Unplanned Hospitalization among Senior High Cost Healthcare Users in Ontario, Canada: population-based, matched cohort study

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ABSTRACT

BACKGROUND

A better understanding of factors that influence the transition to high-cost user (HCU) status is needed. We examined the attributes of first (index) unplanned acute hospitalisation (IH) and its predictors among new senior HCUs compared to non-HCUs in Ontario.

METHODS:

Using Ontario administrative healthcare records, incident senior HCUs were identified and matched 1:3 to non-HCU seniors. HCUs were defined as persons aged ≥66 years within the top 5% most costly healthcare users during fiscal year (FY) 2013 but not during FY2012. IHs were defined as the first unplanned hospital admission during FY2013 with no hospitalizations in preceding 12 months. IH costs were calculated by most responsible ICD-10 diagnosis codes (MRDx). Predictors of IHs were identified using logistic regression.

RESULTS:

Over half (54.2%) of all HCUs (N=175,847) had an IH compared to 1.7% of non-HCUs (N=527,541). Ten MRDx accounted for one third of the IH costs. IH costs were higher for HCUs than for non-HCUs (mean, $12,471 vs $3,749), partly because of longer acute length of stay (mean, 7.5 vs 2.9 days) and more frequent designation as alternate level of care pre-discharge (20.8% vs. 1.7%). A lower risk of IH among HCUs was associated with residence in long-term care (LTC), attachment to a primary care provider, and recent consultation by a geriatrician.

INTERPRETATION

Unplanned IHs contribute to incident senior HCU conversion as suggested by IHs' prevalence and costs among HCUs compared with non-HCUs. Improved access to specialist outpatient care, home-based social care, and LTC when required are worth further investigation.

Introduction

Senior high-cost users (HCUs), defined as those above 65 years of age, represent 60% of the overall HCU population which itself accounts for 61.1% of all publicly funded healthcare costs in Ontario(1). Approximately two-thirds of HCU costs are accrued through hospital admissions(1-4), thus providing the rationale for interventions aimed to reduce hospitalization rates (e.g., a “virtual ward”, “hot spotting”, discharge planning, bundled care, Ontario Health Links)(5-7). Detailed examination of hospitalized senior HCUs can inform and improve ongoing HCU management programs.

Currently, there is limited information on several key aspects of senior HCU admissions such as: 1) characteristics of incident HCUs, as opposed to prevalent HCUs, which would allow identification of the factors that influence the transition to HCU status; 2) the first hospital admission, as opposed to re-admission, since the first (or index) hospitalization is the most important predictor of subsequent admissions and of disability in general(8-10); 3) contribution of individual conditions to the financial burden of hospitalization, which would help programs identify clinical drivers of the highest inpatient expenditures that are potentially divertible by managing risk factors, and 4) outcomes of admission, such as inpatient mortality. Further, although socio-demographic and health attributes of senior HCUs have been reported in Canada and elsewhere(11-14), little is known about their healthcare prior to the HCU status, especially in Canada, and how these compare to non-HCUs. This is important, as preventing hospitalizations and improving outcomes among seniors, HCUs or non-HCUs, is likely to require a stronger effort on the part of community and ambulatory services (primary care, home care and outpatient specialist visits). Finally, it is also important to separate unplanned and elective hospitalizations to account for differences in patient characteristics, predictors, and preventability.

Given health care planners’ growing concern over the escalating healthcare costs and challenges in managing HCUs(5), a better characterization of the first unplanned hospitalizations among them is a timely exercise with important health policy and program implications. The objectives of the study were therefore to describe attributes of the first unplanned hospitalizations in the year of becoming an HCU among incident senior HCUs in comparison with non-HCUs, and to determine predictors of these admissions in both cohorts.

Methods

Ethics Approval

This study was approved by Hamilton Integrated Research Ethics Board (ID#1715-C).

Study design and data sources

We conducted a retrospective population-based matched cohort study using 2 years of provincial patient data. The 2013 Ontario government fiscal year (April 1, 2013 and March 31, 2014) was considered the incident year (FY2013), while the 2012 fiscal year (FY2012: April 1, 2012 and March 31, 2013) was the baseline or pre-incident year. The individual level dataset was created using health administrative databases from Ontario housed at ICES (www.ices.on.ca). These databases were linked using encrypted patient-specific identifiers. Health care expenditures were calculated using ICES person-level health utilization costing algorithms(15). Costs were expressed in 2013 Canadian Dollars. More details on the study population and data sources were published as a study protocol elsewhere (16).

Study population

Incident senior HCUs were defined as individuals aged 66 years or older with annual total healthcare expenditures within the top 5% threshold of all Ontarians in FY2013, who were not in the top 5% in FY2012 fiscal year. The 5% threshold is commonly used in HCU studies in Canada and elsewhere(3, 4, 11, 17). Non-HCUs were Ontarians in FY2013 with annual total health care expenditures in both FY2012 and FY2013 less than the top 5% threshold. The incident HCU cohort was matched with non-HCUs in a ratio of 1:3 according to age at cohort entry (± 1 month), sex and Local Health Integration Network (LHIN) of patient residence. The >66 year age threshold was applied to capture Ontario Drug Benefits (ODB) costs for at least one year before FY2013.

Patient characteristics

The study population was characterized by socio-demographic (e.g., age, sex, income), health status (e.g., Johns Hopkins Aggregate Diagnosis Groups (ADG))(18), and health care variables (e.g. number of specialist visits) in the

baseline year. The variables were described in the study protocol(16) in greater detail and are briefly summarized in Appendix 1.

Unplanned index hospitalization

Patients with an unplanned index hospitalization (IH) were defined as individuals who had not been hospitalized for at least 12 months prior to their first acute inpatient hospitalization in FY2013. Unplanned IHs were defined as non-elective admissions as recorded in the Canadian Institute for Health Information's (CIHI) Discharge Abstract Database (DAD). The ICD10-CA diagnosis code most responsible for resource use (abbreviated as MRDx) was used to define the reason for each hospitalization. The acute portion of each hospital length of stay (ALOS) was summarized as the mean number of the days of hospitalization. Alternate level of care (ALC) status, which refers to patients who no longer require acute care but who occupy a hospital bed while awaiting placement in another healthcare facility(19), was expressed as the proportion of patients with ALC status. We also calculated the proportion of patients who were admitted to a teaching facility and the proportion who resided in a LHIN different than the hospital LHIN (Appendix 1). IH costs were calculated according to MRDx. Inpatient mortality was defined as all-cause in-hospital mortality among the subset of patients who had an unplanned IH. In addition, we calculated the number of days patients were in hospital before death.

Statistical analysis

We first compared the patient characteristics of the two cohorts in FY2012 by measuring absolute standardised difference (aSD). The aSD of 0.1 and above indicated a meaningful difference(20). In the second step, the attributes of the unplanned IHs among senior HCUs versus non-HCUs were described in terms of ALOS, ALC, discharge disposition and death before discharge. Thirdly, the most common clinical causes of admission and their associated costs were determined for both groups. The cumulative percentage of the total unplanned IH costs by MRDx and average annual costs for each diagnosis were also computed.

We used logistic regression, one model for each cohort, to identify independent predictors of unplanned IHs. Odds ratios and 95% confidence intervals were reported. The list of potential predictors consisted of socio-

demographic, health status and health care characteristics measured in FY2012, as described in Appendix 1. We included all relevant variables in the models regardless of their statistical significance. We assessed model discrimination using the c-statistic, where a c-statistic value of 0.70 and above indicates good discrimination (21). Additional information on the statistical methods including model cross-validation and predictive accuracy is provided in Appendix 2.

Results

Baseline patient characteristics

The total study population consisted of 703,388 seniors, of which 175,847 were incident HCUs. The average age was 77.7 years and 53% of individuals in both cohorts were women and resided in suburban areas (Table 1). Compared to non-HCUs, HCUs were sicker (number of ADGs: 10.2 vs. 7.9%, aSD=0.54), were dispensed a higher number of medications (8.4 vs 5.6, aSD=0.6), visited their primary care provider more often (95.6% vs. 84.3%, aSD=0.38), received more specialty care (89.8% vs. 74.2%; aSD=0.41) and home care services in the year preceding the index year. HCUs were more likely to have a primary care provider (primary care group: 97% vs. 88.6%, aSD=0.33). More than one third of the HCUs visited an emergency department compared to non-HCUs (31.8% vs. 19.3%, aSD=0.29). The non-HCUs had a higher proportion of recent immigrants (4.3% vs. 2.4%; aSD=0.11). In terms of the other study characteristics, the study cohorts were otherwise similar.

Characteristics of unplanned index hospitalization

Unplanned IHs accounted for 71% and 82% of index hospitalizations among HCUs and non-HCUs, respectively, in FY2013. More than half of the HCUs (N=95,308; 54.2%) had an unplanned IH compared to only 1.7% (N=8,835) of the non-HCUs (Table 2). Among those hospitalized, HCUs had a longer length of stay (mean ALOS, 7.5 vs 2.9 days; aSD=0.73), were designated ALC status in higher numbers (20.8% vs. 1.7%; aSD=64), and, once transferred to ALC, had a relatively greater number of ALC days (2.96 vs. 0.06 days; aSD=0.32). Compared with 1.3% of non-HCUs, 23.0% of HCU patients were transferred to another acute care or LTC facility, while most non-HCU seniors (83.6%) were discharged home (with or without support). There was a striking difference in inpatient mortality between

the cohorts: non-HCU patients were more than twice as likely to die in hospital compared to HCUs (14.0% vs. 6.4%, aSD=0.25), despite the HCUs longer mean ALOS. Among those who died in hospital, non-HCUs also had a substantially shorter stay before death (2.3 vs. 17.9 days; aSD=1.92).

Index hospitalization costs

Unplanned IHs accounted for 74% (HCU) and 81% (non-HCU) of the costs associated with all IH (unplanned plus elective) during the year of study. The average cost per patient associated with the unplanned IH was $12,471 (SD $19,935) for HCUs and $3,749 (SD: $1,290) for non HCU (Table 3). Ten conditions accounted for one third of the costs: 36.4% (HCU) and 35.3% (non-HCU). Acute myocardial infarction (8%) was the leading most costly reason of IH among HCUs, compared to pneumonia (6%) among non-HCUs. Five conditions (i.e., cerebral infarction, congestive heart failure (HF), pneumonia, chronic obstructive pulmonary disease (COPD), and ileus/intestinal obstruction) were among the top 10 most costly conditions in both cohorts. The costliest conditions were also the most frequent causes of unplanned hospitalizations in both cohorts.

Predictors of unplanned IHs

Overall, the direction, magnitude and significance of odds ratios (OR) were similar across the two cohorts for many of the predictors of unplanned IH (Table 4). Predictors specific to the HCU cohort included having visited a geriatrician in the previous year and living at long-term care facilities. Both were associated with lower odds of IHs (ORs: 0.81, 95%CIs 0.76-0.86 and 0.29, 95%CIs 0.25-0.34, respectively). Recent immigrants had lower odds of IHs which was unique among senior non-HCUs (ORs: 0.72, 95% CIs 0.62-0.84). Some predictors had an opposite but statistically significant impact on admissions across the cohorts. Most notably, HCUs who had a primary care provider were at a lower risk of admission whereas among non-HCUs, attachment to a provider was associated with an increase in IH.

Interpretation

Our study provides an analysis of high cost healthcare use amongst seniors in Ontario. By examining the first hospitalization among “new” cases of senior HCUs in comparison with age, sex and geographically-matched non-

HCUs, we found that unplanned HIs were much more common among high cost seniors, with more than a half of HCUs having an unplanned IH compared to less than 2% of non-HCUs. Ten conditions, many of which have known remediable risk factors of hospitalization(22-26), accounted for a large number of these admissions and one third of their costs. Our findings indicate that despite many similarities in baseline predictors of the first unplanned admission between the two cohorts, a few predictors (e.g., visits to a geriatrician or attachment to a primary care provider) were unique to each cohort.

Our study examines factors that influence the transition of becoming a senior incident HCU by focusing on their first hospitalization during the incident year and exploring the impact of healthcare in the pre-incident year on the HCU status. Besides a greater admission rate, HCUs had longer hospital stays and were frequently designated as ALC. Although lower in costs compared with acute care patients(27), the higher number of days in ALC is likely to contribute to the HCU conversion which was documented recently in the general HCU inpatient population(28). Reduction in the proportion of ALC patients however may not be possible without changing hospital funding (e.g., Ontario funding reform(29)) and improving post-discharge options (e.g., “Home First”, long-term care)(27, 30). Also, compared to senior non-HCUs, HCUs who died in hospital stayed there for weeks on average prior to death suggesting a terminal stage. Evidence indicates that such lengthy inpatient stays, and the corresponding costs, can be avoided or reduced when advanced end-of-life care planning is in place(14, 31). Further Canadian efforts to promote its routine use should be encouraged(32).

Our analyses suggest that increasing access to geriatricians and other specialists with expertise in managing the complexities of multi-morbidity and aging may be worth investigating as a cost-effective strategy to reduce index hospital admissions among seniors, especially HCUs. The fact that attachment to a primary care provider as a predictor of IH travels in opposite directions for the two cohorts may allude to the existence of subgroups of ‘orphan’ patients that differ based on severity of illness, personality type, social circumstance or, among HCUs, access to primary care(33). Compared with previous studies of the general senior population that suggest residence at a nursing home can be a predictor of future admissions, especially for fracture(34, 35), living in a LTC facility was associated with lower risk for unplanned IHs among HCUs. In contrast to many predictors with a low

magnitude of association, the "other" category of home care services for HCUs had a non-negligible protective effect in IHs. Since this variable was constructed to include a combination of social services, respite care and case management, it was impossible to tease out the impact of each of these services alone. This lends itself to further investigation.

It is difficult to compare our results with other studies due to methodological heterogeneity, including the lack of differentiation between the category of admission (unplanned vs. elective), inclusion of re-admissions, or the use of a different HCU threshold (e.g., top 1%). However, we found our results to be consistent with previous research in several aspects. First, our list of the most frequent and most costly MRDx is overall in line with prior limited studies on senior HCUs from Canada and elsewhere that examined the financial contribution of individual conditions: cardio-vascular, orthopedic, infectious diseases are predominant reasons of admissions(4, 36). Further, a number of models from different jurisdictions examined this risk among community-dwelling seniors(10). Similar to our results, older age, male sex, visits to the ED and prevalent chronic conditions were associated with higher odds of admission. Finally, our findings support earlier reports of the "healthy immigrant" effect(37): recent senior immigrants were less likely to become HCUs or be admitted with an IH.

Key strengths of this study include its population-based, matched design, and our examination of poorly studied aspects of the senior HCU population in the Canadian context. Our study also has limitations. The discriminatory power of the models was only fair, although the values of c-statistic were close to a number of previously reported risk prediction models in the general senior population(10). Running the models on more homogeneous subgroups of patients (e.g. COPD, HF) improved model discrimination (e.g. c-statistics above .7), especially for HCUs (Appendix 4), and these results were consistent with the main analyses. Further, some findings are based on variables with low prevalence: LTC residence status (n=835; 0.5%), geriatrician visits (n=4967; 2.8%), although this is relative to the very large size of the study population. The study focused only on unplanned IHs rather than including elective admissions. This limits the generalizability of our results to all hospitalizations, but unplanned admissions account for >70% in either cohort. Finally, our modeling is exploratory - the results suggest association but certainly not causation.

Conclusions

Unplanned IHs contribute to the conversion of seniors from non-HCU to HCU as suggested by the high prevalence of IH among HCUs and the corresponding costs driven partly by longer lengths of stay for acute hospital need and more ALC. Improved access to specialist outpatient care, home-based social care, and LTC when required, are worth further investigation.

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Table 1: Characteristics of HCU Study Population in the Pre-incident Year

Characteristic		HCU (N=175,847)	Non-HCU (N=527,541)	aSD
Socio-demographics				
Age, mean ± SD, yr		77.66 ± 7.65	77.66 ± 7.65	0
Sex, female		93,119 (53%)	279,501 (53.0%)	0
Rural Index of Ontario (RIO) score[a], mean ± SD		12.23 ± 18.20	11.81 ± 18.18	0.02
Low income		31,843 (18.1%)	92,566 (17.5%)	0.01
Recent immigrant (<15 yr in Canada)		4,210 (2.4%)	22,577 (4.3%)	0.11
Health Status				
# Adjusted Diagnostic Groups, mean ± SD		10.22 ± 4.00	7.93 ± 4.47	0.54
Hypertension[b]		110,692 (63.0%)	282,867 (53.6%)	0.19
Congestive Heart Failure[c]		25,195 (14.3%)	36,877 (7.0%)	0.24
Chronic Obstructive Disease Pulmonary[c]		48,738 (27.7%)	96,513 (18.3%)	0.23
Diabetes[c]		62,014 (35.3%)	138,794 (26.3%)	0.2
Myocardial infarction[c]		12,892 (7.3%)	24,024 (4.6%)	0.12
Rheumatoid Arthritis[c]		5,607 (3.2%)	9,334 (1.8%)	0.09
Malignancy[b]		56,855 (32.3%)	123,932 (23.5%)	0.2
Mental Health condition[b]		67,441 (38.4%)	144,377 (27.4%)	0.24
Health Care utilization[d]				
Long-term care facility, #/yr (%/yr)		835 (0.5%)	316 (0.1%)	0.08
Primary care provider enrollment model, #/yr (%/yr)				
	Fee for service	16,938 (9.6%)	45,751 (8.7%)	0.03
	Capitation	48,703 (27.7%)	133,915 (25.4%)	0.05
	Enhanced fee for service	51,637 (29.4%)	143,940 (27.3%)	0.05
	Family Health Team	51,159 (29.1%)	137,516 (26.1%)	0.07
	None (no primary care provider identified)	5,187 (3.0%)	60,170 (11.4%)	0.33
Number of medications, mean ± SD		8.44 ± 4.96	5.61 ± 4.47	0.6
Emergency department visits	#/yr (%/yr)	55,964 (31.8%)	101,896 (19.3%)	0.29
	mean ± SD	0.56 ± 1.13	0.30 ± 0.80	0.26
Visits to a general practitioner	#/yr (%/yr)	168,024 (95.6%)	444,614 (84.3%)	0.38
	mean ± SD	8.03 ± 6.79	5.63 ± 5.58	0.39
Visits to a specialist	#/yr (%/yr)	157,823 (89.8%)	391,557 (74.2%)	0.41
	mean ± SD	7.40 ± 6.65	4.43 ± 5.13	0.5
Visits to a geriatrician		4,967 (2.8%)	5,935 (1.1%)	0.12
Homecare visits				
Nursing	#/yr (%/yr)	7,218 (4.1%)	7,385 (1.4%)	0.17
	mean ± SD	0.54 ± 4.03	0.16 ± 2.00	0.12
Personal support (%/yr)	#/yr	13,789 (7.8%)	10,612 (2.0%)	0.27
	mean ± SD	6.43 ± 30.57	1.46 ± 13.53	0.21
Allied health	#/yr (%/yr)	9,250 (5.3%)	7,982 (1.5%)	0.21
	mean ± SD	0.18 ± 0.99	0.05 ± 0.52	0.17
Other[e]	#/yr (%/yr)	27,605 (15.7%)	25,965 (4.9%)	0.36
	mean ± SD	0.58 ± 2.30	0.14 ± 0.96	0.25

a- RIO score classification: urban= <10; suburban=10-39; rural ≥40

b- constructed based on Expanded Diagnosis Codes; c- ICES-derived cohort; d- a mean of care utilization refers to the number per person per FY2012;

e - included a combination of social support, respite care, and case management;

aSD- absolute standardized difference with aSD > 0.1 indicating meaningful difference between admitted and non-admitted; SD- standard deviation

Table 2: Characteristics of unplanned index hospitalizations*

Characteristic	HCU	Non-HCU	aSD
Number of individuals with an IH (% of total population)	133,821 (71%)	10770 (82%)	
Number of individuals with an unplanned IHs (% of total patient with IH)	95,308 (54.2%)	8,835 (1.7%)	
Acute length of stay, mean ± SD, days	7.52 ± 8.71	2.91 ± 2.16	0.73
Alternate level of care# (ALC)	19,849 (20.8%)	147 (1.7%)	0.64
# days spent in ALC (for those with ALC designation), mean ± SD	2.96 ± 12.71	0.06 ± 0.72	0.32
Discharge disposition			
Inpatient hospital care	6,279 (6.6%)	47 (0.5%)	0.33
Long term or continuing care facility	15,602 (16.4%)	70 (0.8%)	0.58
Home with support§	23,810 (25.0%)	1,097 (12.4%)	0.33
Home	42,994 (45.1%)	6,293 (71.2%)	0.55
Admission to a teaching care facility	25,597 (26.9%)	2,097 (23.7%)	0.07
Admission to an out of health district acute care facility	10,390 (10.9%)	770 (8.7%)	0.07
Death before discharge	6,112 (6.4%)	1,241 (14.0%)	0.25
Number of days spent at the hospital before death outcome	17.86 ± 25.27	2.32 ± 1.85	0.87

*- defined as first admission in the incident year among those without hospitalization in the past 12 months

- refers to seniors that no longer require acute care but occupy hospital beds waiting for placement in other healthcare facilities

§-support options include: senior's lodge, attendant care, home care, meals on wheels, homemaking, supportive housing, etc

SD- standard deviation; aSD- absolute standardized difference with aSD > 0.1 indicating meaningful difference between women and men

Table 3: Top 20 most expensive conditions, unplanned index hospitalization

	HCU: n= 95,308 Total 1-year inpatient cost associated with unplanned IHs: $1,188,544,347 (74% of all HCU hospitalizations) Average costs per HCU (mean ± SD): 12,471 ± 19,935							Non-HCU: n= 8.835 Total 1-eyar inpatient costs associated with unplanned IHs: $33,130,373 (81% of all non-HCU hospitalizations) Average costs per non-HCU (mean ± SD): 3,749 ± 1,290					
	ICD10 code	Condition	Inpatient costs	Frequency	Average cost	Cumulative to total unplanned costs		ICD10 code	Condition	Inpatient costs	Frequency	Average cost	Cumulative to total unplanned costs
1	I21	Acute myocardial infarction	$ 92,924,331.27	6045	$ 15,372.10	7.8%		J18	Pneumonia	$ 1,970,228.65	439	$ 4,487.99	6%
2	S72	Fracture of femur	$ 84,898,511.82	5181	$ 16,386.51	15.0%		J44	Chronic obstructive pulmonary disease	$ 1,448,358.06	304	$ 4,764.34	10.3%
3	I63	Cerebral infarction	$ 54,321,115.26	3912	$ 13,885.77	19.5%		R55	Syncope and collapse	$ 1,337,333.96	432	$ 3,095.68	14.4%
4	I50	Heart failure	$ 41,778,511.43	4069	$ 10,267.51	23.0%		I48	Atrial fibrillation and flutter	$ 1,120,050.76	316	$ 3,544.46	17.7%
5	J44	Other chronic obstructive pulmonary disease	$ 37,347,675.22	4184	$ 8,926.31	26.2%		N39	Disorders of urinary system	$ 1,115,864.19	267	$ 4,179.27	21.1%
6	A41	Other septicaemia	$ 31,204,568.40	1487	$ 20,984.91	28.8%		I50	Heart failure	$ 1,114,152.33	235	$ 4,741.07	24.5%
7	J18	Pneumonia, organism unspecified	$ 25,734,867.64	2811	$ 9,155.06	31.0%		R07	Pain in throat and chest	$ 1,040,653.40	373	$ 2,789.96	27.6%
8	I25	Chronic ischaemic heart disease	$ 25,625,722.16	1352	$ 18,953.94	33.1%		K56	Paralytic ileus and intestinal obstruction	$ 887,672.60	266	$ 3,337.12	30.3%
9	F05	Delirium, not induced by alcohol and other psychoactive substances	$ 20,132,341.32	1305	$ 15,427.08	34.8%		I63	Cerebral infarction	$ 834,442.33	153	$ 5,453.87	32.8%
10	K56	Paralytic ileus and intestinal obstruction without hernia	$ 19,169,068.91	1501	$ 12,770.87	36.4%		Z51	Other medical care	$ 818,227.58	266	$ 3,076.04	35.3%
	64 ICD10codes account for 75% of the total unplanned IH costs							53 ICD10codes account for 75% of the total unplanned IH costs					
	852 ICD10codes account for 100% of the total unplanned IH costs							435 ICD10codes account for 100% of the total unplanned IH costs					

Table 4 Predictors of unplanned index hospitalization

Covariates		HCUs		Non-HCUs	
		OR (95% CI)	P value	OR (95% CI)	P value
Age:					
	75-84y **vs.** 66-74y	1.33 (1.29-1.37)	<.0001	1.5 (1.42-1.58)	<.0001
	>=85y vs. 66-74y	1.66 (1.6-1.71)	<.0001	2.53 (2.39-2.69)	<.0001
Sex (M)		1.03 (1.01-1.06)	0.0081	1.06 (1.01-1.1)	0.0167
Low income status		1.04 (1.01-1.08)	0.013	1.06 (1-1.12)	0.0359
Rurality Index for Ontario, score		1 (1-1)	0.7553	1.01 (1.01-1.01)	<.0001
Immigrant status		0.98 (0.9-1.05)	0.5213	0.72 (0.62-0.84)	<.0001
Malignancy		0.81 (0.79-0.83)	<.0001	1 (0.95-1.05)	0.9556
Hypertension		1.09 (1.06-1.12)	<.0001	1.08 (1.03-1.13)	0.0015
Congestive heart failure (CHF)		1.36 (1.32-1.41)	<.0001	1.47 (1.37-1.57)	<.0001
History of myocardial infarction		1.21 (1.16-1.27)	<.0001	1.43 (1.32-1.55)	<.0001
Chronic Obstructive Pulmonary Disease (COPD)		1.26 (1.22-1.29)	<.0001	1.27 (1.21-1.34)	<.0001
Diabetes		0.93 (0.91-0.96)	<.0001	0.95 (0.9-1)	0.0485
Rheumatoid arthritis		1.09 (1.02-1.16)	0.0111	1.08 (0.93-1.25)	0.3401
Mental health condition		0.98 (0.96-1.01)	0.113	1.09 (1.04-1.14)	0.0004
LTC residence		0.29 (0.25-0.34)	<.0001	1.13 (0.58-2.21)	0.7235
Primary care enrollment					
	FFS vs. no provider	0.83 (0.77-0.91)	<.0001	3.64 (3.18-4.17)	<.0001
	Capitation vs. no provider	0.75 (0.7-0.82)	<.0001	3.14 (2.77-3.55)	<.0001
	Enhanced FFS vs. no provider	0.78 (0.72-0.84)	<.0001	2.99 (2.64-3.39)	<.0001
	FHT vs. no provider	0.79 (0.73-0.85)	<.0001	3.65 (3.23-4.13)	<.0001
Prescription drugs		0.99 (0.98-0.99)	<.0001	1.01 (1.01-1.02)	0.0001
Emergency department visits		1.06 (1.05-1.08)	<.0001	1.16 (1.14-1.18)	<.0001
Visits to general practitioner		1 (0.99-1)	<.0001	1 (0.99-1)	0.2336
Visits to specialist		0.95 (0.95-0.95)	<.0001	0.99 (0.99-1)	0.0035
Visit to a geriatrician		0.81 (0.76-0.86)	<.0001	1.06 (0.89-1.26)	0.5223
Homecare visits					
	nursing	0.99 (0.99-1)	<.0001	1.01 (1-1.01)	0.1919
	personal support	1 (1-1)	<.0001	1 (0.99-1)	<.0001
	allied health	1.01 (1-1.02)	0.2753	1.01 (0.98-1.05)	0.4088
	other	0.94 (0.93-0.94)	<.0001	1.02 (1.01-1.04)	0.0007
C-statistics		0.65		0.67	
C-statistics (cross-validated)		0.65		0.67	

Note: See Appendix 5 for detail on predictive accuracy

COPD- Chronic Obstructive Pulmonary Disease (COPD)

CHF- Congestive heart failure (CHF)

FFS- fee for service

LTC- long-term care

Appendix 1 Description of key variables

Key variables	Description
Demographics (baseline year, FY2012)	
Age	Age in years
Sex	Sex; female=0, male=1
Rio2008	Rurality Index for Ontario; on a scale of 0 to 100 with 100 being most rural
Lowinc	Subjects with low income status were identified based upon net household income reported to receive public drug benefit subsidy in FY2012 which relies on actual net income. For a small proportion of HCU (3%) and non-HCU (13%) who did not fill a prescription in FY2012, low-income status was defined as census neighborhood income quintile
Recent_immigration	Whether immigrated in 15 years prior to FY2012 (based on landing records for permanent legal immigrants in Ontario)
Health status/comorbidity (baseline year, FY2012)	
# of ADGs	Aggregated Diagnosis Groups (ADGs) are derived from Johns Hopkins Adjusted Clinical Groups (ACGs, the Johns Hopkins ACG® System Version 10): a person-focused, diagnosis-based way to measure patients' illness
Hypertension, Malignancy, Mental health condition	For each condition, whether the patient was diagnosed with the condition in the past 3 years prior to FY2013; computed using John Hopkins Expanded Diagnosis Clusters (EDCs)
Congestive heart failure (CHF), History of myocardial infarction, Chronic Obstructive Pulmonary Disease (COPD), Diabetes, Rheumatoid arthritis	Whether the patient is listed in a corresponding ICES-derived cohort for each condition
Healthcare characteristics (baseline year, FY2012)	
# of drugnames	Number of prescription drugs the patient was dispensed
# of physician visits	Number of physician visits; reported by categories (family practitioner and specialist)
# of home care visits	Number of home care visists; reported as total and by categories (nursing, personal support, allied health and other)
Geriatrician	Whether visited a geriatrician
Primarycare group	Primary care payment models: Fee for Service (FFS), Enhanced FFS, Family Health Team (FHT), Capitation, and None
Long-term care (LTC)	Whether was placed in a LTC facility
Features of Index hospitalizations (incident year, FY2013)	
LOS	Length of stay, days
instftyp_	Institution from where admitted
instlhin_	LHIN where admitted
dx10code1-25	Diagnosis ICD10 codes for each admission
dischdisp	Institution where discharged to
inpatient_costs_	Inpatient hospitalization Costs

Appendix 2: Supplemental statistical and sensitivity analysis section

Model discrimination (predictive accuracy) was assessed by the area under the receiver operating characteristic curve (AUROC) represented by the c-statistic. We used a threshold of a c-statistic value of 0.70 and above indicates good discrimination between those admitted versus not admitted(1). We evaluated the model's ability to predict subgroups of patients with a differing risk of index hospitalization by plotting predicted vs. observed events in deciles(2, 3). Each model was validated through cross-validation (4). As a sensitivity analysis and to check for collinearity, we also re-ran each multivariable model using the forward stepwise procedure with p-value <0.1 set as the inclusion criterion and p-value >0.05 as the removal threshold. We then compared the final selection of variables, the sign and magnitude of the odds ratios (OR) as well as their standard errors (SE): no discrepancy with the original results provided further evidence of a good fit and no/low collinearity. Analyses were conducted using SAS software version 9.4 (SAS Institute Inc., Cary, NC, USA).

Since dying in hospital could represent primarily the palliative or terminally ill senior with advanced directives requesting comfort interventions only(5), we carried out a sensitivity analysis excluding those who were admitted urgently but died before discharge.

Results

The results of the stepwise approach were closely aligned with the original models (data available from the authors on request). Re-running the models on a dataset with deceased patients removed did not reveal notable deviations in the coefficients from the original models (Appendix 3). We also re-ran the models individually on 5 most costly conditions in both cohorts: the predictor estimates remained unaffected while c-statistics improved to above 0.7, especially among HCUs (Appendix 4).

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3. Pocock SJ, Wang D, Pfeffer MA, Yusuf S, McMurray JJ, Swedberg KB, et al. Predictors of mortality and morbidity in patients with chronic heart failure. European heart journal. 2006;27(1):65-75.
4. ROC analysis using validation data and cross validation. SAS Support. © SAS Institute Inc. [Available from: http://support.sas.com/kb/39/724.html.
5. Clark D, Armstrong M, Allan A, Graham F, Carnon A, Isles C. Imminence of death among hospital inpatients: Prevalent cohort study. Palliative medicine. 2014;28(6):474-9.

Appendix 3: Predictors of unplanned index hospitalization (deceased excluded)

Covariates		HCUs		Non-HCUs	
		OR (95% CI)	P value	OR (95% CI)	P value
Age:					
	75-84y **vs.** 66-74y	1.31 (1.28-1.35)	<.0001	1.42 (1.34-1.5)	<.0001
	>=85y vs. 66-74y	1.6 (1.54-1.65)	<.0002	2.14 (2-2.28)	<.0002
Sex (M)		1.02 (0.99-1.04)	<.0003	1.03 (0.98-1.08)	<.0003
Low income status		1.03 (1-1.07)	<.0004	1.03 (0.97-1.1)	<.0004
Rurality Index for Ontario, score		1 (1-1)	<.0005	1.01 (1.01-1.01)	<.0005
Immigrant status		0.97 (0.9-1.05)	<.0006	0.77 (0.66-0.9)	<.0006
Malignancy		0.81 (0.79-0.83)	<.0007	0.98 (0.92-1.03)	<.0007
Hypertension		1.1 (1.07-1.13)	<.0008	1.11 (1.06-1.17)	<.0008
Congestive heart failure (CHF)		1.33 (1.29-1.38)	<.0009	1.28 (1.19-1.38)	<.0009
History of myocardial infarction		1.21 (1.16-1.27)	<.0010	1.45 (1.33-1.59)	<.0010
Chronic Obstructive Pulmonary Disease (COPD)		1.24 (1.2-1.27)	<.0011	1.24 (1.17-1.31)	<.0011
Diabetes		0.94 (0.91-0.96)	<.0012	0.94 (0.89-0.99)	<.0012
Rheumatoid arthritis		1.09 (1.02-1.16)	<.0013	1.06 (0.91-1.25)	<.0013
Mental health condition		0.99 (0.96-1.01)	<.0014	1.08 (1.03-1.14)	<.0014
LTC residence		0.29 (0.25-0.34)	<.0015	0.69 (0.26-1.86)	<.0015
Primary care enrollment					
	FFS vs. no provider	0.85 (0.78-0.93)	<.0016	3.64 (3.14-4.22)	<.0016
	Capitation vs. no provider	0.77 (0.71-0.84)	<.0017	3.08 (2.69-3.53)	<.0017
	Enhanced FFS vs. no provider	0.8 (0.74-0.86)	<.0018	2.98 (2.6-3.42)	<.0018
	FHT vs. no provider	0.81 (0.74-0.87)	<.0019	3.69 (3.23-4.22)	<.0019
Prescription drugs		0.99 (0.98-0.99)	<.0020	1.01 (1-1.02)	<.0020
Emergency department visits		1.07 (1.06-1.08)	<.0021	1.17 (1.15-1.2)	<.0021
Visits to general practitioner		1 (0.99-1)	<.0022	1 (0.99-1)	<.0022
Visits to specialist		0.95 (0.95-0.95)	<.0023	1 (0.99-1)	<.0023
Visit to a geriatrician		0.8 (0.75-0.85)	<.0024	0.96 (0.78-1.17)	<.0024
Homecare visits					
	nursing	0.99 (0.99-1)	<.0025	1 (0.99-1.01)	<.0025
	personal support	1 (1-1)	<.0026	0.99 (0.99-0.99)	<.0026
	allied health	1 (0.99-1.01)	<.0027	0.98 (0.94-1.03)	<.0027
	other	0.93 (0.93-0.94)	<.0028	1.01 (1-1.03)	<.0028
C-statistics		0.65		0.66	
C-statistics (cross-validated)		0.65		0.66	

COPD- Chronic Obstructive Pulmonary Disease (COPD)
CHF- Congestive heart failure (CHF)
FFS- fee for service

Appendix 4: Predictors of unplanned index hospitalization for top most expensive 5 conditions among senior HCUs

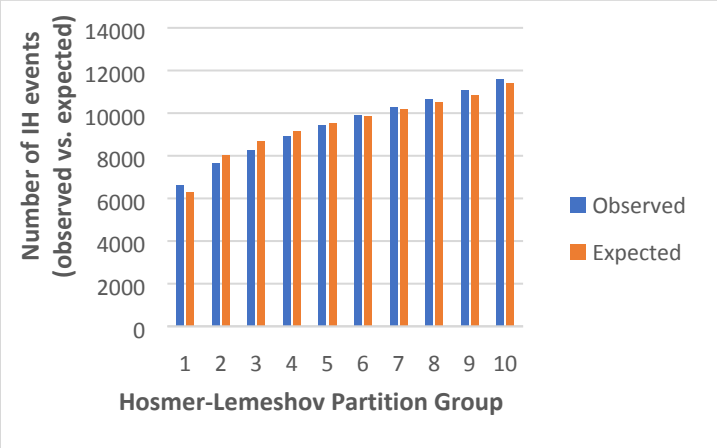
Covariates	AIM		Fracture		Cerebral infarction		CHF		COPD	
	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value
Age:										
75-84y **vs.** 66-74y	1.05 (0.99-1.12)	0.7996	2.3 (2.11-2.49)	<.0001	1.56 (1.44-1.7)	0.0006	1.78 (1.62-1.94)	0.6417	1.14 (1.06-1.24)	0.0032
>=85y vs. 66-74y	1.12 (1.03-1.22)	0.0188	4.06 (3.72-4.44)	<.0001	1.92 (1.75-2.12)	<.0001	3.05 (2.76-3.37)	<.0001	1.05 (0.95-1.17)	0.7335
Sex (M)	1.53 (1.45-1.63)	<.0001	0.46 (0.43-0.5)	<.0001	1.13 (1.05-1.21)	0.001	1.06 (0.99-1.14)	0.0919	1.11 (1.03-1.19)	0.0071
Low income status	1.07 (0.99-1.15)	0.1084	0.94 (0.87-1.02)	0.1232	1.09 (1-1.2)	0.0471	1.13 (1.04-1.23)	0.0056	0.98 (0.9-1.07)	0.6319
Rurality Index for Ontario, score	1 (1-1.01)	<.0001	1 (1-1)	0.0004	0.99 (0.99-0.99)	<.0001	1 (1-1)	0.0129	1 (1-1)	0.1301
Immigrant status	1.05 (0.88-1.25)	0.6063	0.96 (0.77-1.19)	0.7184	1.09 (0.89-1.33)	0.4023	0.92 (0.73-1.17)	0.5191	0.97 (0.74-1.28)	0.8338
Malignancy	0.68 (0.63-0.72)	<.0001	0.83 (0.77-0.89)	<.0001	0.68 (0.62-0.73)	<.0001	0.74 (0.68-0.8)	<.0001	0.76 (0.7-0.82)	<.0001
Hypertension	1.15 (1.08-1.22)	<.0001	1.03 (0.96-1.1)	0.4391	1.34 (1.24-1.44)	<.0001	1.19 (1.1-1.28)	<.0001	0.87 (0.81-0.94)	0.0002
Congestive heart failure (CHF)	1.16 (1.06-1.26)	0.0011	1.02 (0.93-1.12)	0.7105	1.29 (1.16-1.42)	<.0001	5.16 (4.78-5.56)	<.0001	1.48 (1.36-1.62)	<.0001
History of myocardial infarction	2.33 (2.13-2.55)	<.0001	1.18 (1.04-1.35)	0.0101	1.39 (1.23-1.58)	<.0001	1.45 (1.31-1.61)	<.0001	1.04 (0.92-1.18)	0.5676
Chronic Obstructive Pulmonary Disease (COPD)	1.03 (0.96-1.1)	0.4529	1.16 (1.08-1.24)	<.0001	1 (0.92-1.09)	0.9637	1.07 (0.99-1.16)	0.0762	14.03 (12.8-15.37)	<.0001
Diabetes	1 (0.94-1.07)	0.9908	0.79 (0.74-0.85)	<.0001	0.99 (0.91-1.07)	0.7299	1.26 (1.17-1.35)	<.0001	0.6 (0.55-0.65)	<.0001
Rheumatoid arthritis	1.04 (0.87-1.24)	0.6965	1.56 (1.33-1.83)	<.0001	1.01 (0.82-1.26)	0.8981	1.04 (0.85-1.28)	0.7109	1.04 (0.86-1.26)	0.6953
Mental health condition	0.86 (0.81-0.92)	<.0001	1.03 (0.96-1.1)	0.4202	0.92 (0.85-0.99)	0.0209	0.84 (0.78-0.9)	<.0001	0.95 (0.88-1.02)	0.1581
LTC residence	0.15 (0.06-0.38)	<.0001	0.4 (0.28-0.59)	<.0001	0.27 (0.13-0.56)	0.0004	0.29 (0.16-0.53)	<.0001	0.23 (0.11-0.48)	<.0001
Primary care enrollment										
Capitation vs. FFS	0.91 (0.82-1.01)	0.0526	0.84 (0.76-0.94)	0.0128	0.85 (0.75-0.96)	0.0005	0.81 (0.71-0.91)	0.0019	1.08 (0.94-1.24)	0.0606
Enhanced FFS vs. FFS	0.93 (0.83-1.03)	0.1639	0.82 (0.73-0.92)	0.002	0.84 (0.75-0.95)	0.0004	0.81 (0.71-0.91)	0.0028	1.06 (0.92-1.21)	0.0222
Family health team vs. FFS	0.89 (0.8-0.99)	0.0098	0.88 (0.78-0.98)	0.1244	0.85 (0.75-0.96)	0.0006	0.9 (0.8-1.02)	0.5013	1.08 (0.94-1.24)	0.0659
No provider identified vs. FFS	1.06 (0.89-1.27)	0.2201	1.14 (0.94-1.39)	0.0068	1.5 (1.23-1.83)	<.0001	1.46 (1.16-1.84)	<.0001	1.4 (1.09-1.81)	0.0687
Prescription drugs	0.97 (0.96-0.97)	<.0001	0.95 (0.94-0.96)	<.0001	0.94 (0.93-0.95)	<.0001	1.01 (1-1.01)	0.2352	1.05 (1.05-1.06)	<.0001
Emergency department visits	1.05 (1.02-1.08)	0.0008	1.02 (0.99-1.05)	0.2613	1.01 (0.97-1.05)	0.571	0.99 (0.95-1.02)	0.3894	1.07 (1.04-1.1)	<.0001
Visits to general practitioner	0.99 (0.98-0.99)	<.0001	1 (0.99-1.01)	0.8979	1 (0.99-1)	0.1243	1 (0.99-1)	0.7077	0.98 (0.97-0.98)	<.0001
Visits to specialist	0.92 (0.91-0.93)	<.0001	0.93 (0.92-0.93)	<.0001	0.93 (0.93-0.94)	<.0001	0.95 (0.95-0.96)	<.0001	0.94 (0.93-0.95)	<.0001
Visit to a geriatrician	0.60 (0.48-0.75)	<.0001	0.89 (0.76-1.05)	0.1561	0.75 (0.6-0.93)	0.0084	0.61 (0.49-0.75)	<.0001	0.63 (0.49-0.81)	0.0002
Homecare visits										
nursing	0.99 (0.98-1)	0.0035	0.99 (0.98-1)	0.0041	0.99 (0.98-1)	0.0096	0.99 (0.99-1)	0.0756	0.99 (0.99-1)	0.1523
personal support	0.99 (0.99-1)	<.0001	0.99 (0.99-1)	<.0001	1 (0.99-1)	<.0001	0.99 (0.99-1)	<.0001	1 (0.99-1)	<.0001
allied health	0.96 (0.92-1)	0.0522	0.99 (0.96-1.02)	0.6209	0.97 (0.93-1.02)	0.2188	1 (0.97-1.04)	0.9914	1 (0.96-1.04)	0.9425
social	0.82 (0.79-0.84)	<.0001	0.92 (0.91-0.94)	<.0001	0.85 (0.83-0.88)	<.0001	0.92 (0.9-0.94)	<.0001	0.91 (0.89-0.93)	<.0001
C-statistics	0.73		0.75		0.71		0.78		0.85	
C-statistics (cross-validated)	0.73		0.75		0.71		0.78		0.85	

AIM- Acute myocardial infarction
COPD- Chronic Obstructive Pulmonary Disease (COPD)
CHF- Congestive heart failure (CHF)
FFS- fee for service

Appendix 5: Predictive accuracy of the models

The models were able to predict the number of events (i.e., IHs) for subgroups of patients with a high degree of accuracy according to the plots below. This supports a good fit of the models.

A. Index hospitalization – HCU



B. Index hospitalization – non-HCU