 121,188 adults aged 45 or above with one or more chronic conditions who were discharged from any Hong Kong public hospital in 2005 (1st January to 31st December) and followed over nine years. Stratified by age groups, those identified as multimorbid based on past medical records (in-patient diagnoses and out-patient prescription data) during the 12 months prior to the baseline were compared with those with only one condition.

2.2. Setting and participants

As part of a broader study examining end-of-life care and policy and service needs of people with multiple chronic conditions in Hong Kong, we obtained data from the Hospital Authority (HA), which oversees the entire public sector of in-patient services in Hong Kong. We applied two exclusion criteria: i.) absence of any listed chronic condition over the 12 months prior to the baseline; and ii.) admissions to psychiatry wards, nursing homes with continuous medical support provided by HA, and mental handicap wards.

In order to focus analysis on examining age differences in a reasonably well-defined population, we excluded patients without any listed conditions because they were clinically very diverse, consisting of those having acute problems or injuries but otherwise healthy, as well as those having chronic conditions that were not listed in this study. We did not include admissions to psychiatry wards, nursing homes with continuous medical support, and mental handicap wards because these provide markedly different services and have significantly different costs and longer lengths of stay compared with non-psychiatric

hospitalization. This could lead to underestimation of psychiatric disorder prevalence but patients that would have been included through these admissions were only 2.4% of all in-patients with any chronic conditions in our records.

Chronic conditions were defined by a list of 40 diseases previously adopted for a large-scale Scottish study [6]. Please see Appendix Table A.1 for the list and corresponding coding method using both in-patient medical records and out-patient prescription data. We used all diagnoses made during the hospital stay based on the Ninth Revision of the International Classification of Diseases (ICD-9) as the primary approach for the coding of conditions, supplemented with out-patient prescription data to minimize omissions.

The day on which in-patients were first discharged home in 2005 was taken as the baseline (day 0). Their records over the 12 months prior to this day, including the current episode from which they were discharged, were used to code multimorbidity and potential confounders (see Section 2.5). We then followed up and examined any hospitalization until in-hospital death or until nine years after the baseline discharge date (calendar year 2014).

2.3. Outcome

The primary outcome was the number of annual hospital admissions (the first until the ninth), while the secondary outcome was the annual number of hospitalized days. As a preliminary analysis, we also modeled time to in-hospital death which could potentially confound the association between multimorbidity and hospitalization.

2.4. Stratification variables: multimorbidity and age-group

Multimorbidity was defined as the presence of two or more chronic conditions according to the aforementioned list [6] which was repeatedly used in previous large studies [30,31]. We categorized patients into having one, two, and three or more conditions. Also, we further classified patients into age groups 45–64, 65–74, and 75 or above to examine how hospitalization may be differentially affected by multimorbidity across age groups.

2.5. Multivariable adjustment

Sex, recipient status of Comprehensive Social Security Assistance (CSSA, typically provided by the Government for Hong Kong residents with low income and net worth), and care home residential status were included for statistical adjustment in the multivariable analysis since they were empirically related to both the presence of multimorbidity and to hospitalization [32,7]. Without proper adjustment, they might confound the estimation. We also included the number of days survived within the follow-up year as an offset term to adjust for the confounding effect of the potentially differential mortality risk with respect to age and multimorbidity, in order to adjust the association between multimorbidity and hospitalization for the number of days a patient lived in each follow-up year [33].

2.6. Statistical analysis

We plotted the Kaplan-Meier curve by the cross-classification between multimorbidity status (one, two, and three or more conditions) and age group (45–64, 65–74, 75 or more) for a description of the survival of patients across follow-up years. We, then, estimated the adjusted risk of in-hospital death associated with multimorbidity status and age group with a Cox proportional hazard model adjusted for sex, CSSA, and care home residential status. In an extended model, we further tested for the interaction between multimorbidity and age group in relation to the risk of in-hospital death to examine the potentially differential effect of multimorbidity on mortality across age groups.

For hospitalization, we plotted the average number of hospital

admissions and average number of hospitalized days per person-year (365 days) to describe hospital utilization over the follow-up years adjusted for number of days survived (see Appendix Text A.1 for detailed calculation). Generalized linear models (negative binomial distribution) stratified by follow-up year (1st to 9th) for the number of hospital admissions and number of hospitalized days were then estimated to examine the varying extent of utilization associated with multimorbidity status and age group adjusted for sex, CSSA, and care home residential status, and number of days survived (as an offset term). Using a simple score test [34], we tested for the presence of excessive zeros in number of admissions and hospitalized days since many patients recorded zero hospitalization which might cause an underprediction of events [35]. To address this issue, we fitted hurdle models with R package 'pscl' in cases of excessive zeros. Like earlier survival analysis with Cox models, we tested an extended model with an interaction between multimorbidity status and age group to identify any differential effect of multimorbidity on hospitalization.

All analyses were conducted in R statistical environment (Version 3.4.3).

3. Results

3.1. Sample characteristics

We identified and included 121,188 eligible discharged patients with chronic conditions. Table 1 shows the baseline characteristics of the cohort (by multimorbidity status), of which 66.1% had only one condition, 21.6% had two, and 12.3% had three or more. Number of chronic conditions generally increased with older age, with only 22.8% of those aged 45–64 years being multimorbid, compared with 41.8% among those aged 75 or more. The average number of conditions

Table 1
Baseline characteristics by multimorbidity status.

Number of conditions	One	Two	Three or more	Total
n	80,125	26,191	14,872	121,188
Sex				
Female	36,681 (45.8)	12,438 (47.5)	7219 (48.5)	56,338 (46.5)
Male	43,444 (54.2)	13,753 (52.5)	7653 (51.5)	64,850 (53.5)
Age				
45–49	6983 (8.7)	1095 (4.2)	371 (2.5)	8449 (7.0)
50–54	7177 (9.0)	1441 (5.5)	507 (3.4)	9125 (7.5)
55–59	7064 (8.8)	1692 (6.5)	633 (4.3)	9389 (7.7)
60–64	6727 (8.4)	1769 (6.8)	751 (5.0)	9247 (7.6)
65–69	9760 (12.2)	2945 (11.2)	1490 (10.0)	14,195 (11.7)
70–74	12,412 (15.5)	4360 (16.6)	2427 (16.3)	19,199 (15.8)
75–79	12,101 (15.1)	4905 (18.7)	3055 (20.5)	20,061 (16.6)
80–84	9278 (11.6)	4028 (15.4)	2863 (19.3)	16,169 (13.3)
85–89	5413 (6.8)	2414 (9.2)	1814 (12.2)	9641 (8.0)
90–94	2417 (3.0)	1178 (4.5)	749 (5.0)	4344 (3.6)
95–99	664 (0.8)	286 (1.1)	184 (1.2)	1134 (0.9)
100 +	129 (0.2)	78 (0.3)	28 (0.2)	235 (0.2)
CSSA [a]				
Non-recipient	62,272 (77.7)	18,706 (71.4)	9864 (66.3)	90,842 (75.0)
Recipient	17,853 (22.3)	7485 (28.6)	5008 (33.7)	30,346 (25.0)
Care home				
Non-resident	72,788 (90.8)	22,187 (84.7)	11,577 (77.8)	106,552 (87.9)
Resident	7337 (9.2)	4004 (15.3)	3295 (22.2)	14,636 (12.1)

[a] CSSA stands for Comprehensive Social Security Assistance given by the Hong Kong Government to residents with low income and asset.

among those with three or more did not differ substantially by age group, ranging from 3.37 conditions among those aged 45–64 to 3.52 conditions among those aged 75 or more. We also tabulated the frequencies of listed conditions by age group and multimorbidity status as Table 2. Hypertension was the most prevalent condition, with an overall prevalence of 24.7%, followed by cancer (21.9%), coronary heart disease (16.0%), and chronic obstructive pulmonary disease (12.8%). Mental disorders such as depression, anxiety, alcohol problems, and other substance misuse were much more prevalent among younger patients with multimorbidity than among older ones.

3.2. Survival

Fig. 1 shows the survival of patients by the cross-classification between multimorbidity status and age group (nine groups). The differences in the risk of in-hospital death across age groups and across multimorbidity status was sustained over the nine years with little overlap of confidence intervals within categories of age and multimorbidity status. Unsurprisingly, survival was consistently worse as number of conditions and age of the patient increased. At 4.5 years from the baseline, which was the mid-point of our follow-up, < 20% of the middle-aged patients (45–64 years) with one condition had died while > 60% of the patients aged 75 or above with three or more conditions had died. Middle-aged patients with three or more conditions had a similar survival curve to those aged 65–74 with two conditions, especially in the first half of the follow-up period, while the survival curves of those aged 65–74 with three conditions and of those aged 75 or above with one condition noticeably overlapped.

The comparison (analysis of deviance) between the adjusted Cox models with and without the interaction between multimorbidity status and age group confirmed the presence of such interaction ($\chi^2 = 149.26$, DF = 4, $P = 0.000$). Specifically, compared with middle-aged patients, there was an attenuation of the effect of having three or more conditions (relative to having only one) on mortality in those aged 65–74 (HR: 0.88, 95% CI: 0.82–0.96) and in those aged 75 or above (HR: 0.71, 95% CI: 0.66–0.76). The effect of having two conditions on mortality also attenuated in those aged 75 or above (HR: 0.85, 95% CI: 0.80–0.90).

3.3. Hospitalization

Fig. 2 shows the average number of hospital admissions and number of hospitalized days per person year, adjusted for number of days survived within the year, over the follow-up period. There was a general decline in both numbers, which was not surprising given our sampling strategy of including in-patients who had just experienced an episode (see Discussion for detailed explanations). Among those with only one condition, number of admissions did not differ substantially by age, but among those with three or more, younger age groups tended to be admitted more often. The pattern in number of hospitalized days was reversed in that among those with one condition, number of hospitalized days differed substantially by age with older patients staying much longer, whereas among those with three or more conditions, no substantial difference was observed.

In the multivariable analysis, simple score test results confirmed the presence of excessive zero counts in both number of hospital admissions and hospitalized days for every follow-up year and supported our adoption of hurdle models in the adjusted analysis ($P < 0.05$). Likelihood ratio tests on the inclusion of interaction between multimorbidity and age group in generalized linear models stratified by follow-up year all confirmed the statistical significance of the interaction in relation to the number of hospital admissions and the number of hospitalized days, which was all negative in direction ($P < 0.05$).

We tabulated the adjusted relative risks (count model coefficients) across the cross-classification between multimorbidity status and age group by follow-year as Table 3. Matching the results as shown in

Table 2
Frequencies (percentages) of chronic conditions [a] counted towards multimorbidity by age group and multimorbidity status.

Multimorbidity status	One chronic condition			Two chronic conditions			Three or more chronic conditions		
Age group	45–64	65–74	75+	45–64	65–74	75+	45–64	65–74	75+
n	27,951	22,172	30,002	5997	7305	12,889	2262	3917	8693
Hypertension	2732 (9.8)	3034 (13.7)	5344 (17.8)	1842 (30.7)	2927 (40.1)	5327 (41.3)	999 (44.2)	2353 (60.1)	5373 (61.8)
Depression	526 (1.9)	327 (1.5)	898 (3.0)	649 (10.8)	375 (5.1)	844 (6.5)	496 (21.9)	513 (13.1)	1010 (11.6)
Painful condition	633 (2.3)	380 (1.7)	636 (2.1)	743 (12.4)	521 (7.1)	773 (6.0)	611 (27.0)	546 (13.9)	984 (11.3)
Asthma	599 (2.1)	366 (1.7)	504 (1.7)	212 (3.5)	331 (4.5)	573 (4.4)	138 (6.1)	332 (8.5)	692 (8.0)
Coronary heart disease	2952 (10.6)	2482 (11.2)	2298 (7.7)	1041 (17.4)	1660 (22.7)	2725 (21.1)	655 (29.0)	1652 (42.2)	3866 (44.5)
Dyspepsia	111 (0.4)	76 (0.3)	98 (0.3)	40 (0.7)	34 (0.5)	62 (0.5)	21 (0.9)	38 (1.0)	117 (1.3)
Diabetes	671 (2.4)	722 (3.3)	861 (2.9)	381 (6.4)	538 (7.4)	726 (5.6)	409 (18.1)	750 (19.1)	1166 (13.4)
Rheumatoid arthritis, other inflammatory polyarthropathies & systematic connective tissue disorders	224 (0.8)	107 (0.5)	94 (0.3)	80 (1.3)	57 (0.8)	55 (0.4)	26 (1.1)	43 (1.1)	66 (0.8)
Hearing loss	161 (0.6)	51 (0.2)	36 (0.1)	24 (0.4)	25 (0.3)	45 (0.3)	19 (0.8)	27 (0.7)	78 (0.9)
Chronic obstructive pulmonary disease	856 (3.1)	2230 (10.1)	4065 (13.5)	655 (10.9)	1350 (18.5)	2775 (21.5)	280 (12.4)	897 (22.9)	2447 (28.1)
Anxiety & other neurotic, stress related & somatoform disorders	975 (3.5)	569 (2.6)	731 (2.4)	1336 (22.3)	819 (11.2)	990 (7.7)	893 (39.5)	890 (22.7)	1213 (14.0)
Irritable bowel syndrome	59 (0.2)	31 (0.1)	47 (0.2)	65 (1.1)	54 (0.7)	57 (0.4)	91 (4.0)	64 (1.6)	78 (0.9)
Cancer	11,009 (39.4)	5335 (24.1)	4810 (16.0)	1130 (18.8)	1071 (14.7)	1312 (10.2)	414 (18.3)	514 (13.1)	1001 (11.5)
Alcohol problems	169 (0.6)	45 (0.2)	26 (0.1)	63 (1.1)	18 (0.2)	6 (0.0)	47 (2.1)	16 (0.4)	15 (0.2)
Other psychoactive substance misuse	66 (0.2)	4 (0.0)	1 (0.0)	40 (0.7)	7 (0.1)	2 (0.0)	24 (1.1)	4 (0.1)	1 (0.0)
Constipation	214 (0.8)	277 (1.2)	733 (2.4)	64 (1.1)	146 (2.0)	358 (2.8)	63 (2.8)	153 (3.9)	447 (5.1)
Stroke & transient ischaemic attack	649 (2.3)	710 (3.2)	952 (3.2)	472 (7.9)	715 (9.8)	965 (7.5)	233 (10.3)	549 (14.0)	1054 (12.1)
Chronic kidney disease	935 (3.3)	491 (2.2)	459 (1.5)	518 (8.6)	466 (6.4)	511 (4.0)	401 (17.7)	550 (14.0)	796 (9.2)
Diverticular disease of intestine	7 (0.0)	3 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Atrial fibrillation	771 (2.8)	761 (3.4)	1449 (4.8)	443 (7.4)	844 (11.6)	1966 (15.3)	272 (12.0)	868 (22.2)	2728 (31.4)
Peripheral vascular disease	69 (0.2)	101 (0.5)	247 (0.8)	45 (0.8)	64 (0.9)	168 (1.3)	62 (2.7)	147 (3.8)	363 (4.2)
Heart failure	417 (1.5)	749 (3.4)	2262 (7.5)	471 (7.9)	946 (13.0)	2772 (21.5)	412 (18.2)	1169 (29.8)	3715 (42.7)
Prostate disorder	826 (3.0)	1966 (8.9)	1720 (5.7)	135 (2.3)	457 (6.3)	877 (6.8)	93 (4.1)	440 (11.2)	1091 (12.6)
Glaucoma	327 (1.2)	459 (2.1)	413 (1.4)	88 (1.5)	99 (1.4)	104 (0.8)	40 (1.8)	53 (1.4)	117 (1.3)
Epilepsy	335 (1.2)	133 (0.6)	182 (0.6)	191 (3.2)	115 (1.6)	208 (1.6)	194 (8.6)	213 (5.4)	397 (4.6)
Dementia	15 (0.1)	51 (0.2)	255 (0.8)	14 (0.2)	49 (0.7)	288 (2.2)	16 (0.7)	91 (2.3)	379 (4.4)
Schizophrenia (and related non-organic psychosis) or bipolar disorder	126 (0.5)	41 (0.2)	34 (0.1)	108 (1.8)	59 (0.8)	28 (0.2)	115 (5.1)	69 (1.8)	47 (0.5)
Psoriasis or eczema	109 (0.4)	59 (0.3)	92 (0.3)	40 (0.7)	35 (0.5)	61 (0.5)	23 (1.0)	31 (0.8)	92 (1.1)
Inflammatory bowel disease	105 (0.4)	24 (0.1)	8 (0.0)	13 (0.2)	3 (0.0)	2 (0.0)	7 (0.3)	8 (0.2)	3 (0.0)
Migraine	156 (0.6)	57 (0.3)	93 (0.3)	155 (2.6)	90 (1.2)	111 (0.9)	107 (4.7)	66 (1.7)	133 (1.5)
Blindness or low vision	18 (0.1)	6 (0.0)	24 (0.1)	5 (0.1)	9 (0.1)	21 (0.2)	11 (0.5)	7 (0.2)	36 (0.4)
Chronic sinusitis	150 (0.5)	27 (0.1)	13 (0.0)	12 (0.2)	7 (0.1)	3 (0.0)	2 (0.1)	5 (0.1)	6 (0.1)
Anorexia or bulimia	3 (0.0)	2 (0.0)	14 (0.0)	0 (0.0)	0 (0.0)	6 (0.0)	0 (0.0)	3 (0.1)	7 (0.1)
Bronchiectasis	0 (0.0)	0 (0.0)	0 (0.0)	339 (5.7)	344 (4.7)	488 (3.8)	135 (6.0)	230 (5.9)	493 (5.7)
Parkinson's disease	72 (0.3)	189 (0.9)	399 (1.3)	42 (0.7)	134 (1.8)	367 (2.8)	25 (1.1)	148 (3.8)	430 (4.9)
Multiple sclerosis	9 (0.0)	0 (0.0)	0 (0.0)	7 (0.1)	0 (0.0)	0 (0.0)	4 (0.2)	1 (0.0)	0 (0.0)
Viral hepatitis	405 (1.4)	80 (0.4)	39 (0.1)	240 (4.0)	92 (1.3)	56 (0.4)	127 (5.6)	106 (2.7)	58 (0.7)
Chronic liver disease	490 (1.8)	227 (1.0)	165 (0.5)	291 (4.9)	149 (2.0)	146 (1.1)	165 (7.3)	156 (4.0)	171 (2.0)

[a] Zero frequency of learning disability and thyroid disease was recorded and omitted from the table.
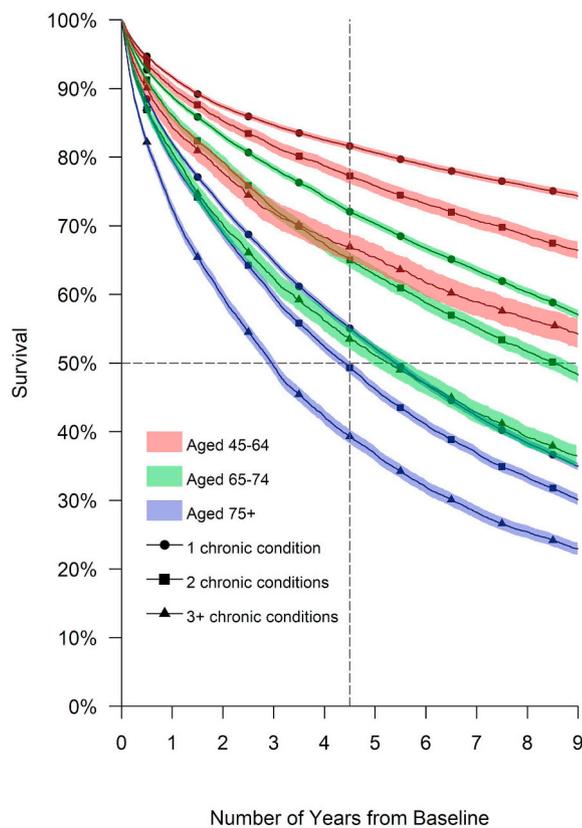
Fig. 1. Survival plot over the follow-up period by age group and multimorbidity status. Shaded areas represent 95% confidence intervals.

Fig. 2, it was found that even after adjustment for sex, CSSA, care home residential status, and number of days survived in the follow-up year, younger age was associated with more admissions across all follow-up years given the same multimorbidity status. The results for number of hospitalized days were reversed in that older age was associated with more days spent in hospitals among those with one and two conditions, but not among those with three or more.

4. Discussion

We found that middle-aged discharged patients (aged 45–64) with three or more chronic health conditions were hospitalized more often than all other groups given the same survival, although their number of hospitalized days were similar to those who also had three or more conditions. Overall, we revealed a significantly stronger sustained impact of multimorbidity on younger than on older age groups in terms of both mortality and hospitalization. We also found that, given the same multimorbidity status, younger age groups tended to be admitted more often but older age groups tended to spend more days in hospital. As far as we know, this is the first Asian study that investigated the impact of multimorbidity over a follow-up period of more than five years [13,25–29]. Our findings agreed with a previous study showing a negative age moderation effect of multimorbidity and short-term hospitalization outcomes [14]. It is shown that although there have been relatively few younger people with multimorbidity, they are a highly vulnerable group with distinctive patterns of health service use whose needs warrant more attention.

4.1. Interpretation

The downward trends of hospital utilization as shown in Fig. 2 was largely due to our sampling strategy of only including discharged in-patients who had acute problems which sometimes required multiple

follow-up admissions to fully address. In addition, the lower mortality of less severe cases in the cohort (given the same age range and multimorbidity status) has also contributed to a lower average utilization in later follow-up years even after adjustment for survival because of a generally lower risk among those who survived long enough to be followed up. Hence, although within the same patients, utilization might have increased, a decrease of average utilization among the surviving patients was still observed. Nevertheless, we mainly focus on the comparison of long-term utilization across age groups and multimorbidity status and is less concerned about the within-subject change of utilization.

It is important to recognize that the study population is those discharged from in-patient care rather than the community population with multimorbidity, which may have different selection effects at different ages and may suffice to explain the observed pattern of hospitalization by age and multimorbidity status. Notably, compared to the community population, admitted older adults are more likely to have frailty and poor physical or mental function (for a given level of multimorbidity) and admitted middle-aged patients are more likely to have more severe illness precipitating admission. This would be consistent with the observed higher baseline prevalence of cancer among middle-aged multimorbid patients (19.0% and 18.3% in those with two and three or more conditions) than among older ones (10.2% and 11.5% in those with two and three or more conditions). The data available did not allow exploration of this in more depth, but it is an important area for future research to explore.

Given the same multimorbidity status, a substantially higher prevalence of mental disorders such as depression, anxiety, and schizophrenia might explain the high utilization rate among middle-aged patients adjusted for survival as shown in Table 2. In a large study of a Scottish primary care population, it was found that the risk of unplanned hospital admission associated with physical morbidities was significantly exacerbated by the coexistence of one or more mental health conditions [28]. In another study of the Dutch National Medical Registry, depressed patients in middle and old age were admitted more often, stayed longer in hospital, and were more likely to die during the stay [36]. A systematic review found that people with mental illness presented challenges to non-psychiatric in-patient care [37], which might impact treatment effectiveness because of non-adherence or failure of services to address all the patient's needs.

In both number of admissions and number of hospitalized days, we observed a diminishing effect of multimorbidity in age group 75 + over the follow-up period. Consistent with Gruneir et al. [14] which identified a similar pattern in hospitalization within one year, we speculate this might be due to the different disease clustering across age groups. For example, Larsen et al. [38] conducted a latent class analysis in a nationally representative sample of Danish adults and found different age compositions in the various classes of diseases. Also, as people age, the likelihood of frailty increases independently of the number of morbidities [39,40]. Previous research has suggested the importance of frailty in addition to multimorbidity in explaining healthcare utilization [41,42]. It is possible that very old non-multimorbid patients suffered from severe frailty and had similar healthcare utilization as their multimorbid counterparts did. A local study of community living older people [43] showed that while number of chronic diseases was associated with use of hospital services in the preceding twelve months, geriatric syndromes per se without multimorbidity (such as sarcopenia, frailty, cognitive impairment) also increased use of hospital services to the same extent (increase of approximately 20%). These geriatric syndromes, notably frailty and cognitive impairment, together with a higher risk of medication-related adverse events and other hospital-related complications [44] in older patients might also suffice to explain the generally greater annual number of hospitalized days given the same multimorbidity status [45,46].
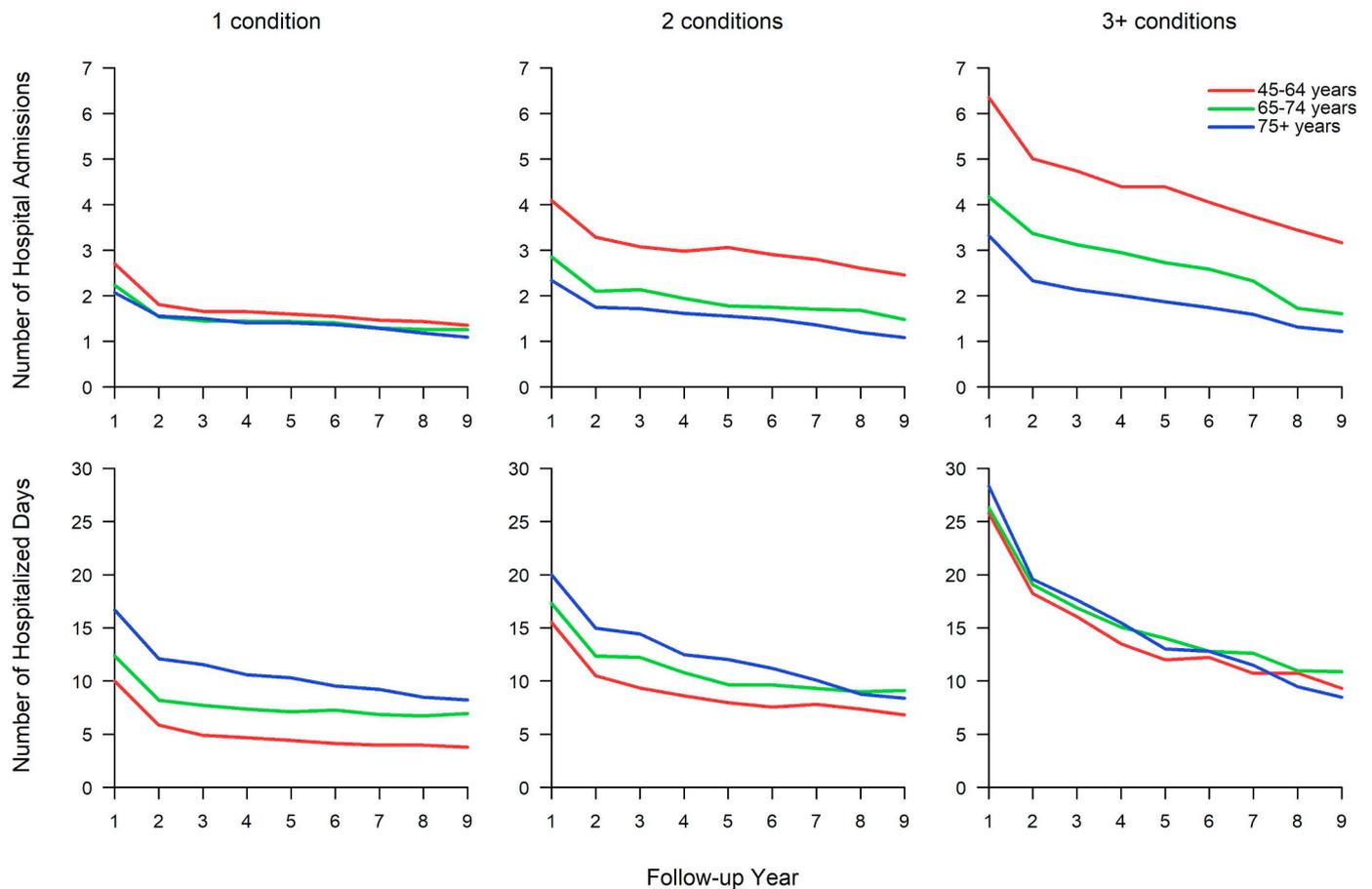
Fig. 2. Average number of hospital admissions and average number of hospitalized days per person-year over the follow-up period by age group and multimorbidity status.

4.2. Strengths and limitations

The major strength of the study is the use of longitudinal data consistently coded with ICD-9 from the clinical records of the whole public sector of in-patient services. There are, however, several limitations too. First, the population examined is discharged in-patients, meaning that results must not be over-generalized to the general population, because this cohort only included patients who had been admitted to hospital and therefore, were likely to be more ill than the general population. We, also, may have missed admissions to private hospitals of which we have no record. However, the public sector provides over 90% of in-patient bed days, with private sector users more likely to be of working age with employer-provided health insurance. Switching from public to private in-patient care is, therefore, believed to be unusual, and we believe that incomplete ascertainment would not alter our conclusion that middle-aged patients with multimorbidity have distinct needs that require more attention. There may also be an underestimation of the prevalence of certain chronic conditions for which an in-patient clinical assessment is not always done. For example, prevalence of dementia is relatively low in our sample (see Table 2) likely because of under-diagnosis and under-coding of known dementia in this context. Second, we have operationalized multimorbidity as an unweighted count. Hence, a patient with dementia and cancer, for example, would be coded as multimorbid as another patient with dyspepsia and prostate disorder would be, but show a drastically different utilization pattern. Although weighted measures such as the Charlson Comorbidity Index [47] may show different findings, the simple count of diseases is the most commonly used approach [2] and enhances the comparability of results with other studies. In some contexts, including primary care use, simple counts have been shown to be

equally predictive as weighted counts [48]. Future research may focus more on how differing patterns of multimorbidity across age groups could exert different effects on hospitalization [49]. Third, although a high proportion of in-patients are elderly, and frailty is a common case of admission and re-admission, we did not examine frailty as a covariate, due to limited data availability, but confined the analysis to multimorbidity. Fourth, mortality is only observed in hospitals such that deaths outside hospitals have not been recorded. Nevertheless, > 90% of deaths in Hong Kong occur in hospitals and this percentage is believed to be even higher among discharged chronic disease patients.

4.3. Implications

Health services are increasingly acknowledging the importance of multimorbidity in older people, but services are often age-restricted with, for example, no equivalent of comprehensive geriatric assessment for middle-aged people. However, middle-aged people with multimorbidity also have significantly impaired survival and more subsequent hospital admissions. They, therefore, represent a distinct vulnerable population whose needs are probably different to older people with multimorbidity (with a greater preponderance of mental disorders for example, and likely less physical frailty) and these needs may not be well met by current services.

Adults aged 45–64 are typically economically active. It is difficult for them to seek help with their health conditions because of their employment status, the change of which may bring economic difficulties [50]. In the absence of social insurance, the Hong Kong Government may consider subsidizing patients not only based on their age (such as the currently adopted old-age medical voucher) [51] but also on certain chronic conditions or overall morbidity burden such that

Table 3
Adjusted [a] relative risks (95% confidence interval) of hospitalization by the cross-classification between multimorbidity status and age group.

Hospital admissions		Follow-year								
Age	Conditions	1	2	3	4	5	6	7	8	9
45-64	1	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
65-74	1	0.62 (0.59, 0.65)	0.48 (0.45, 0.51)	0.46 (0.43, 0.49)	0.46 (0.43, 0.49)	0.46 (0.42, 0.49)	0.44 (0.41, 0.47)	0.42 (0.39, 0.46)	0.43 (0.40, 0.46)	0.46 (0.42, 0.49)
75+	1	0.45 (0.43, 0.47)	0.35 (0.33, 0.37)	0.33 (0.31, 0.35)	0.32 (0.30, 0.34)	0.33 (0.30, 0.35)	0.34 (0.32, 0.36)	0.35 (0.32, 0.38)	0.35 (0.33, 0.38)	0.37 (0.35, 0.41)
45-64	2	1.43 (1.33, 1.55)	1.53 (1.39, 1.69)	1.56 (1.40, 1.73)	1.54 (1.38, 1.71)	1.64 (1.47, 1.84)	1.62 (1.45, 1.83)	1.73 (1.53, 1.95)	1.60 (1.42, 1.81)	1.61 (1.42, 1.82)
65-74	2	0.77 (0.72, 0.82)	0.65 (0.60, 0.70)	0.66 (0.60, 0.72)	0.61 (0.55, 0.67)	0.55 (0.50, 0.61)	0.53 (0.48, 0.58)	0.57 (0.51, 0.63)	0.60 (0.54, 0.67)	0.54 (0.48, 0.61)
75+	2	0.50 (0.47, 0.52)	0.37 (0.34, 0.39)	0.37 (0.34, 0.39)	0.38 (0.35, 0.40)	0.37 (0.34, 0.40)	0.38 (0.35, 0.42)	0.39 (0.35, 0.43)	0.36 (0.33, 0.40)	0.40 (0.36, 0.45)
45-64	3+	2.04 (1.83, 2.27)	1.92 (1.67, 2.21)	1.96 (1.69, 2.28)	1.98 (1.68, 2.33)	1.94 (1.64, 2.29)	1.85 (1.56, 2.20)	1.86 (1.55, 2.23)	1.83 (1.52, 2.21)	1.66 (1.38, 2.01)
65-74	3+	1.10 (1.01, 1.19)	1.00 (0.90, 1.11)	0.94 (0.84, 1.05)	0.88 (0.78, 0.99)	0.85 (0.75, 0.97)	0.83 (0.72, 0.95)	0.79 (0.68, 0.91)	0.60 (0.52, 0.71)	0.64 (0.54, 0.75)
75+	3+	0.69 (0.65, 0.74)	0.50 (0.46, 0.54)	0.46 (0.42, 0.50)	0.47 (0.42, 0.51)	0.46 (0.42, 0.51)	0.50 (0.45, 0.57)	0.52 (0.46, 0.59)	0.49 (0.43, 0.57)	0.53 (0.46, 0.62)

Hospitalized days		Follow-year								
Age	Conditions	1	2	3	4	5	6	7	8	9
45-64	1	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
65-74	1	1.12 (1.08, 1.17)	1.02 (0.96, 1.08)	1.16 (1.09, 1.24)	1.18 (1.09, 1.28)	1.19 (1.10, 1.27)	1.24 (1.15, 1.33)	1.26 (1.15, 1.36)	1.25 (1.15, 1.35)	1.39 (1.28, 1.50)
75+	1	1.39 (1.34, 1.45)	1.28 (1.21, 1.35)	1.48 (1.40, 1.57)	1.58 (1.47, 1.70)	1.57 (1.46, 1.69)	1.64 (1.52, 1.76)	1.73 (1.60, 1.87)	1.76 (1.62, 1.92)	1.84 (1.69, 2.01)
45-64	2	1.28 (1.20, 1.36)	1.19 (1.09, 1.30)	1.37 (1.24, 1.51)	1.44 (1.27, 1.63)	1.37 (1.22, 1.53)	1.42 (1.26, 1.59)	1.54 (1.36, 1.74)	1.55 (1.36, 1.76)	1.52 (1.34, 1.73)
65-74	2	1.43 (1.35, 1.51)	1.31 (1.21, 1.41)	1.62 (1.49, 1.77)	1.61 (1.44, 1.80)	1.55 (1.40, 1.72)	1.53 (1.38, 1.71)	1.59 (1.42, 1.78)	1.68 (1.49, 1.90)	1.70 (1.51, 1.92)
75+	2	1.55 (1.48, 1.63)	1.45 (1.35, 1.54)	1.74 (1.62, 1.87)	1.83 (1.66, 2.01)	1.83 (1.67, 2.00)	1.91 (1.73, 2.10)	2.02 (1.82, 2.25)	1.94 (1.73, 2.17)	2.08 (1.83, 2.35)
45-64	3+	1.85 (1.68, 2.02)	1.66 (1.46, 1.87)	2.08 (1.81, 2.39)	1.89 (1.58, 2.08)	1.75 (1.48, 2.08)	1.90 (1.60, 2.26)	1.80 (1.50, 2.17)	1.91 (1.57, 2.33)	1.72 (1.41, 2.09)
65-74	3+	1.84 (1.72, 1.98)	1.74 (1.58, 1.92)	1.88 (1.69, 2.10)	1.96 (1.70, 2.22)	1.94 (1.69, 2.22)	1.91 (1.66, 2.21)	2.02 (1.73, 2.37)	2.01 (1.69, 2.39)	2.31 (1.92, 2.77)
75+	3+	1.94 (1.84, 2.05)	1.78 (1.66, 1.92)	2.02 (1.86, 2.20)	2.08 (1.86, 2.33)	1.90 (1.70, 2.12)	2.28 (2.02, 2.58)	2.25 (1.96, 2.58)	2.35 (2.02, 2.75)	2.26 (1.91, 2.67)

[a] Adjusted for sex, comprehensive social security assistance recipient status, elderly home residential status, and number of days survived (as an offset term) in the follow-up year.

middle-aged patients could also benefit. This recommendation is also supported by two additional factors. First, from our findings, given the same multimorbidity status, younger patients are generally admitted more times despite fewer days spent in hospitals. Since evidence suggests that there is a smaller role of the length of stay in determining the cost incurred in hospitalization when compared to that associated with number of admissions, focus on reducing admission episodes may result in larger reduction in overall cost [52]. This implies that better care for younger patients with multimorbidity may reduce even more cost than that for older patients [32]. Second, middle-aged multimorbid people have a greater opportunity cost in terms of productivity compared with that of older patients. With a rapidly ageing population and a foreseeable shortage of labor [53], better care for middle-aged or even younger people may facilitate better socioeconomic development. As middle-aged people with multimorbidity have a higher prevalence of mental disorders, we also recommend strengthening psychiatric support for middle-aged patients with multimorbidity. Specifically, healthcare professionals should assess the patients' needs and provide access to psychiatric or counselling services.

5. Conclusion

Middle-aged multimorbid patients were hospitalized more often than older multimorbid patients given the same survival over a nine-year period, with similar total days in hospital. Further research is needed to understand the implications of the patterns of multimorbidity experienced by middle-aged people, and how services could best respond.

Conflict of interest

Declarations of interest: none.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejim.2018.12.001.

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