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Incremental Healthcare Utilization and Costs Among New Senior High Cost Users in Ontario, Canada: a retrospective matched cohort study

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Incremental Healthcare Utilization and Costs Among New Senior High Cost Users in Ontario, Canada: a retrospective matched cohort study Sergei Muratov¹, Justin Lee^{1,2}, Anne Holbrook^{1,3}, Jason R Guertin^{5,6}, Lawrence Mbuagbaw¹, J Michael Paterson^{6,7}, Tara Gomes^{6,8}, Priscila Pequeno⁶, Jean-Eric Tarride^{1,9} ¹Department of Health Research Methods, Evidence, and Impact, McMaster University, Hamilton, Ontario, Canada ²Division of Geriatric Medicine, Department of Medicine, McMaster University, Hamilton, Ontario, Canada ³Division of Clinical Pharmacology and Toxicology, Department of Medicine, McMaster University, Hamilton, Ontario, Canada ⁴Département de médecine sociale et préventive, Faculté de Médecine, Université Laval, Quebec City, Quebec, Canada ⁵Centre de recherche du CHU de Québec, Université Laval, Axe Santé des Populations et Pratiques Optimales en Santé, Québec City, QC, Canada ⁶ICES, Toronto, Ontario, Canada ⁷Department of Family Medicine, McMaster University, Hamilton, Ontario, Canada ⁸Li Ka Shing Knowledge Institute, St. Michael's Hospital, Toronto, Ontario, Canada ⁹Center for Health Economics and Policy Analysis (CHEPA), McMaster University, Hamilton, Ontario, Canada **Corresponding author:** Sergei Muratov Department of Health Research Methods, Evidence, and Impact, McMaster University 1280 Main Street West, Hamilton, ON L8S 4K1 muratos@mcmaster.ca (905)523-7284 Key words: health policy, health economics, geriatrics medicine Word count (excluding title page, abstract, references, figures and tables): 4038

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Strengths

- This population-based study examines incident (new) senior high-cost users (HCU), which provides important information on the driving factors for HCU status
- Inclusion of all incident senior HCU in the province into the study population allowed us to calculate their monetary impact on the provincial healthcare budget
- This analysis includes a comprehensive spectrum of the most important cost categories that contribute to total public healthcare expenditures in the province

Limitations

- Despite the comprehensiveness of cost analyses, a few of the cost categories may not have been captured in full, e.g. outpatient intravenous chemotherapy
- The findings, especially with respect to the total incremental costs and the budget impact, are only comparable to studies with the same HCU threshold and the choice of cost categories

Authors' contributions:

SM, JET, AH, JL, JMP, TG, LM, JRG conceptualized the study. SM, JET, AH, JL, JRG, LM, JMP, TG, PP have contributed to its design. JMP, PP, TG were instrumental in creating datasets. PP provided assistance with data analysis. SM prepared the initial draft of the manuscript and revised it based on co- authors' feedback: JET, AH, JL, JMP, TG, JRG, LM, PP provided comments to the initial draft, further revisions, read and approved the final manuscript. The responsibility of study implementation lies with the principal investigator (SM) that is supported and supervised primarily by JET.

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Competing Interests:

None declared.

Abstract

Objectives: To describe healthcare use and spending before and on becoming a new (incident) senior HCU compared with senior non-HCUs; to estimate the incremental costs, overall and by service category, attributable to HCU status; and to quantify its monetary impact on the provincial healthcare budget in Ontario, Canada.

Design: We conducted a retrospective, population-based comparative cohort study using administrative healthcare records. Incremental healthcare utilization and costs were determined using the method of recycled predictions allowing adjustment for pre-incident and incident year values, and covariates. Estimated budget impact was computed as the product of the mean annual total incremental cost and the number of senior HCUs.

Participants: Incident senior HCUs were defined as Ontarians aged ≥66 years who were in the top 5% of healthcare cost users during fiscal year 2013 (FY2013) but not during fiscal year 2012 (FY2012). The incident HCU cohort was matched with senior non-HCUs in a ratio of 1:3.

Results: Senior HCUs (n=175,847) reached the annual HCU threshold of \$10,192 through different combinations of incurred costs. Although HCUs had higher healthcare utilization and costs at baseline, HCU status was associated with a substantial spike in both, with prolonged hospitalizations playing a major role. Twelve percent of HCUs reached the HCU expenditure threshold without hospitalization. Compared to non-HCUs (n=527,541), HCUs incurred an additional \$25,527 per patient in total healthcare costs; collectively \$4.5 billion or 9% of the 2013 Ontario healthcare budget. Inpatient care had the highest incremental costs: \$13,427, 53% of the total incremental spending.

Conclusions: Costs attributable to incident senior HCU status accounted for almost one-tenth of the provincial healthcare budget. Prolonged hospitalizations made a major contribution to the total incremental costs. A subgroup of patients that became HCU without hospitalization requires further investigation.

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Introduction

Healthcare spending has more than doubled in the countries of the Organization for Economic Cooperation and Development (OECD) over the past two decades[1]. In Canada, where public health and health care are under provincial jurisdiction, health spending accounts for 37% of the total provincial program spending on average [2]. Much of the spending is disproportionately attributed to a small but heterogenous group of patients, commonly referred to as high-cost healthcare users (HCU)[3-5]. The pressing need to control healthcare spending and the inconclusive evidence and varying success of clinical interventions targeting the HCU group[6, 7] have prompted policy makers to revise their management strategies and to seek specific segments of the HCU population who may benefit from certain interventions more than others[4, 8, 9].

Incident (or new) senior HCUs represent one such segment whose patient care characteristics and spending patterns have not been well studied. A recent systematic review identified 55 studies published over the past two decades that reported HCU characteristics and healthcare utilization[5]. The vast majority (n=42) of the publications originated from the US, 9 were from Canada, 3 were generated by researchers from European countries, and 1 was from Taiwan. Compared to 9 US-based studies of the Medicare (i.e., senior) population, only the study from Taiwan among the others had a specific focus on seniors, even though approximately 45-55% of senior healthcare care resources are reportedly consumed by senior HCUs in various jurisdictions[10-12]. Moreover, these studies do not differentiate between prevalent (who retain the HCU status over years) and incident senior HCUs. This is important, as understanding the path to HCU status may identify opportunities for intervention[4]. Further, it is well known that senior HCUs, both prevalent and incident, generally have poor functional status and consume a high level of healthcare resources, including typically reported acute inpatient care and physician services[7, 13, 14]. However, comprehensive descriptions of cost drivers to HCU status are few[10, 15]. A recent example is a study conducted in Ontario, the largest province in Canada, which presented a system-wide assessment of cost

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concentration among HCUs over 3 years using both longitudinal and cross-sectional approaches to their analysis[10]. While providing valuable information on the transition of patients between various cost strata, their longitudinal analyses focused on the persistence of costs among all HCUs. Their cross-sectional analysis of expenditures by cost category was limited by only reporting on the top 1% of HCUs and was not stratified by age. Another poorly explored aspect of HCU cost analysis is the economic burden associated with HCU status, which remains largely unknown in Canada and elsewhere. While some international studies have compared costs between HCUs and non-HCU cohorts in a particular year using a cross-sectional design[3, 16, 17], these comparative studies did not consider any secular trends over time (e.g. costs in the years before the incident year). This limits our understanding of the true incremental costs of becoming a new HCU, especially among seniors.

We recently reported on a cohort of incident senior HCUs compared to matched non-HCUs to examine regional variation in mortality and costs in Ontario using cross-sectional data[18]. Here we aim to determine the incremental healthcare utilization and costs among new senior HCUs in Ontario by looking at the same data longitudinally. The main objectives of this study were to 1) describe healthcare use and spending before and on becoming a senior HCU compared with senior non-HCUs; 2) estimate costs and healthcare use attributable to the incident senior HCU status, and to 3) quantify the monetary impact of incident senior HCUs on the provincial healthcare budget.

Methods

Ethics Approval

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

Study design

We conducted a retrospective population-based matched cohort study using administrative healthcare data from Ontario, Canada. The protocol for this research has been published[19].

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Ontario is Canada's most populous province, with almost 14 million residents (approximately 40% of the Canadian population)[20]. The Ontario Ministry of Health and Long-Term Care (MOHLTC) pays for approximately 70% of health care provided in the province. This includes nearly 100% of hospital care, physician services, and prescription drugs for seniors[21]. Contribution to other services (e.g., long-term care) may be less[19].

We used 2 years of linked administrative data. The Ontario government fiscal year 2013 (April 1, 2013 and March 31, 2014) was considered the incident year (FY2013). Fiscal year 2012 (FY2012: April 1, 2012 and March 31, 2013) was the baseline or pre-incident year. A patient-level dataset was created by linking 19 health administrative databases[19] using unique encoded identifiers at ICES (www.ices.on.ca). ICES is an independent, non-profit research corporation funded by the Ontario MOHLTC.

Study population

Incident senior HCUs were defined as individuals aged 66 years or above with annual total healthcare expenditures within the top 5% threshold of all Ontarians in FY2013, who were not in the top 5% in FY2012. The 5% threshold is commonly reported in HCU studies in Canada and elsewhere[10, 14, 22, 23]. The >66 year age threshold was applied to capture Ontario Drug Benefit (ODB) expenditures for at least one year before the incident year: ODB coverage starts automatically when Ontarians reach 65 years of age[24]. The "non-HCU" cohort included those whose annual total health care expenditures in FY2012 and FY2013 were below the top 5% threshold in both years. The incident HCU cohort was matched with non-HCU in a ratio of 1:3 according to age at cohort entry (+/- 1 month), sex and Local Health Integration Network (LHIN) of patient residence. LHINS, Ontario's 14 regional health districts, are responsible for the planning and administration of most of hospital- and community-based health services delivered within their geographic boundaries[25].

Variables

Our dataset included key information on socio-demographic and health status, healthcare utilization and costs. Described in the study protocol[19] in more detail, key variables are briefly summarized below.

Socio-demographic status included age, sex, low income status, and geography of residence (urban/suburban/rural). Low income status was based upon net household income reported to receive ODB subsidy in FY2012. Rurality was based on the Rurality Index for Ontario (RIO) which is a scale from 0 to 100. A RIO between 0 and 9 defined an individual from the urban area, between 10 and 40 described a suburban resident, and a resident from a rural area had a RIO score of 40 and above[26].

Health status was assessed using several variables. We used two tools derived from Johns Hopkins Adjusted Clinical Groups (ACG[®]) System, Version 10, a case-mix methodology to describe a population's healthcare utilization[27]. First, the general degree of comorbidity was captured by the number of Johns Hopkins Aggregated Diagnosis Groups (ADGs): person-focused, diagnosis-based method to measure patients' illness by assigning individual ACGs into diagnosis clusters[28]. A higher number of ADGs per patient indicates a greater burden of illness. In addition, we identified the proportion of patients with a history of hypertension, malignancy, and mental health condition using John Hopkins Expanded Diagnosis Clusters (EDCs). For each condition, we checked whether the patient was diagnosed with the condition in the 3 years prior to FY2013. Finally, we used validated administrative data case definitions to identify whether the patient had a history of several common chronic diseases, including congestive heart failure, diabetes, and chronic obstructive pulmonary disease[29, 30].

Whereas socio-demographic characteristics and health status were captured at baseline, healthcare utilization and expenditures were obtained for the full two years of study. Utilization variables included the number of hospitalizations (all, elective and unplanned), emergency department (ED) visits, physician encounters, and publicly-funded home care services. Home care services were subclassified by type of

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service: nursing, personal support, and allied health. For each hospitalization, we obtained the total length of stay (TLOS), in days.

Health care expenditures were estimated using ICES person-level health utilization costing algorithms,[31] which report expenditures according to twelve health service cost categories. Hospital costs were the sum of costs associated with acute inpatient care and same-day surgery. Mental health admissions were costed separately. Physician expenditures were the sum of fee-for-service billings and capitation payments. Costs were expressed in 2013 Canadian Dollars.

Outcomes

The primary outcome measures were 1) one-year incremental healthcare utilization for hospital admissions (total and by types such as unplanned and elective), emergency visits, physician encounters (total and separately for specialists and general practitioners [GP]), and home care services (total and by type); 2) one-year incremental costs attributable to becoming an HCU (total healthcare expenditures and by cost category); and 3) provincial budget impact of new senior HCUs in FY2013. Incremental healthcare use and costs were calculated as the difference between the two cohorts over time.

Statistical analysis

Baseline patient socio-demographic and health status characteristics of the two cohorts in FY2012 were compared using the absolute standardised difference (aSD), with aSD>0.1 indicating a meaningful difference[32]. We then described the HCU cohort in the context of cost categories and their contribution to the HCU status by calculating the proportion (%) of HCU in each cost category. Since we expected hospitalizations to be a frequent cause of new HCU status, we repeated this analysis for HCUs who were not hospitalized during the incident year to evaluate the contributions of cost drivers other than hospital admission. This was followed by a longitudinal comparison of the unadjusted healthcare use and costs in both cohorts for both the incident year and the preceding year.

Incremental healthcare use and costs were estimated using the recycled predictions method [33-36]. Commonly used to evaluate the marginal effect of a covariate on the response variable, the method uses fitted regression models to predict incremental values of the outcomes in two hypothetical populations: one where all subjects are HCU and another where all are non-HCU, all the other covariates being the same. The difference in predicted means between the two populations indicates the incremental value. The method allows for correlation between outcome values in the year before the index year (FY2012) and after the index year (FY2013), while comparing HCU with non-HCU. Confidence intervals (CI) of the incremental values was obtained through the percentile method: random bootstrap resampling with 1000 iterations created a distribution where the 2.5th and 97.5th percentiles were the 95% lower and upper bound Cls, respectively [36].

We used generalized linear regression to model the study outcomes. Costs were modeled with gamma distribution and log-link function to handle the right-skewed data[37, 38]. The choice of gamma distribution was confirmed by the modified Park test[39]. For count data (e.g., hospital admissions or home care visits), a negative binomial (NB) distribution was specified as the leading option to better account for overdispersion (i.e., observed variance is greater than the assumed variance)[40, 41]. In cases of a NB model not converging, Poisson distribution was used. For both costs and count data, we used two-part models (Hurdle regression) to manage zero values in the response variables: the first part used a logistic regression to predict the probability of positive values of the outcome, while a gamma or a negative binomial model was applied in the second stage for positive costs and counts, respectively[40, 42]. All the models were adjusted for previous resource use (e.g., costs or healthcare use in FY2012), age, sex, ADGs, and low-income status. Because our dataset included all senior HCU subjects in the province at the time of the study, we were able to estimate the total provincial public healthcare expenditures attributable to HCU status among Ontario seniors by multiplying the total incremental costs by the total number of senior HCU. Statistical analyses were conducted using SAS version 9.4.3 (SAS Institute Inc., Cary, NC).

Results

Patient characteristics

The total study population consisted of 703,388 seniors, of which 175,847 were incident HCUs. This population of incident HCUs represents 46% of all HCUs in FY2013 (n= 383,257) but only 9.4% of the Ontario senior population and 1.4% of the total population in the province[20]. As expected, the mean ages of the HCU and non-HCU cohorts were identical at 77.7 years (standard deviation (SD) 7.7); 53% were women; and most resided in suburban areas (12.2 vs. 11.8, aSD=0.02) (Table 1). Compared to non-HCUs, HCUs had poorer health status as defined by both the number of aggregated diagnosis groups (10.2 vs. 7.9, aSD=0.54) and higher prevalence of chronic diseases. A relatively greater percentage of HCU cohort members had a primary care provider (97% vs. 88.6%, aSD=0.33).

Table 1 Patient characteristics

Characteristic	HCU (N=175,847)	Non-HCU (N=527,541)	aSD
Socio-demographics	· L .		
Age, mean (SD), yr	77.7 ± 7.7	77.7 ± 7.7	0
Sex, female	93,119 (53%)	248,040 (47.0%)	0
Rural Index of Ontario score, mean (SD)	12.2 ± 18.2	11.8 ± 18.2	0.02
Low income	31,843 (18.1%)	92,566 (17.5%)	0.01
Health Status			
# Adjusted Diagnostic Groups, mean (SD)	10.2 ± 4.0	7.9 ± 4.5	0.54
Hypertension ^{\$}	110,692 (63.0%)	282,867 (53.6%)	0.19
Congestive Heart Failure [#]	25,195 (14.3%)	36,877 (7.0%)	0.24
Chronic Obstructive Disease Pulmonary#	48,738 (27.7%)	96,513 (18.3%)	0.23
Diabetes [#]	62,014 (35.3%)	138,794 (26.3%)	0.2
Myocardial infarction [#]	12,892 (7.3%)	24,024 (4.6%)	0.12
Rheumatoid Arthritis [#]	5,607 (3.2%)	9,334 (1.8%)	0.09
Malignancy ^{\$}	56,855 (32.3%)	123,932 (23.5%)	0.2
Mental Health condition ^{\$}	67,441 (38.4%)	144,377 (27.4%)	0.24
\$- constructed based on Expanded Diagnosis	Codes		
#- ICES-derived cohort			
SD- standard deviation; aSD- absolute standa difference between admitted and non-admit		SD > 0.1 indicating meani	ngful

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HCU status

The 5% HCU status threshold for this study was \$10,192. As shown in Figure 1, patients could become HCU through different combinations of incurred costs. Approximately 40% of the HCU became a HCU (i.e., incurred at least \$10,192 in total annual healthcare expenditures) due to a single cost category, predominantly hospital admissions (70.1%). For 13% of the HCUs, more than one cost category was above the threshold (e.g., hospital admission and rehabilitation costs). Among the remaining 47%, no single cost category was sufficient to meet the expenditure threshold for HCU status: HCU status was achieved through expenditures in several cost categories. In this case, the most common contributing categories were physician compensation, drug benefits, and hospitalization.

As many as 11.7% (N=20,501) of the HCU were not hospitalized during the incident year (Appendix 1). Their new HCU status was mainly due to a combination of physician compensation (99.8%), ODB (99.4%), and laboratory test costs (87.3%), home care (54.1%) and emergency department visits (45.3%). Of note, some of the patients within several cost categories had costs high enough for the patient to become a HCU. Examples include 72.3% of patients in long-term care, 63.4% of patients with cancer care, and 19.1% of patients with drug costs.

Dynamics of change in healthcare use and costs

Analysis of observed healthcare utilization in the two cohorts identifies an upward trajectory in health services consumption among senior HCU. As shown in Figure 2, compared to non-HCU, the HCU consumed more services in the pre-incident year across all care categories: physician encounters (mean per patient: 15.4 vs. 10.1, aSD=0.55), home care visits (mean per patient: 7.7 vs. 1.8; aSD=0.24), emergency department (ED) visits (mean per patient: 0.6 vs. 0.3; aSD=0.26), and hospital admissions (mean per patient: 0.04 vs. 0.02; aSD=0.08). This was followed by a dramatic increase in healthcare use among senior HCU during FY2013, while the service consumption among non-HCU remained relatively unchanged.

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Similarly, the total public healthcare expenditures among senior HCU were higher in the pre-incident year compared to non-HCU (mean per patient: \$4,166 vs. \$2,372, aSD=0.74), followed by a substantial spike during the incident year (\$29,784 vs. \$2,471; aSD=1.33) (Figure 3). While the major drivers of total costs were analogous in the two cohorts in the year before (in descending order: drug benefits, physician costs, hospital admissions or home care), the top contributors in the HCU cohort changed during the incident year. With an annual mean of 1.07 of hospital admissions (mean TLOS: 8.8 (SD 14.8)) among senior HCU compared to a mean of 0.03 admissions (mean TLOS: 2.8 (SD 9.6)) for non-HCUs in FY2013, prolonged hospitalizations were the major driver of total healthcare expenditures (\$13, 558) in the incident year. These were followed by physician (\$4,214) and ODB costs (\$2,456). Categories such as rehabilitation, complex continuing care, dialysis, and mental health admissions were almost exclusively associated with the HCU status. Little change in the list of major cost drivers and the trajectory of costs over time was noticeable among non-HCU seniors. More detail is provided in Appendices 2 and 3.

Incremental costs and healthcare use

Table 2 shows the magnitude of incremental healthcare use by senior HCU during the incident year adjusting for the pre-incident values and other covariates. Compared to the year before becoming an HCU, unplanned hospitalizations accounted for 74% of all incremental admissions at an additional mean of 0.77 hospitalizations per HCU (95%CI: 0.77-0.78) annually. Similarly, specialist visits constituted 75% of the incremental physician encounters at an additional mean of 22.8 visits (95%CI: 22.7-22.9), whereas personal support worker visits contributed the most to the incremental home care use at additional mean of 15.6 visits (95%CI: 15.3-15.9) per HCU patient.

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Healthcare type	Annual incremental utilization,
	mean (95% CI)
Hospital admission, All	1.04 (1.04 -1.05)
Hospital admission, elective	0.29 (0.29 -0.3)
Hospital admission, unplanned	0.77 (0.77 -0.78)
Emergency department visits	1.4 (1.4 -1.4)
Physician visits, All	32.1 (31.9 -32.3)
General practitioner visits	9.3 (8.7 -9.5)
Specialist visits	22.8 (22.7 -22.9)
Home care services, All*	25.1 (24.4 -25.7)
Personal support	15.6 (15.3 -15.9)
Nursing	5.3 (4.9 -6.0)
Allied	1.5 (1.5 -1.6)
Other*#	2.8 (2.7 -2.9)

Table 2: Incremental healthcare use associated with HCU status, by healthcare type

* - fit using Poisson distribution; all other are fit using Negative Binomial *- "Other" includes social services, case management, and respite care

Annual incremental utilization is an additional mean number of services received by a HCU in the incident year compared with a non-HCU and the baseline year

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The total annual mean adjusted costs attributable to HCU status were \$25,527 (95%CI: \$25,383 - \$25,670) (Table 3), with hospital admissions being by far the major contributor at an additional mean of \$13,428 (95%CI: \$13,333 - \$13,533) per HCU. Details of the regression analyses are provided in Appendices 4-5. Given the size of the senior incident HCU population (n=175,847), the estimated provincial budget impact of the senior incident HCU status was \$4.5 billion (CAD). This accounts for approximately 9% of the 2013 total provincial healthcare expenditures (\$51 billion)[43].

Cost component	Annual incremental costs*,
	mean (95% CI)
Hospital admission	\$ 13,428 (13,334 -13,534)
Physicians	\$ 3,150 (3,134 -3,168)
Outpatient Drug Benefits	\$ 1,493 (1,462 -1,523)
Rehabilitation	\$ 1,430 (1,392 -1,467)
Home care	\$ 1,363 (1,347 -1,378)
Cancer care	\$ 1,226 (1,200 -1,253)
Complex continuing care	\$ 1,213 (1,168 -1,257)
Long-term care	\$ 1,021 (995 -1,046)
Emergency department	\$ 684 (679 -687)
Mental health admissions	\$ 258 (238 -278)
Dialysis	\$ 89 (79 -99)
Laboratory tests	\$ 51 (50 -52)
Fotal incremental cost	\$ 25,527 (25,383 -25,670)

Annual incremental costs are additional mean expenditures incurred by a HCU in the incident year compared with a non-HCU and the baseline year

Discussion

The study has examined a cohort of new senior HCU patients compared with matched non-HCUs focusing on the absolute and incremental comparative healthcare use and expenditures before and after HCU conversion. We determined that although senior HCUs were already on an upward trajectory during the year before HCU status, showing higher healthcare utilization and costs in the pre-incident year, the HCU status was associated with a spike in healthcare expenditures. We found that seniors became HCU through incurring costs in various combinations, although half of the senior HCU could reach the HCU status by incurring costs from only one or two categories reaching the threshold, mainly prolonged hospitalization. Approximately 12% of HCUs who had no hospitalization in the incident year achieved HCU status through incurring a combination of predominantly physician, ODB, and laboratory test costs. Compared to non-HCU, senior HCU incurred an additional \$25,527 per patient in total incremental public healthcare expenditures and cost almost one-tenth of the provincial budget in the incident year. Hospitalizations, physician compensation and ODB were responsible for the highest incremental costs.

This study fills a current gap in the HCU economic literature, especially Canadian HCU studies where few of them have focused on seniors or used a comparative group of non-HCUs. Also, as opposed to crosssectional studies that are common in the area of HCU research, we were able to capture the economic burden attributable to HCU status among senior Ontarians using longitudinal data. Our approach of the recycled predictions has allowed us to compare the healthcare use and costs between HCUs and a matched cohort of non-HCUs while taking account of the correlation between the pre- and post values, managing excessive zero values by developing two-part models, and adjusting for confounding by including important socio-demographic and health status covariates in the models. Another option we considered was the difference in differences (DID) estimator[44, 45]. Frequently employed by economists to assess the impact of introducing a policy or a change in the system, its use is however conditional on two major assumptions that need to be met: parallel trends and no group variation at baseline. While the latter could be dealt with using statistical adjustment, the former assumes that trajectories in outcomes (i.e., costs and use) between the groups are the same prior to the exposure (i.e., HCU conversion). Because we only had access to one year of data prior to the incident year (i.e., the baseline year) by design, it was not possible to determine the trajectories between the cohorts.

Consistent with 9 studies of senior HCUs identified by Wammes et al., our results confirm the high burden of common conditions among senior HCUs, the important impact of inpatient care costs, the increasing role of home and long-term care in the HCU cost profile. Some studies also mention non-hospitalized senior HCUs without providing their detailed description[10, 46]. Our findings are however challenging to compare with these for several reasons. First, in addition to the incremental values, we provide a comprehensive assessment of costs and healthcare utilization for a specific segment of the HCU population: senior incident cases. To our knowledge, no other studies have examined this specific patient population, especially in such detail[5]. Second, as Wammes et el show, the HCU threshold used in the US and other countries (e.g., Denmark and Germany) is often 10%, while Canadian studies commonly apply the 5% threshold[5]. Third,

the spectrum of cost categories included in analysis may vary between countries and even provinces in Canada. Prescription drug costs, for example, the source of one of the highest incremental values in our study, were not covered by the US Medicare program (which covers senior patients) until 2003, although the launch of a fully developed program was delayed until mid-2000s[47, 48], limiting the comparability of earlier studies that relied only on Medicare payments[11, 23, 49]. In this respect, our efforts to standardize cost analyses by using a costing methodology that allows obtaining patient-level expenditures from multiple sources in one standard way is a step toward higher comparability of future studies.

Strengths and limitations

Our study has several strengths. First, the study is population-based, including all incident senior HCU in the province. Second, the study examines incident HCU, which provides important information on the driving factors for HCU status. Third, we included a comprehensive spectrum of the most important cost categories that contribute to total public healthcare expenditures in the province.

The study also has important limitations. The nature of methodology applied to calculate the costs was different across various cost categories. As opposed to the nominal costs per visit (e.g., physician or home care) or prescription claim, some of the costs were estimations, e.g. a provincial average cost per case of inpatient care weighted for resource intensity[50]. However, when used for comparisons at a provincial level, these estimations are considered acceptable[50]. Also, despite our comprehensive coverage of cost categories, some public healthcare expenditures are not accounted for. Examples include community services (e.g., community services for elderly) and public health costs. In addition, a few of the cost categories included the analysis may not be captured in full. Most notably, we did not have access to the costs of outpatient intravenous chemotherapy, which can be costly[51]. Despite these limitations, it is unlikely that the unaccounted costs for individual healthcare services amount to more than 5-8% of total public expenditures on healthcare[10, 52]. At the same time, the true hospitalization expenses may be

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underestimated as physician billings for inpatient services are currently captured by a separate cost category which makes our estimates of the hospital costs conservative. Finally, different HCU threshold may yield different estimations of the incremental costs. Although ours is the most commonly used HCU threshold in Canada[5], our findings are largely comparable to studies with the same threshold and the choice of cost categories.

Despite these limitations, our findings have policy and research implications. There is currently no clear internationally accepted definition of the HCU[7]. They are also referred to by many names (e.g., heavy, frequent or high needs users) that are used interchangeably with HCU[7]. However, our data shows that frequent users of healthcare may not be synonymous with high-cost users of healthcare and both need to be distinguished. One prolonged hospital stay, for example, can drive a senior patient to become a HCU. Although interventions have been introduced to either prevent or divert such hospitalizations, their success is unclear[7]. Further efforts are needed to examine predictors at the pre-hospital level and to identify actionable cost drivers during admission. At the same time, more than one tenth of senior HCUs had no hospital costs. The latter subset of HCUs requires further investigation. Reducing ODB expenditures by exploring pharmaceutical policy or pricing strategies (e.g. generic drug tendering) stands out as a promising but challenging area to achieve potential cost reductions [53]. Canada has recently made steps to alleviate the burden of drug costs by negotiating lower prices of generic and non-generic drugs with manufacturers[54]. Although there may be room for further savings among generic drugs[55], these may be offset by the growing share of expensive biologics coupled with just a modest uptake of biosimilars[56]. Finally, future cost analysis of senior HCUs could benefit from greater data granularity. Following a patient by type of care received in the incident year, for example, it may be possible to more precisely identify the point of HCU conversion, differentiate between outpatient and inpatient costs that contribute to it, and allocate costs more precisely.

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Costs attributable to incident senior HCU status accounted for almost one-tenth of the provincial budget. Prolonged hospitalizations made a major contribution to the total incremental costs. However, categories such as physician billings, drug benefits and other, in various combinations, also were important. A subgroup of patients that became HCU without hospitalization requires further investigation.

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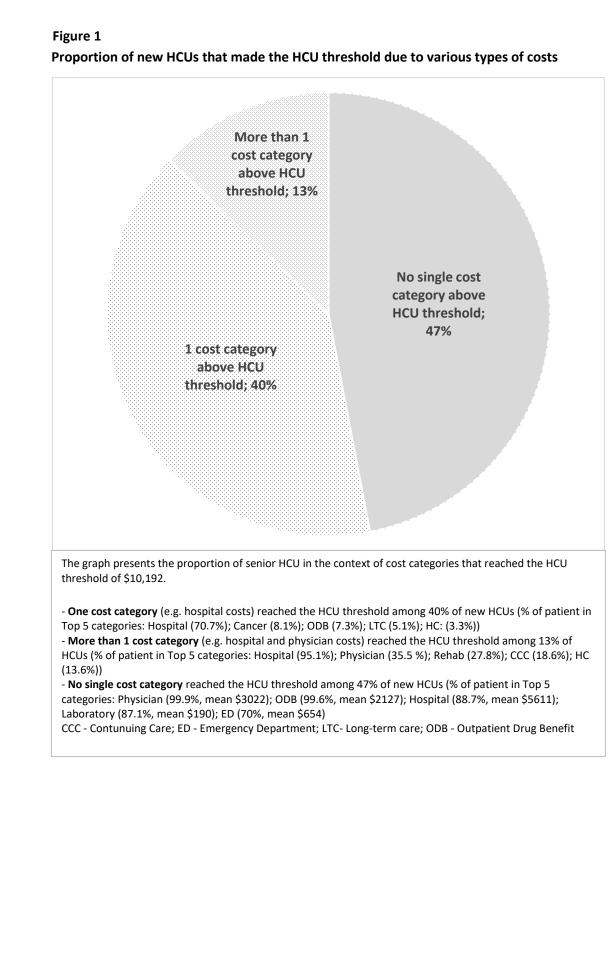


Figure 2

Dynamics of change in annual healthcare use, before (baseline) and during incident year, by HCU status and cost categories (mean per patient)

n	ion-HCU	НСО
Physician visits, ALL, baseline yr	10.1	15.4
incident yr	10.0	4
General practitioner, baseline yr	5.6	8.0
incident yr	5.5	16.1
Specialist, baseline yr	4.4	7.4
incident yr	4.5	29.5
Home care services, ALL, baseline yr	1.8	7.7
incident yr	2.5	33.3
Personal support, baseline yr	1.5	6.4
incident yr	1.9	22.6
Nursing, baseline yr	0.2 0.5	5
incident yr	0.2	5.6
Allied, baseline yr	0.1 0.2	
incident yr	0.2 1	.8
Other, baseline yr	0.1 0.6	5
incident yr	0.2	3.2
Emergency department visits, baseline yr	0.3 0.6	5
incident yr	0.3	.9
Hospital admission, ALL, baseline yr	0.02 0.0	3
incident yr	0.02 1.	1
Unplanned, baseline yr	0.02 0.0	3
incident yr	0.02 0.3	8
Elective, baseline yr	0.00	0
incident yr	0.00 0.3	3

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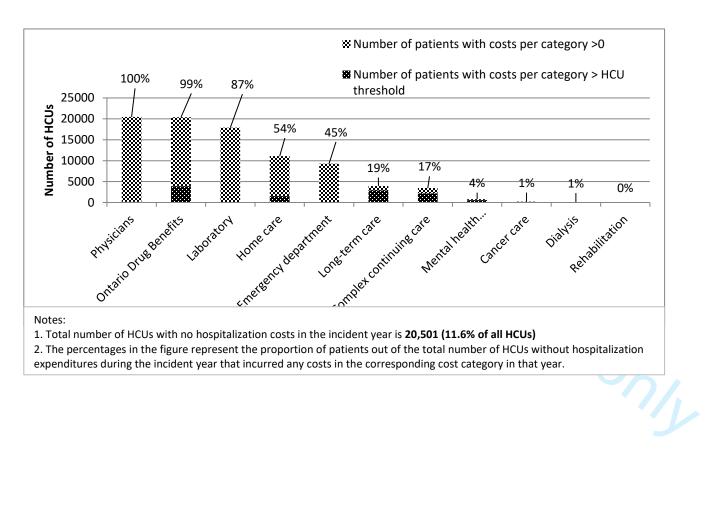
Figure 3

Dynamics of change in annual healthcare care expenditures before and after index year, by HCU status and cost categories (annual, mean per patient)

тс	non-HCU DTAL COSTS per patient, mean: Baseline year: \$2,372	HCU TOTAL COSTS per patient, mean: Baseline year: \$4,166 Incident year: \$29,784
Hospital admission, baseline	\$214	\$317
incident	\$224	\$13,55
Physicians, baseline	\$760	\$1,136
incident	\$786	\$4,214
Ontario Drug Benefits, baseline	\$823	\$1,496
incident	\$854	\$2,456
Home care, baseline	\$90	\$340
incident	\$125	\$1,765
Rehabilitation, baseline	\$0	\$1
incident	\$0	\$1,376
Cancer, baseline	\$3	\$14
incident	\$4	\$1,257
Complex continuing care, baseline	\$0	\$0
incident	\$0	\$1,114
Long-term care, baseline	\$1	\$10
incident	\$2	\$1,003
Emergency department, baseline	\$84	\$161
incident	\$95	\$856
Mental health admissions, baseline	\$0	\$1
incident	\$0	\$255
Laboratory, baseline	\$101	\$148
incident	\$103	\$186
Dialysis, baseline	\$0	\$1
incident	\$0	\$104

Appendix 1

HCUs with no hospitalization costs during incident year: contribution of cost categories





Appendix 2

		on-neos by pre-	incident a	ind incident year		
Cost components	FY20 (pre-incid			FY20 (inciden		
	HCU N=175847	Non-HCU N=527541		HCU N=175847	Non-HCU N=527541	aS
	Mean, \$ (SD)	Mean, \$ (SD)	aSD	Mean, \$ (SD)	Mean, \$ (SD)	aS
Cancer clinics	14 (196)	4 (90)	0.54	1258 (5234)	4 (92)	0.9
Complex continuing care	1 (36)	1 (17)	0.50	1114 (7685)	1 (24)	0.9
Dialysis	2 (40)	1 (15)	0.31	104 (2166)	1 (12)	0.5
Emergency department	162 (327)	84 (226)	0.13	857 (881)	96 (249)	0.6
Home care	341 (1023)	90 (498)	0.28	1765 (3667)	125 (589)	0.2
Hospital admission	318 (864)	215 (714)	0.33	13558 (20529)	225 (743)	0.3
Laboratory	149 (160)	102 (123)	0.07	187 (192)	104 (125)	0.2
Long-term care	11 (192)	1 (45)	0.07	1003 (4800)	3 (91)	0.2
Mental health admissions	1 (60)	1 (33)	0.03	256 (3924)	1 (29)	1.1
Outpatient Drug Benefits	1497 (1441)	824 (1002)	0.01	2456 (3822)	854 (1052)	0.0
Physicians	1136 (821)	761 (671)	0.01	4215 (3217)	787 (694)	0.5
Rehabilitation	1 (41)	1 (33)	0.01	1376 (6792)	1 (20)	0.0
Total cost	4167 (2664)	2372 (2166)	0.74	29785 (29029)	2471 (2252)	1.3
aSD- absolute standardized difference; FY- fiscal year	·					
						0.0

Appendix 3

5 Appendix 3 Description of healthcare use amo	ng HCUs and non	-HCUs by pre- ind	BMJ Ope			136/bmjopen-2018-028637
Cost components	FY20 (pre-incide)12		ہ FY20 (inciden		on 28
	HCU N=175847	Non-HCU N=527541		HCU N=175847	Non-HCU N=527541	aSD:
	Mean (SD)	Mean (SD)	aSD	Mean (SD)	Mean (SD)	aSD
Hospital admission, All	0.04 ± 0.18	0.02 ± 0.14	0.08	1.07 ± 0.87	0.03 ± 0.15	1.63
Elective	0.01 ± 0.07	0.01 ± 0.07	0.01	0.3 ± 0.51	0.01 ± 0.07	0.8 1.28 0.99
Unplanned	0.03 ± 0.17	0.02 ± 0.13	0.08	0.8 ± 0.89	0.02 ± 0.14	1.28
Emergency department visits	0.56 ± 1.13	0.31 ± 0.8	0.26	1.88 ± 2.2	0.32 ± 0.82	0.9
Physician visits, All	15.43 ± 10.69	10.06 ± 8.9	0.55	45.62 ± 32.55	10.03 ± 8.98	1.49
General practitioner	8.03 ± 6.8	5.64 ± 5.59	0.39	16.08 ± 14.74	5.48 ± 5.56	0.9
Specialist	7.4 ± 6.65	4.43 ± 5.13	0.5	29.55 ± 25.97	4.55 ± 5.24	1.3
Home care services, All	7.74 ± 31.92	1.81 ± 14.15	0.24	33.27 ± 82.17	2.47 ± 17.33	0.5
Personal support	0.54 ± 4.03	0.16 ± 2.00	0.12	5.60 ± 18.59	0.20 ± 2.26	0.4
Nursing	6.44 ± 30.59	1.46 ± 13.53	0.21	22.62 ± 73.93	1.91 ± 16.39	0.3
Allied	0.18 ± 0.99	0.05 ± 0.52	0.17	1.82 ± 4.27	0.15 ± 1.41	0.52
Other	0.58 ± 2.30	0.14 ± 0.96	0.25	3.22 ± 5.23	0.21 ± 1.09	0.8 0.8

FY- fiscal year

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Appendix 4

Regression coefficients, recycled prediction, costs

									BN	IJ Oper	I						136/bmjopen-2018-028637				Ρ
Appendix 4																	2018				
Regression coef	fficient	s. rec	vcled p	redicti	on. co	osts											-0286				
		,	,p		,												637 on				
Corre estas avies	1																28				
Care categories Covariates	Hospit	al admis	ssion		Physicia	in		Homeca	re	Ontari	io Drug	benefits		imerger epartm		M	ental he admissio	alth on		Total	
	Coeff	SE	P- value	Coeff	SE	P- value	Coeff	SE	P- value	Coeff	SE	P- value	Coeff	SE	P- value	Coeff	ber#20	P- value	Coeff	SE	P- value
p(costs)=0; Intercept	1.03	0.04	<.0001	-3.52	0.08	<.0001	9.30	0.05	<.0001	-1.85	0.06	<.0001	3.91	0.03	<.0001	5.94	019 0.32	<.0001	-4.95	0.09	<.000
HCU status	-3.79	0.01	<.0001	-5.16	0.15	<.0001	-3.13	0.01	<.0001	-2.25	0.03	<.0001	-2.39	0.01	<.0001	-5.16	OVASII0	<.0001	- 13.88	14.60	0.34
Cost pre	0.00	0.00	<.0001	-0.01	0.00	<.0001	0.00	0.00	<.0001	-0.01	0.00	<.0001	0.00	0.00	<.0001	0.00	0 2000 000	<.0001	-0.01	0.00	<.000
ADG	-0.09	0.00	<.0001	-0.38	0.00	<.0001	-0.04	0.00	<.0001	-0.34	0.00	<.0001	-0.09	0.00	<.0001	-0.01	fr@01	0.214	-0.47	0.01	<.000
Age	0.02	0.00	<.0001	0.06	0.00	<.0001	-0.08	0.00	<.0001	0.04	0.00	<.0001	-0.02	0.00	<.0001	0.05		<.0001	0.08	0.00	<.000
Sex	-0.22	0.01	<.0001	0.13	0.02	<.0001	0.34	0.01	<.0001	0.20	0.01	<.0001	0.04	0.01	<.0001	0.19		0	0.10	0.02	<.000
Low income	0.18	0.01	<.0001	0.05	0.02	0.011	-0.06	0.01	<.0001	0.59	0.02	<.0001	-0.03	0.01	<.0001	-0.18	0 0 0 0	0.003	0.32	0.02	<.00
p(costs)>0; Intercept	6.73	0.02	<.0001	6.26	0.01	<.0001	6.17	0.03	<.0001	5.41	0.01	<.0001	5.46	0.02	<.0001	7.82	<u>,</u> 0,28	<.0001	6.51	0.01	<.00
HCU status	2.27	0.00	<.0001	1.53	0.00	<.0001	0.76	0.01	<.0001	0.79	0.00	<.0001	0.88	0.00	<.0001	1.82	9 16	<.0001	2.34	0.00	<.00
Cost pre	0.00	0.00	<.0001	0.00	0.00	<.0001	0.00	0.00	<.0001	0.00	0.00	<.0001	0.00	0.00	<.0001	0.00		0.37	0.00	0.00	<.00
ADG	-0.02	0.00	<.0001	0.03	0.00	<.0001	-0.01	0.00	<.0001	0.02	0.00	<.0001	0.01	0.00	<.0001	-0.02	201 201	<.0001	0.03	0.00	<.00
Age	0.01	0.00	<.0001	0.00	0.00	<.0001	0.01	0.00	<.0001	0.01	0.00	<.0001	0.01	0.00	<.0001	0.01	24gy	0.002	0.01	0.00	<.00
Sex	0.08	0.00	<.0001	0.05	0.00	<.0001	0.00	0.01	0.727	0.03	0.00	<.0001	0.02	0.00	<.0001	0.01	gues	0.882	0.04	0.00	<.00
Low income	0.02	0.01	0	-0.03	0.00	<.0001	0.00	0.01	0.749	0.09	0.00	<.0001	0.04	0.00	<.0001	0.07	:- 0205 0	0.214	0.04	0.00	<.00
log_theta	0.36	0.00	<.0001	0.79	0.00	<.0001	0.34	0.00	<.0001	0.15	0.00	<.0001	0.84	0.00	<.0001	0.24		<.0001	0.58	0.00	<.000
ADG- Aggregate	e Diagn	osis G	iroup; C	coeff- r	egres	sion coe	efficier	nt; HC	U- high	-cost u	ser; S	E- stanc	lard er	ror			by copyright.				

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 Regression coefficients, recycled prediction, costs (CONT)

Care categories Covariates	Lab			Dialysis			Cancer care			Long-term care			Continuing complex care			Rehab		
	Coeff	SE	P-value	Coeff	SE	P-value	Coeff	SE	P-value	Coeff	SE	P-value	Coeff	SE 2	P-value	Coeff	SE	P-valu
p(costs)=0; Intercept	- 0.72	0.03	<.0001	7.03	0.33	<.0001	1.96	0.09	<.0001	15.60	0.13	<.0001	15.32	0.23	.0001	13.08	0.23	<.00
HCU status	- 0.52	0.01	<.0001	-2.14	0.07	<.0001	-3.29	0.02	<.0001	-4.60	0.05	<.0001	-6.87	0.19	. <.0001	-7.59	0.21	<.00
Cost pre	- 0.01	0.00	<.0001	-0.03	0.00	<.0001	0.00	0.00	<.0001	0.00	0.00	<.0001	0.00	0.00	<.0001	0.00	0.00	<.00
ADG	- 0.15	0.00	<.0001	-0.04	0.01	<.0001	0.01	0.00	0	0.03	0.00	<.0001	0.04	0.00	<.0001	0.02	0.00	<.00
Age	0.02	0.00	<.0001	0.02	0.00	<.0001	0.05	0.00	<.0001	-0.11	0.00	<.0001	-0.07	0.00	<.0001	-0.04	0.00	<.00
Sex	0.05	0.01	<.0001	-0.60	0.06	<.0001	-0.11	0.02	<.0001	0.42	0.02	<.0001	0.13	0.02	· <.0001	0.26	0.02	<.00
Low income	0.08	0.01	<.0001	-0.39	0.07	<.0001	0.22	0.02	<.0001	-0.11	0.02	<.0001	-0.01	0.03	0.763	0.02	0.02	0.36
p(costs)>0; Intercept	4.41	0.01	<.0001	6.22	0.44	<.0001	8.30	0.10	<.0001	7.54	0.10	<.0001	7.15	0.23	.0001	7.54	0.19	<.00
HCU status	0.30	0.00	<.0001	3.99	0.08	<.0001	2.76	0.02	<.0001	1.81	0.04	<.0001	2.47	0.19	<.0001	1.74	0.18	<.00
Cost pre	0.00	0.00	<.0001	0.00	0.00	0.792	0.00	0.00	<.0001	0.00	0.00	<.0001	0.00	0.00	0	0.00	0.00	0.4
ADG	0.01	0.00	<.0001	-0.05	0.01	<.0001	-0.01	0.00	<.0001	-0.01	0.00	<.0001	-0.01	0.00	0.05	0.00	0.00	0.14
Age	0.00	0.00	<.0001	0.00	0.01	0.958	-0.02	0.00	<.0001	0.01	0.00	<.0001	0.01	0.00 + C	<.0001	0.01	0.00	<.00
Sex	0.02	0.00	<.0001	-0.04	0.07	0.547	0.12	0.02	<.0001	-0.06	0.02	0.001	-0.01	0.02	0.665	0.10	0.02	<.00
Low income	0.03	0.00	<.0001	-0.33	0.08	<.0001	-0.07	0.02	0.003	-0.02	0.02	0.174	0.01	0.03 -	0.652	0.02	0.02	0.2
log_theta	0.81	0.00	<.0001	-0.68	0.03	<.0001	-0.07	0.01	<.0001	0.35	0.01	<.0001	0.02	0.01	0.176	0.44	0.01	<.00

ADG- Aggregate Diagnosis Group; Coeff- regression coefficient; HCU- high-cost user; SE- standard error

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Appendix 5

Regression coefficients, recycled prediction, health care use

Care categories Covariates	Hospit	Hospital admission, All			Hospital admission, urgent			Hospital admission, elective			Physician visits, All			ysician višits, Specialists	Physi	Physician visits, General practitioner		
	Coeff	SE	P-value	Coeff	SE	P-value	Coeff	SE	P-value	Coeff	SE	P-value	Coeff	SE P-va	ue Coeff	SE	P-value	
p(event) ≠0; Intercept	0.57	0.05	<.0001	-8.08	0.05	<.0001	4.07	0.06	<.0001	7.74	0.15	<.0001	4.80	0.05 0 <.00	4.03	0.06	<.0001	
HCU status	5.11	0.01	<.0001	4.48	0.01	<.0001	4.66	0.02	<.0001	5.60	0.14	<.0001	3.78	0.03 0 <.00	01 2.71	0.03	<.0001	
Pre-incident value	0.78	0.03	<.0001	0.82	0.03	<.0001	0.80	0.07	<.0001	0.40	0.00	<.0001	0.29	0.00 0.00	0.62	0.00	<.0001	
Age	0.01	0.00	<.0001	0.05	0.00	<.0001	-0.07	0.00	<.0001	-0.05	0.00	<.0001	-0.03	0.00 0 <.00	-0.04	0.00	<.0001	
ADG	0.00	0.00	0.002	0.00	0.00	<.0001	0.00	0.00	0.006	0.38	0.00	<.0001	0.25	0.00 8 <.00	0.26	0.00	<.0001	
Sex	0.08	0.01	<.0001	0.12	0.01	<.0001	0.05	0.01	<.0001	-0.13	0.01	<.0001	-0.12	0.01	-0.12	0.01	<.0001	
Low income	-0.04	0.01	6E-04	0.17	0.01	<.0001	-0.40	0.02	<.0001	-0.20	0.02	<.0001	-0.20	0.01 0.00	-0.16	0.01	<.0001	
p(event) >0; Intercept	-2.16	0.07	<.0001	-6.77	0.19	<.0001	-1.37	0.20	<.0001	3.02	0.01	<.0001	3.10	0.01 - <.00	001 1.41	0.01	<.0001	
HCU status	4.21	0.13	<.0001	4.62	0.17	<.0001	2.59	0.28	<.0001	1.33	0.00	<.0001	1.63	0.00 0 <.00	0.91	0.00	<.0001	
Pre-incident value	0.39	0.03	<.0001	0.42	0.03	<.0001	0.71	0.11	<.0001	0.03	0.00	<.0001	0.04	0.00 o <.00	0.06	0.00	<.0001	
Age	0.01	0.00	<.0001	0.01	0.00	<.0001	-0.01	0.00	0.041	0.00	0.00	<.0001	0.00	0.00 pril <.00	0.01	0.00	<.0001	
ADG	0.02	0.00	<.0001	0.03	0.00	<.0001	0.00	0.00	0.268	0.02	0.00	<.0001	0.02	0.00 0 <.00	0.02	0.00	<.0001	
Sex	0.19	0.01	<.0001	0.11	0.01	<.0001	0.29	0.03	<.0001	0.02	0.00	<.0001	0.06	0.00 <u>24</u> <.00	001 -0.01	0.00	<.0001	
Low income	0.07	0.01	<.0001	0.06	0.02	0.0004	-0.04	0.05	0.45	0.01	0.00	<.0001	-0.02	0.00 <u>(0</u> <.00	0.05	0.00	<.0001	
Scale parameter	1.51	0.08		0.60	0.04	<.0001	0.00	0.00		0.32	0.00		0.49	0.00	0.36	0.00	1	

ADG- Aggregate Diagnosis Group; Coeff- regression coefficient; HCU- high-cost user; SE- standard error

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Sex

Low income

Scale parameter

Regression coefficie	nts, rec	cycled	predicti	on, hea	alth ca	re use (C		3MJ Of	ben						136/bmjopen-2018-028637 (
Care categories Covariates	Emerge	ency dep visits	partment	Home o	care serv	vices, All*		care sei onal sup	-	Hom	e care se Nursin		Hom	e care se Allied	\cap ·	Home	e care se Other*	
	Coeff	SE	P-value	Coeff	SE	P-value	Coeff	SE	P-value	Coeff	SE	P-value	Coeff	SE	0 D P-value	Coeff	SE	P-value
p(event) ≠0; Intercept	-1.58	0.03	<.0001	-9.51	0.05	<.0001	-9.22	0.07	<.0001	-3.04	0.05	<.0001	-7.21	0.05	2 01<.0001 9.	-9.28	0.05	<.000
HCU status	2.40	0.01	<.0001	3.11	0.01	<.0001	2.97	0.01	<.0001	3.06	0.01	<.0001	2.71	0.01	Q<.0001	3.07	0.01	<.000
Pre-incident value	0.39	0.00	<.0001	0.08	0.00	<.0001	0.09	0.00	<.0001	0.11	0.00	<.0001	0.26	0.00	nload	0.58	0.00	<.000
Age	0.02	0.00	<.0001	0.08	0.00	<.0001	0.09	0.00	<.0001	0.02	0.00	<.0001	0.07	0.00	ed<.0001 frc	0.08	0.00	<.000
ADG	0.09	0.00	<.0001	0.05	0.00	<.0001	0.02	0.00	<.0001	0.02	0.00	<.0001	0.04	0.00	n <.0001	0.05	0.00	<.000
Sex	0.04	0.01	<.0001	-0.34	0.01	<.0001	-0.47	0.01	<.0001	0.12	0.01	<.0001	-0.45	0.01	0.//bn	-0.34	0.01	<.000
Low income	0.04	0.01	<.0001	0.04	0.01	<.0001	0.15	0.01	<.0001	-0.10	0.01	<.0001	-0.01	0.01	0.600 Diope	0.08	0.01	<.000
p(event) >0; Intercept	-0.02	0.03	0.658	0.52	0.00	<.0001	-0.70	0.14	<.0001	2.40	0.06	<.0001	0.20	0.05	.0001	-0.47	0.01	<.000
HCU status	0.97	0.01	<.0001	0.74	0.00	<.0001	0.62	0.03	<.0001	0.76	0.02	<.0001	0.24	0.01	.0001	0.74	0.00	<.000
Pre-incident value	0.21	0.00	<.0001	0.01	0.00	<.0001	0.01	0.00	<.0001	0.03	0.00	<.0001	0.02	0.00	on <.0001	0.03	0.00	<.000
Age	0.00	0.00	0.179	0.03	0.00	<.0001	0.02	0.00	<.0001	0.00	0.00	<.0001	0.01	0.00	pri<.0001	0.02	0.00	<.000
ADG	0.03	0.00	<.0001	0.00	0.00	<.0001	-0.01	0.00	0.001	0.00	0.00	0.091	0.02	0.00	,0 ,0 ,0001 N	0.00	0.00	<.000

Regression coefficients, recycled prediction, health care use (CONT)

*-models were fit using Poisson distribution

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ADG- Aggregate Diagnosis Group; Coeff- regression coefficient; HCU- high-cost user; SE- standard error

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	Item No	Recommendation	Page No
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the	1
		abstract	
		(b) Provide in the abstract an informative and balanced summary of what was	4
		done and what was found	
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being	5
		reported	
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	6-10
Setting	5	Describe the setting, locations, and relevant dates, including periods of	7
		recruitment, exposure, follow-up, and data collection	
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of	7
		participants. Describe methods of follow-up	
		(b) For matched studies, give matching criteria and number of exposed and	
		unexposed	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and	8-9
		effect modifiers. Give diagnostic criteria, if applicable	
Data sources/	8*	For each variable of interest, give sources of data and details of methods of	6,8,9
measurement		assessment (measurement). Describe comparability of assessment methods if	
		there is more than one group	
Bias	9	Describe any efforts to address potential sources of bias	9-10
Study size	10	Explain how the study size was arrived at	6-7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable,	8-10
		describe which groupings were chosen and why	
Statistical methods	12	(a) Describe all statistical methods, including those used to control for	9-10
		confounding	
		(b) Describe any methods used to examine subgroups and interactions	
		(c) Explain how missing data were addressed	
		(d) If applicable, explain how loss to follow-up was addressed	
		(<u>e</u>) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers	11
i urterpunts	15	potentially eligible, examined for eligibility, confirmed eligible, included in the	
		study, completing follow-up, and analysed	
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social)	11
Descriptive data	17	and information on exposures and potential confounders	
		(b) Indicate number of participants with missing data for each variable of	1
		(b) indicate number of participants with missing data for each variable of interest	
		morosi	
		(c) Summarise follow-up time (eg, average and total amount)	

Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and	12-13
		their precision (eg, 95% confidence interval). Make clear which confounders were	
		adjusted for and why they were included	
		(b) Report category boundaries when continuous variables were categorized	
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a	
		meaningful time period	
Other analyses	17	Report other analyses done-eg analyses of subgroups and interactions, and sensitivity	Appendix
		analyses	1
Discussion			
Key results	18	Summarise key results with reference to study objectives	15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or	17-18
		imprecision. Discuss both direction and magnitude of any potential bias	
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations,	16,17,18
		multiplicity of analyses, results from similar studies, and other relevant evidence	
Generalisability	21	Discuss the generalisability (external validity) of the study results	18
Other information	on		
Funding	22	Give the source of funding and the role of the funders for the present study and, if	3
		applicable, for the original study on which the present article is based	1

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

BMJ Open

Incremental Healthcare Utilization and Costs Among New Senior High Cost Users in Ontario, Canada: a retrospective matched cohort study

Journal:	BMJ Open
Manuscript ID	bmjopen-2018-028637.R1
Article Type:	Original research
Date Submitted by the Author:	23-Jul-2019
Complete List of Authors:	Muratov, Sergei; McMaster University Faculty of Health Sciences, Health Research Methods, Evidence, and Impact Lee, Justin; McMaster University Faculty of Health Sciences, Department of Health Research Methods, Evidence, and Impact Holbrook, Anne; St. Joseph's Healthcare, Clinical Pharmacology & Toxicology Guertin, Jason; Université Laval, Département de médecine sociale et préventive, Faculté de Médecine Mbuagbaw, Lawrence; McMaster University, Department of Health Research Methods, Evidence, and Impact Paterson, Michael; ICES Gomes, Tara; Li Ka Shing Knowledge Institute; ICES Pequeno, Priscila; ICES Tarride, Jean-Eric; McMaster University, Health Research Methods, Evidence, and Impact
Primary Subject Heading :	Health services research
Secondary Subject Heading:	Health economics, Health policy
Keywords:	Health policy < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, GERIATRIC MEDICINE, HEALTH ECONOMICS

SCHOLARONE[™] Manuscripts

1		
2	1	Incremental Healthcare Utilization and Costs Among New Senior High Cost Users in
3 4	2	Ontario, Canada: a retrospective matched cohort study
5 6	3	Sergei Muratov ¹ , Justin Lee ^{1,2} , Anne Holbrook ^{1,3} , Jason R Guertin ^{5,6} , Lawrence Mbuagbaw ¹ , J Michael
7	4	Paterson ^{6,7} , Tara Gomes ^{6,8} , Priscila Pequeno ⁶ , Jean-Eric Tarride ^{1,9}
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20	12	Quebec, Canada
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Authors' contributions:

SM, JET, AH, JL, JMP, TG, LM, JRG conceptualized the study. SM, JET, AH, JL, JRG, LM, JMP, TG, PP have contributed to its design. JMP, PP, TG were instrumental in creating datasets. PP provided assistance with data analysis. SM prepared the initial draft of the manuscript and revised it based on co- authors' feedback: JET, AH, JL, JMP, TG, JRG, LM, PP provided comments to the initial draft, further revisions, read and approved the final manuscript. The responsibility of study implementation lies with the principal ort investigator (SM) that is supported and supervised primarily by JET.

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Competing Interests:

None declared.

Data sharing:

The dataset from this study is held securely in coded form at the Institute for Clinical Evaluative Sciences

(ICES). While data sharing agreements prohibit ICES from making the dataset publicly available, access may

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Objectives: To describe healthcare use and spending before and on becoming a new (incident) senior HCU
 compared with senior non-HCUs; to estimate the incremental costs, overall and by service category,

attributable to HCU status; and to quantify its monetary impact on the provincial healthcare budget in
Ontario, Canada.

Design: We conducted a retrospective, population-based comparative cohort study using administrative

7 healthcare records. Incremental healthcare utilization and costs were determined using the method of

8 recycled predictions allowing adjustment for pre-incident and incident year values, and covariates.

9 Estimated budget impact was computed as the product of the mean annual total incremental cost and the

10 number of senior HCUs.

Abstract

Participants: Incident senior HCUs were defined as Ontarians aged ≥66 years who were in the top 5% of
 healthcare cost users during fiscal year 2013 (FY2013) but not during fiscal year 2012 (FY2012). The incident
 HCU cohort was matched with senior non-HCUs in a ratio of 1 HCU :3 non-HCU.

Results: Senior HCUs (n=175,847) reached the annual HCU threshold of \$10,192 through different

15 combinations of incurred costs. Although HCUs had higher healthcare utilization and costs at baseline, HCU

16 status was associated with a substantial spike in both, with prolonged hospitalizations playing a major role.

17 Twelve percent of HCUs reached the HCU expenditure threshold without hospitalization. Compared to non-

18 HCUs (n=527,541), HCUs incurred an additional \$25,527 per patient in total healthcare costs; collectively

19 \$4.5 billion or 9% of the 2013 Ontario healthcare budget. Inpatient care had the highest incremental costs:

20 \$13,427, 53% of the total incremental spending.

Conclusions: Costs attributable to incident senior HCU status accounted for almost one-tenth of the

22 provincial healthcare budget. Prolonged hospitalizations made a major contribution to the total incremental

23 costs. A subgroup of patients that became HCU without hospitalization requires further investigation.

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 This population-based study examines incident (new) senior high-cost users (HCU), which provides important information on the driving factors for HCU status Inclusion of all incident senior HCU in the province into the study population allowed us to calculate their monetary impact on the provincial healthcare budget This analysis includes a comprehensive spectrum of the most important cost categories that contribute to total public healthcare expenditures in the province Limitations Despite the comprehensiveness of cost analyses, a few of the cost categories may not have been captured in full, e.g. outpatient intravenous chemotherapy The findings, especially with respect to the total incremental costs and the budget impact, are only comparable to studies with the same HCU threshold and the choice of cost categories 	1 2	1	Strengths
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1 Introduction

Healthcare spending has more than doubled in the countries of the Organization for Economic Cooperation and Development (OECD) over the past two decades[1]. In Canada, where public health and health care are under provincial jurisdiction, health spending accounts for 37% of the total provincial program spending on average [2]. Much of the spending is disproportionately attributed to a small but heterogenous group of patients, commonly referred to as high-cost healthcare users (HCU)[3-5]. The pressing need to control healthcare spending and the inconclusive evidence and varying success of clinical interventions targeting the HCU group[6, 7] have prompted policy makers to revise their management strategies and to seek specific segments of the HCU population who may benefit from certain interventions more than others[4, 8, 9].

Incident (or new) senior HCUs represent one such segment whose patient care characteristics and spending patterns have not been well studied. A recent systematic review identified 55 studies published over the past two decades that reported HCU characteristics and healthcare utilization[5]. The vast majority (n=42) of the publications originated from the US, 9 were from Canada, 3 were generated by researchers from European countries, and 1 was from Taiwan. Compared to 9 US-based studies of the Medicare (i.e., senior) population, only the study from Taiwan among the others had a specific focus on seniors, even though approximately 45-55% of senior healthcare care resources are reportedly consumed by senior HCUs in various jurisdictions[10-12]. Moreover, these studies do not differentiate between prevalent (who retain the HCU status over years) and incident senior HCUs. This is important, as understanding the path to HCU status may identify opportunities for intervention[4]. Further, it is well known that senior HCUs, both prevalent and incident, generally have poor functional status and consume a high level of healthcare resources, including typically reported acute inpatient care and physician services[7, 13, 14]. However, comprehensive descriptions of cost drivers to HCU status are few [10, 15]. A recent example is a study conducted in Ontario, the largest province in Canada, which presented a system-wide assessment of cost

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1	concentration among HCUs over 3 years using both longitudinal and cross-sectional approaches to their
2	analysis[10]. While providing valuable information on the transition of patients between various cost strata,
3	their longitudinal analyses focused on the persistence of costs among all HCUs. Their cross-sectional analysis
4	of expenditures by cost category was limited by only reporting on the top 1% of HCUs and was not stratified
5	by age. Another poorly explored aspect of HCU cost analysis is the economic burden associated with HCU
6	status, which remains largely unknown in Canada and elsewhere. While some international studies have
7	compared costs between HCUs and non-HCU cohorts in a particular year using a cross-sectional design[3,
8	16, 17], these comparative studies did not consider any secular trends over time (e.g. costs in the years
9	before the incident year). This limits our understanding of the true incremental costs of becoming a new
10	HCU, especially among seniors.
11	We recently reported on a cohort of incident senior HCUs compared to matched non-HCUs to examine
12	
13	determine the incremental healthcare utilization and costs among new senior HCUs in Ontario by looking at
14	the same data longitudinally. The main objectives of this study were to 1) describe healthcare use and
15	spending before and on becoming a senior HCU compared with senior non-HCUs; 2) estimate costs and
16	healthcare use attributable to the incident senior HCU status, and to 3) quantify the monetary impact of
17	incident senior HCUs on the provincial healthcare budget.
18	incident senior HCUs on the provincial healthcare budget. Methods
10	Methods -
19	Ethics Approval
20	This study was approved by Hamilton Integrated Research Ethics Board (ID#1715-C).
21	Study design
22	We conducted a retrospective population-based matched cohort study using administrative healthcare data
23	from Ontario, Canada. The protocol for this research has been published[19].
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1 Setting and data sources

 2 Ontario is Canada's most populous province, with almost 14 million residents (approximately 40% of the

- 3 Canadian population)[20]. The Ontario Ministry of Health and Long-Term Care (MOHLTC) pays for
- 4 approximately 70% of health care provided in the province. This includes nearly 100% of hospital care,
- 5 physician services, and prescription drugs for seniors[21].
- 6 A patient-level dataset was created by linking 19 health administrative databases[19] using unique encoded
- 7 identifiers at ICES (www.ices.on.ca). ICES is an independent, non-profit research corporation funded by the
- 8 Ontario MOHLTC. The Ontario government fiscal year 2013 (April 1, 2013 and March 31, 2014) was
- 9 considered the incident year (FY2013). Fiscal year 2012 (FY2012: April 1, 2012 and March 31, 2013) was the
- 10 baseline or pre-incident year.

11 Study population

Incident senior HCUs were defined as individuals aged 66 years or above with annual total healthcare expenditures in the top 5% of all Ontarians in FY2013, who were not in the top 5% healthcare users in FY2012. The 5% threshold is commonly reported in HCU studies in Canada and elsewhere[10, 14, 22, 23]. The >66 year age threshold was applied to capture Ontario Drug Benefit (ODB) expenditures for at least one year before the incident year: ODB coverage starts automatically when Ontarians reach 65 years of age[24]. The "non-HCU" cohort included those whose annual total health care expenditures in FY2012 and FY2013 were below the top 5% threshold in both years. The incident HCU cohort was matched with non-HCU in a ratio of 1 HCU :3 non-HCUs by age at the cohort entry (within 1 month), sex and Local Health Integration Network (LHIN) of patient residence. LHINs, Ontario's 14 regional health districts, are responsible for the planning and administration of most of hospital- and community-based health services delivered within their geographic boundaries[25].

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1 2 3	1	Variables
4 5	2	Our dataset included key information on socio-demographic and health status, healthcare utilization and
6 7 8	3	costs. Described in the study protocol[19] in more detail, key variables are briefly summarized below.
9 10 11	4	Socio-demographic status included age, sex, low income status, and geography of residence
12 13	5	(urban/suburban/rural). Low income status was based upon net household income reported to receive ODB
14 15	6	subsidy in FY2012. Rurality was based on the Rurality Index for Ontario (RIO) which is a scale from 0 to 100.
16 17	7	A RIO between 0 and 9 defined an individual from the urban area, between 10 and 40 described a suburban
18 19 20	8	resident, and a resident from a rural area had a RIO score of 40 and above[26].
21 22 23	9	Health status was assessed using several variables. We used two tools derived from Johns Hopkins Adjusted
24 25	10	Clinical Groups (ACG [®]) System, Version 10, a case-mix methodology to describe a population's healthcare
26 27	11	utilization looking back for 3 years prior to the incident year[27]. First, the general degree of comorbidity
28 29	12	was captured by the number of Johns Hopkins Aggregated Diagnosis Groups (ADGs): person-focused,
30 31	13	diagnosis-based method to measure patients' illness by assigning individual ACGs into diagnosis
32 33 34	14	clusters[28]. A higher number of ADGs per patient indicates a greater burden of illness. In addition, we
35 36	15	identified the proportion of patients with a history of hypertension, malignancy, and mental health
37 38	16	condition using John Hopkins Expanded Diagnosis Clusters (EDCs). For each condition, we checked whether
39 40	17	the patient was diagnosed with the condition in the 3 years prior to FY2013. Finally, we used validated
41 42 43	18	administrative data case definitions to identify whether the patient had a history of several common chronic
44 45	19	diseases, including congestive heart failure, diabetes, and chronic obstructive pulmonary disease[29, 30].
46 47	20	The choice of specific conditions used to describe patients was driven by several factors: 1) chronic
48 49	21	conditions that are commonly associated with high economic burden (cardiovascular and pulmonary
50 51 52	22	diseases, malignancy) [31-33]; 2) conditions that are well known risk factors (e.g., hypertension, diabetes);
52 53 54 55 56 57	23	3) availability of data.

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Whereas socio-demographic characteristics and health status were captured at baseline, healthcare utilization and expenditures were obtained for the full two years of study. Utilization variables included the number of hospitalizations (all, elective and unplanned), emergency department (ED) visits, physician encounters, and publicly funded home care services. Home care services were subclassified by type of service: nursing, personal support, and allied health. For each hospitalization, we obtained the total length of stay (TLOS), in days.

Health care expenditures were estimated using ICES person-level health utilization costing algorithms, [34] which report expenditures according to twelve health service cost categories. Hospital costs were the sum of costs associated with acute inpatient care and same-day surgery. Mental health admissions were costed separately. Physician expenditures were the sum of fee-for-service billings and capitation payments. The cost categories also separately included publicly funded long-term homes, inpatient rehabilitations services, community home care, and admissions to complex continuing care. Costs were expressed in 2013 Canadian 2/18 Dollars.

Outcomes

The primary outcome measures were 1) one-year incremental healthcare utilization for hospital admissions (total and by types such as unplanned and elective), emergency visits, physician encounters (total and separately for specialists and general practitioners [GP]), and home care services (total and by type); 2) one-year incremental costs attributable to becoming an HCU (total healthcare expenditures and by cost category); and 3) provincial budget impact of new senior HCUs in FY2013. Incremental healthcare use and costs were calculated as the difference between the two cohorts over one-year period. They represent additional mean visits made or costs incurred by a HCU in the incident year compared with a non-HCU and the baseline year. Statistical analysis

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Baseline patient socio-demographic and health status characteristics of the two cohorts in FY2012 were compared using the absolute standardised difference (aSD), with aSD>0.1 indicating a meaningful difference[35]. We then described the HCU cohort in the context of cost categories and their contribution to the HCU status by calculating the proportion (%) of HCU in each cost category. Since we expected hospitalizations to be a frequent cause of new HCU status, we repeated this analysis for HCUs who were not hospitalized during the incident year to evaluate the contributions of cost drivers other than hospital admission. This was followed by a longitudinal comparison of the unadjusted healthcare use and costs in both cohorts for both the incident year and the preceding year. Incremental healthcare use and costs were estimated using the recycled predictions method [36-39]. Commonly used to evaluate the marginal effect of a covariate on the response variable, the method uses fitted regression models to predict incremental values of the outcomes in two hypothetical populations: one where all subjects are HCU and another where all are non-HCU, all the other covariates being the same. The difference in predicted means between the two populations indicates the incremental value. The method allows for correlation between outcome values in the year before the index year (FY2012) and after the index year (FY2013), while comparing HCU with non-HCU. Confidence intervals (CI) of the incremental values was obtained through the percentile method: random bootstrap resampling with 1000 iterations created a distribution where the 2.5th and 97.5th percentiles were the 95% lower and upper bound Cls, respectively [39]. We used generalized linear regression to model the study outcomes. Costs were modeled with gamma distribution and log-link function to handle the right-skewed data[40, 41]. The choice of gamma distribution

21 was confirmed by the modified Park test[42]. For count data (e.g., hospital admissions or home care visits),

- 22 a negative binomial (NB) distribution was specified as the leading option to better account for
- 23 overdispersion (i.e., observed variance is greater than the assumed variance)[43, 44]. In cases of a NB model
- not converging, Poisson distribution was used. For both costs and count data, we used two-part models

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1	(Hurdle regression) to manage zero values in the response variables: the first part used a logistic regression
2	to predict the probability of positive values of the outcome, while a gamma or a negative binomial model
3	was applied in the second stage for positive costs and counts, respectively[43, 45]. All the models were
4	adjusted for previous resource use (e.g., costs or healthcare use in FY2012), age, sex, ADGs, and low-income
5	status. Because our dataset included all senior HCU subjects in the province at the time of the study, we
6	were able to estimate the total provincial public healthcare expenditures attributable to HCU status among
7	Ontario seniors by multiplying the total incremental costs by the total number of senior HCU. Statistical
8	analyses were conducted using SAS version 9.4.3 (SAS Institute Inc., Cary, NC).
9	Patient and Public Involvement
10	Patients or public were not involved in the design of this retrospective cohort study.
11	Results
12	Patient characteristics
13	The total study population consisted of 703,388 seniors, of which 175,847 were incident HCUs. This
14	population of incident HCUs represents 46% of all HCUs in FY2013 (n= 383,257) but only 9.4% of the Ontario
15	senior population and 1.4% of the total population in the province[20]. As expected, the mean ages of the
16	HCU and non-HCU cohorts were identical at 77.7 years (standard deviation (SD) 7.7); 53% were women; and
17	most resided in suburban areas (12.2 vs. 11.8, aSD=0.02) (Table 1). Compared to non-HCUs, HCUs had
18	poorer health status as defined by both the number of aggregated diagnosis groups (10.2 vs. 7.9, aSD=0.54)
19	and higher prevalence of chronic diseases. A relatively greater percentage of HCU cohort members had a
20	primary care provider (97% vs. 88.6%, aSD=0.33).
24	Table 1 Datiant sharestaristics

21 Table 1 Patient characteristics

Characteristic	HCU (N=175,847)	Non-HCU (N=527,541)	aSD
Socio-demographics			
Age, mean (SD), yr	77.7 ± 7.7	77.7 ± 7.7	0

Sex, female	93,119 (53%)	279,501 (53%)	C
Rural Index of Ontario score, mean (SD)	12.2 ± 18.2	11.8 ± 18.2	0.0
Low income	31,843 (18.1%)	92,566 (17.5%)	0.0
Health Status			
# Adjusted Diagnostic Groups, mean (SD)	10.2 ± 4.0	7.9 ± 4.5	0.5
Hypertension ^{\$}	110,692 (63.0%)	282,867 (53.6%)	0.1
Congestive Heart Failure [#]	25,195 (14.3%)	36,877 (7.0%)	0.2
Chronic Obstructive Disease Pulmonary#	48,738 (27.7%)	96,513 (18.3%)	0.2
Diabetes [#]	62,014 (35.3%)	138,794 (26.3%)	0.
Myocardial infarction [#]	12,892 (7.3%)	24,024 (4.6%)	0.1
Rheumatoid Arthritis [#]	5,607 (3.2%)	9,334 (1.8%)	0.0
Malignancy ^{\$}	56,855 (32.3%)	123,932 (23.5%)	0.
Mental Health condition ^{\$}	67,441 (38.4%)	144,377 (27.4%)	0.2

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

2 <u>HCU status</u>

3 The 5% HCU annual threshold for this study was \$10,192. As shown in Figure 1, patients could become HCU

4 through different combinations of incurred costs. Approximately 40% of the HCU became a HCU (i.e.,

5 incurred at least \$10,192 in total annual healthcare expenditures) due to a single cost category,

6 predominantly hospital admissions (70.1%). For 13% of the HCUs, more than one cost category was above

7 the threshold (e.g., hospital admission and rehabilitation costs). Among the remaining 47%, no single cost

8 category was sufficient to meet the expenditure threshold for HCU status: HCU status was achieved through

9 expenditures in several cost categories. In this case, the most common contributing categories were

- 10 physician compensation, drug benefits, and hospitalization.
- 11 As many as 11.7% (N=20,501) of the HCU were not hospitalized during the incident year (Appendix 1). Their
 - new HCU status was mainly due to a combination of physician compensation (99.8%), ODB (99.4%), and
- 13 laboratory test costs (87.3%), home care (54.1%) and emergency department visits (45.3%). Of note, some
- 14 of the patients within several cost categories had costs high enough for the patient to become a HCU.

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Examples include 72.3% of patients in long-term care, 63.4% of patients with cancer care, and 19.1% of
patients with drug costs.

3 Dynamics of change in healthcare use and costs

Analysis of observed healthcare utilization in the two cohorts identifies an upward trajectory in health services consumption among senior HCU. As shown in Figure 2, compared to non-HCU, the HCU consumed more services in the pre-incident year across all care categories: physician encounters (mean per patient: 15.4 vs. 10.1, aSD=0.55), home care visits (mean per patient: 7.7 vs. 1.8; aSD=0.24), emergency department (ED) visits (mean per patient: 0.6 vs. 0.3; aSD=0.26), and hospital admissions (mean per patient: 0.04 vs. 0.02; aSD=0.08). This was followed by a dramatic increase in healthcare use among senior HCU during FY2013, while the service consumption among non-HCU remained relatively unchanged. Similarly, the total public healthcare expenditures among senior HCU were higher in the pre-incident year compared to non-HCU (mean per patient: \$4,166 vs. \$2,372, aSD=0.74), followed by a substantial spike during the incident year (\$29,784 vs. \$2,471; aSD=1.33) (Figure 3). While the major drivers of total costs were analogous in the two cohorts in the year before (in descending order: drug benefits, physician costs, hospital admissions or home care), the top contributors in the HCU cohort changed during the incident year. With an annual mean of 1.07 of hospital admissions (mean TLOS: 8.8 (SD 14.8)) among senior HCU compared to a mean of 0.03 admissions (mean TLOS: 2.8 (SD 9.6)) for non-HCUs in FY2013, prolonged hospitalizations were the major driver of total healthcare expenditures (\$13, 558) in the incident year. These were followed by physician (\$4,214) and ODB costs (\$2,456). In categories such as rehabilitation, complex continuing care, dialysis, and mental health admissions, the costs incurred by senior HCUs at baseline and non-HCUs across both years were approximating zero: these categories were almost exclusively associated with the HCU status. Little change in the list of major cost drivers and the trajectory of costs over time was noticeable among non-HCU seniors. More detail is provided in Appendices 2 and 3.

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L	Incremental costs and healthcare use	
2	Table 2 shows the magnitude of incremental healthcare	e use by senior HCU during the incident year
3	adjusting for the pre-incident values and other covariat	es. Compared to the year before becoming an HCU,
ļ	unplanned hospitalizations accounted for 74% of all inc	remental admissions at an additional mean of 0.77
5	hospitalizations per HCU (95%CI: 0.77-0.78) annually. Si	milarly, specialist visits constituted 75% of the
5	incremental physician encounters at an additional mean	n of 22.8 visits (95%CI: 22.7-22.9), whereas persona
7	support worker visits contributed the most to the incre	mental home care use at additional mean of 15.6
3	visits (95%CI: 15.3-15.9) per HCU patient.	
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)	Table 2: Incremental healthcare use associated	
)	Table 2: Incremental healthcare use associated Healthcare type	Annual incremental utilization,
	Healthcare type	Annual incremental utilization, mean (95% CI)
	Healthcare type Hospital admission, All	Annual incremental utilization, mean (95% Cl) 1.04 (1.04 -1.05)
	Healthcare type Hospital admission, All Hospital admission, elective	Annual incremental utilization, mean (95% Cl) 1.04 (1.04 -1.05) 0.29 (0.29 -0.3)
	Healthcare type Hospital admission, All	Annual incremental utilization, mean (95% Cl) 1.04 (1.04 -1.05)
	Healthcare type Hospital admission, All Hospital admission, elective Hospital admission, unplanned	Annual incremental utilization, mean (95% Cl) 1.04 (1.04 -1.05) 0.29 (0.29 -0.3) 0.77 (0.77 -0.78) 1.4 (1.4 -1.4)
	Healthcare type Hospital admission, All Hospital admission, elective Hospital admission, unplanned Emergency department visits	Annual incremental utilization, mean (95% Cl) 1.04 (1.04 -1.05) 0.29 (0.29 -0.3) 0.77 (0.77 -0.78)
	Healthcare type Hospital admission, All Hospital admission, elective Hospital admission, unplanned Emergency department visits Physician visits, All	Annual incremental utilization, mean (95% Cl) 1.04 (1.04 -1.05) 0.29 (0.29 -0.3) 0.77 (0.77 -0.78) 1.4 (1.4 -1.4) 32.1 (31.9 -32.3)
	Healthcare type Hospital admission, All Hospital admission, elective Hospital admission, unplanned Emergency department visits Physician visits, All General practitioner visits	Annual incremental utilization, mean (95% Cl) 1.04 (1.04 -1.05) 0.29 (0.29 -0.3) 0.77 (0.77 -0.78) 1.4 (1.4 -1.4) 32.1 (31.9 -32.3) 9.3 (8.7 -9.5)
	Healthcare type Hospital admission, All Hospital admission, elective Hospital admission, unplanned Emergency department visits Physician visits, All General practitioner visits Specialist visits	Annual incremental utilization, mean (95% Cl) 1.04 (1.04 -1.05) 0.29 (0.29 -0.3) 0.77 (0.77 -0.78) 1.4 (1.4 -1.4) 32.1 (31.9 -32.3) 9.3 (8.7 -9.5) 22.8 (22.7 -22.9)
	Healthcare type Hospital admission, All Hospital admission, elective Hospital admission, unplanned Emergency department visits Physician visits, All General practitioner visits Specialist visits Home care services, All*	Annual incremental utilization, mean (95% Cl) 1.04 (1.04 -1.05) 0.29 (0.29 -0.3) 0.77 (0.77 -0.78) 1.4 (1.4 -1.4) 32.1 (31.9 -32.3) 9.3 (8.7 -9.5) 22.8 (22.7 -22.9) 25.1 (24.4 -25.7)
	Healthcare typeHospital admission, AllHospital admission, electiveHospital admission, unplannedEmergency department visitsPhysician visits, AllGeneral practitioner visitsSpecialist visitsHome care services, All*Personal support	Annual incremental utilization, mean (95% Cl) 1.04 (1.04 -1.05) 0.29 (0.29 -0.3) 0.77 (0.77 -0.78) 1.4 (1.4 -1.4) 32.1 (31.9 -32.3) 9.3 (8.7 -9.5) 22.8 (22.7 -22.9) 25.1 (24.4 -25.7) 15.6 (15.3 -15.9)
	Healthcare type Hospital admission, All Hospital admission, elective Hospital admission, unplanned Emergency department visits Physician visits, All General practitioner visits Specialist visits Home care services, All* Personal support Nursing	Annual incremental utilization, mean (95% Cl) 1.04 (1.04 -1.05) 0.29 (0.29 -0.3) 0.77 (0.77 -0.78) 1.4 (1.4 -1.4) 32.1 (31.9 -32.3) 9.3 (8.7 -9.5) 22.8 (22.7 -22.9) 25.1 (24.4 -25.7) 15.6 (15.3 -15.9) 5.3 (4.9 -6.0)
	Healthcare type Hospital admission, All Hospital admission, elective Hospital admission, unplanned Emergency department visits Physician visits, All General practitioner visits Specialist visits Home care services, All* Personal support Nursing Allied	Annual incremental utilization, mean (95% Cl) $1.04 (1.04 - 1.05)$ $0.29 (0.29 - 0.3)$ $0.77 (0.77 - 0.78)$ $1.4 (1.4 - 1.4)$ $32.1 (31.9 - 32.3)$ $9.3 (8.7 - 9.5)$ $22.8 (22.7 - 22.9)$ $25.1 (24.4 - 25.7)$ $15.6 (15.3 - 15.9)$ $5.3 (4.9 - 6.0)$ $1.5 (1.5 - 1.6)$ $2.8 (2.7 - 2.9)$
	Healthcare type Hospital admission, All Hospital admission, elective Hospital admission, unplanned Emergency department visits Physician visits, All General practitioner visits Specialist visits Home care services, All* Personal support Allied Other*#	Annual incremental utilization, mean (95% Cl) $1.04 (1.04 - 1.05)$ $0.29 (0.29 - 0.3)$ $0.77 (0.77 - 0.78)$ $1.4 (1.4 - 1.4)$ $32.1 (31.9 - 32.3)$ $9.3 (8.7 - 9.5)$ $22.8 (22.7 - 22.9)$ $25.1 (24.4 - 25.7)$ $15.6 (15.3 - 15.9)$ $5.3 (4.9 - 6.0)$ $1.5 (1.5 - 1.6)$ $2.8 (2.7 - 2.9)$ tive Binomial
)	Healthcare type Hospital admission, All Hospital admission, elective Hospital admission, unplanned Emergency department visits Physician visits, All General practitioner visits Specialist visits Home care services, All* Personal support Nursing Allied Other*#	Annual incremental utilization, mean (95% Cl) $1.04 (1.04 - 1.05)$ $0.29 (0.29 - 0.3)$ $0.77 (0.77 - 0.78)$ $1.4 (1.4 - 1.4)$ $32.1 (31.9 - 32.3)$ $9.3 (8.7 - 9.5)$ $22.8 (22.7 - 22.9)$ $25.1 (24.4 - 25.7)$ $15.6 (15.3 - 15.9)$ $5.3 (4.9 - 6.0)$ $1.5 (1.5 - 1.6)$ $2.8 (2.7 - 2.9)$ tive Binomialespite care

- 14 (Table 3), with hospital admissions being by far the major contributor at an additional mean of \$13,428
- 15 (95%CI: \$13,333 \$13,533) per HCU. Details of the regression analyses are provided in Appendices 4-5.
- 16 Given the size of the senior incident HCU population (n=175,847), the estimated provincial budget impact of

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the senior incident HCU status was \$4.5 billion (CAD). This accounts for approximately 9% of the 2013 total

provincial healthcare expenditures (\$51 billion)[46].

Table 3: Incremental expenditures associated with HCU status, by cost component and total

Cost component	Annual incremental costs*,
	mean (95% CI)
Hospital admission	\$ 13,428 (13,334 -13,534)
Physicians	\$ 3,150 (3,134 -3,168)
Outpatient Drug Benefits	\$ 1,493 (1,462 -1,523)
Rehabilitation	\$ 1,430 (1,392 -1,467)
Home care	\$ 1,363 (1,347 -1,378)
Cancer care	\$ 1,226 (1,200 -1,253)
Complex continuing care	\$ 1,213 (1,168 -1,257)
Long-term care	\$ 1,021 (995 -1,046)
Emergency department	\$ 684 (679 -687)
Mental health admissions	\$ 258 (238 -278)
Dialysis	\$ 89 (79 -99)
Laboratory tests	\$ 51 (50 -52)
Total incremental cost	\$ 25,527 (25,383 -25,670)
*- Costs were modelled to follow gamma distribution with	log-link function
Annual incremental costs are additional mean expenditure	es incurred by a HCU in the incident year compared
with a non-HCU and the baseline year	
Viscussion	

Discussion

The study has examined a cohort of new senior HCU patients compared with matched non-HCUs focusing on the absolute and incremental comparative healthcare use and expenditures before and after HCU conversion. We determined that although senior HCUs were already on an upward trajectory during the year before HCU status, showing higher healthcare utilization and costs in the pre-incident year, the HCU status was associated with a spike in healthcare expenditures. We found that seniors became HCU through incurring costs in various combinations, although half of the senior HCU could reach the HCU status by incurring costs from only one or two categories, mainly prolonged hospitalization. Approximately 12% of HCUs had no hospitalization in the incident year: they achieved HCU status by incurring costs largely on physician services and prescription medications. Compared to non-HCU, senior HCU incurred an additional \$25,527 per patient in total incremental public healthcare expenditures and cost almost one-tenth of the

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provincial budget in the incident year. Hospitalizations, physician compensation and ODB were responsible
 for the highest incremental costs.

This study fills a current gap in the HCU economic literature, especially Canadian HCU studies where few of them have focused on seniors or used a comparative group of non-HCUs. Also, as opposed to cross-sectional studies that are common in the area of HCU research, we were able to capture the economic burden attributable to HCU status among senior Ontarians using longitudinal data. Our approach of the recycled predictions has allowed us to compare the healthcare use and costs between HCUs and a matched cohort of non-HCUs while taking account of the correlation between the pre- and post values, managing excessive zero values by developing two-part models, and adjusting for confounding by including important socio-demographic and health status covariates in the models. Another option we considered was the difference in differences (DID) estimator [47, 48]. Frequently employed by economists to assess the impact of introducing a policy or a change in the system, its use is however conditional on two major assumptions that need to be met: parallel trends and no group variation at baseline. While the latter could be dealt with using statistical adjustment, the former assumes that trajectories in outcomes (i.e., costs and use) between the groups are the same prior to the exposure (i.e., HCU conversion). Because we only had access to one year of data prior to the incident year (i.e., the baseline year) by design, it was not possible to determine the trajectories between the cohorts.

Consistent with 9 studies of senior HCUs identified by Wammes et al., our results confirm the high burden
of common conditions among senior HCUs, the important impact of inpatient care costs, the increasing role
of home and long-term care in the HCU cost profile. Some studies also mention non-hospitalized senior
HCUs without providing their detailed description[10, 49]. Our findings are however challenging to compare
with these for several reasons. First, in addition to the incremental values, we provide a comprehensive
assessment of costs and healthcare utilization for a specific segment of the HCU population: senior incident

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1	cases. To our knowledge, no other studies have examined this specific patient population, especially in such
2	detail[5]. Second, as Wammes et el show, the HCU threshold used in the US and other countries (e.g.,
3	Denmark and Germany) is often 10%, while Canadian studies commonly apply the 5% threshold[5]. Third,
4	the spectrum of cost categories included in analysis may vary between countries and even provinces in
5	Canada. Prescription drug costs, for example, the source of one of the highest incremental values in our
6	study, were not covered by the US Medicare program (which covers senior patients) until 2003, although
7	the launch of a fully developed program was delayed until mid-2000s[50, 51], limiting the comparability of
8	earlier studies that relied only on Medicare payments[11, 23, 52]. In this respect, our efforts to standardize
9	cost analyses by using a costing methodology that allows obtaining patient-level expenditures from multiple
10	sources in one standard way is a step toward higher comparability of future studies.
11	
12	Strengths and limitations
13	Our study has several strengths. First, the study is population-based, including all incident senior HCU in the
14	province. Second, the study examines incident HCU, which provides important information on the driving
15	factors for HCU status. Third, we included a comprehensive spectrum of the most important cost categories
16	that contribute to total public healthcare expenditures in the province.
17	
18	The study also has important limitations. The nature of methodology applied to calculate the costs was
19	different across various cost categories. As opposed to the nominal costs per visit (e.g., physician or home
20	care) or prescription claim, some of the costs were estimations, e.g. a provincial average cost per case of
21	inpatient care weighted for resource intensity[53]. However, when used for comparisons at a provincial
22	level, these estimations are considered acceptable[53]. Also, despite our comprehensive coverage of cost
23	categories, some public healthcare expenditures are not accounted for. Examples include community
24	services (e.g., community services for elderly) and public health costs. In addition, a few of the cost
25	categories included the analysis may not be captured in full. Most notably, we did not have access to the
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1	costs of outpatient intravenous chemotherapy, which can be costly[54]. Also, long-term care residents pay a
2	portion of the costs out of pocket[55]. Despite these limitations, it is unlikely that the unaccounted costs for
3	individual healthcare services amount to more than 5-8% of total public expenditures on healthcare[10, 56].
4	At the same time, the true hospitalization expenses may be underestimated as physician billings for
5	inpatient services are currently captured by a separate cost category which makes our estimates of the
6	hospital costs conservative. Finally, different HCU thresholds may yield different estimations of the
7	incremental costs. Although ours is the most commonly used HCU threshold in Canada[5], our findings are
8	largely comparable to studies with the same threshold and the choice of cost categories.
9	
10	Despite these limitations, our findings have policy and research implications. There is currently no clear
11	internationally accepted definition of the HCU[7]. They are also referred to by many names (e.g., heavy,
12	frequent or high needs users) that are used interchangeably with HCU[7]. However, our data shows that
13	frequent users of healthcare may not be synonymous with high-cost users of healthcare and both need to
14	be distinguished. One prolonged hospital stay, for example, can drive a senior patient to become a HCU.
15	Although interventions have been introduced to either prevent or divert such hospitalizations, their success
16	is unclear[7]. Further efforts are needed to examine predictors at the pre-hospital level and to identify
17	actionable cost drivers during admission [57]. At the same time, more than one tenth of senior HCUs had no
18	hospital costs. The latter subset of HCUs requires further investigation. Reducing ODB expenditures by
19	exploring pharmaceutical policy or pricing strategies (e.g. generic drug tendering) stands out as a promising
20	but challenging area to achieve potential cost reductions[58]. Canada has recently made steps to alleviate
21	the burden of drug costs by negotiating lower prices of generic and non-generic drugs with
22	manufacturers[59]. Although there may be room for further savings among generic drugs[60], these may be
23	offset by the growing share of expensive biologics coupled with just a modest uptake of biosimilars[61].
24	Finally, future cost analysis of senior HCUs could benefit from greater data granularity. Following a patient
25	longitudinally by type of care received in the incident year and time of death, for example, it may be
	19

1	possible to more precisely identify the point of HCU conversion, differentiate between outpatient and
2	inpatient costs that contribute to it, and allocate costs more with greater accuracy, including specific clinical
3	conditions (e.g., cognitive impairment among seniors) or conducting joint cost-survival modelling[62, 63].
4	
5	Conclusion
6	Costs attributable to incident senior HCU status accounted for almost one-tenth of the provincial budget.
7	Prolonged hospitalizations made a major contribution to the total incremental costs. However, categories
8	such as physician billings, drug benefits and other, in various combinations, also were important. A
9	subgroup of patients that became HCU without hospitalization requires further investigation.
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12	subgroup of patients that became HCU without hospitalization requires further investigation.
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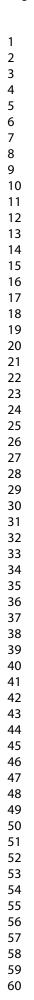
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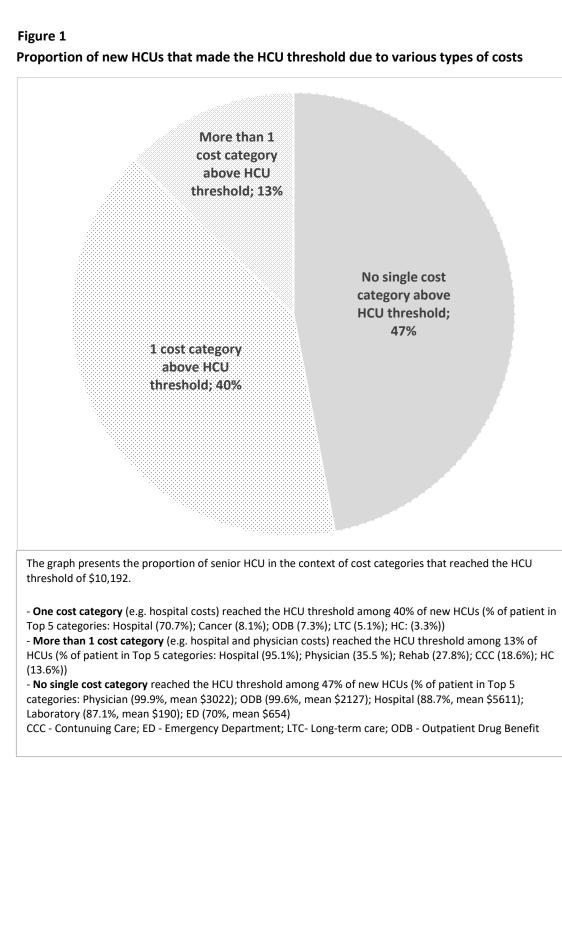
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Figure 2

Dynamics of change in annual healthcare use, before (baseline) and during incident year, by HCU status and cost categories (mean per patient)

n	on-HCU	HCU	
PHYSICIAN VISITS, ALL, baseline yr	10.1		15.4
incident yr	10.0		
General practitioner, baseline yr	5.6	8.0	
incident yr	5.5		16.1
Specialist, baseline yr	4.4	7.4	
incident yr	4.5		29.5
HOME CARE SERVICES, ALL, baseline yr	1.8	7.7	
incident yr	2.5		33.3
Personal support, baseline yr	1.5	6.4	
incident yr	1.9		22.6
Nursing, baseline yr	0.2	0.5	
incident yr	0.2	5.6	
Allied, baseline yr	0.1	0.2	
incident yr	0.2	1.8	
Other, baseline yr	0.1	0.6	
incident yr	0.2	3.2	
EMERGENCY DEPARTMENT VISITS, baseline yr	0.3	0.6	
incident yr	0.3	1.9	
HOSPITAL ADMISSION, ALL, baseline yr	0.02	0.03	
incident yr	0.02	1.1	
Unplanned, baseline yr	0.02	0.03	
incident yr	0.02	2 0.8	
Elective, baseline yr	0.00	0.00	
incident yr	0.00	0.3	

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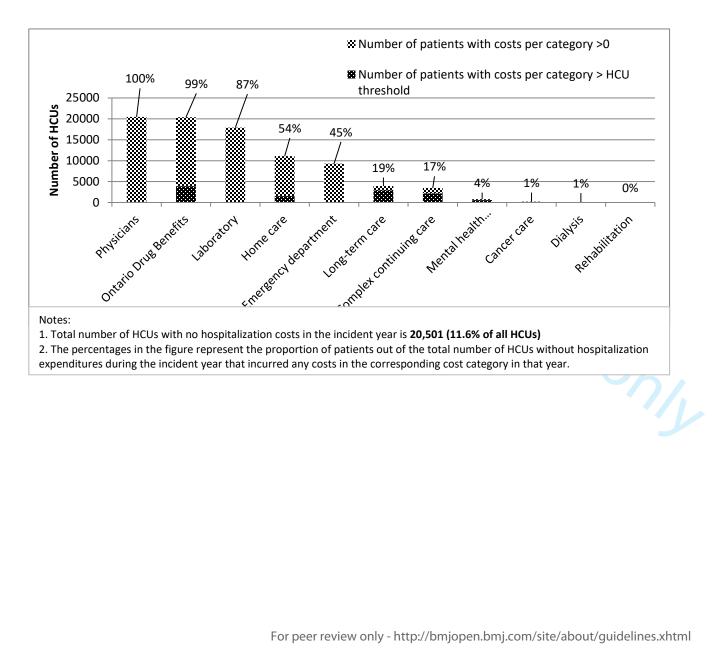
Figure 3

Dynamics of change in annual healthcare care expenditures before and after index year, by HCU status and cost categories (annual, mean per patient)

1	non-HCU OTAL COSTS per patient, mean: Baseline year: \$2,372	HCU TOTAL COSTS per patient, mean: Baseline year: \$4,166 Incident year: \$29,784	
Hospital admission, baseline	\$214	\$317	
incident	\$224	\$13	,558
Physicians, baseline	\$760	\$1,136	
incident	\$786	\$4,214	
Ontario Drug Benefits, baseline	\$823	\$1,496	
incident	\$854	\$2,456	
Home care, baseline	\$90	\$340	
incident	\$125	\$1,765	
Rehabilitation, baseline	\$0	\$1	
incident	\$0	\$1,376	
Cancer, baseline	\$3	\$14	
incident	\$4	\$1,257	
Complex continuing care, baseline	\$0	\$0	
incident	\$0	\$1,114	
Long-term care, baseline	\$1	\$10	
incident	\$2	\$1,003	
Emergency department, baseline	\$84	\$161	
incident	\$95	\$856	
Mental health admissions, baseline	\$0	\$1	
incident	\$0	\$255	
Laboratory, baseline	\$101	\$148	
incident	\$103	\$186	
Dialysis, baseline	\$0	\$1	
incident	\$0	\$104	

Appendix 1

HCUs with no hospitalization costs during incident year: contribution of cost categories



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Appendix 2

Description of cost components among HCUs and non-HCUs by pre-incident and incident year

Cost components	FY2012 (pre-incident year)			FY2013			
	HCU N=175847	ent year) Non-HCU N=527541		(inciden) HCU N=175847	Non-HCU N=527541	as	
	Mean, \$ (SD)	Mean, \$ (SD)	aSD	Mean, \$ (SD)	Mean, \$ (SD)	a	
Cancer clinics	14 (196)	4 (90)	0.54	1258 (5234)	4 (92)	0.	
Complex continuing care	1 (36)	1 (17)	0.50	1114 (7685)	1 (24)	1.	
Dialysis	2 (40)	1 (15)	0.31	104 (2166)	1 (12)	0.	
Emergency department	162 (327)	84 (226)	0.13	857 (881)	96 (249)	0	
Home care	341 (1023)	90 (498)	0.28	1765 (3667)	125 (589)	0	
Hospital admission	318 (864)	215 (714)	0.33	13558 (20529)	225 (743)	0.	
Laboratory	149 (160)	102 (123)	0.07	187 (192)	104 (125)	0	
Long-term care	11 (192)	1 (45)	0.07	1003 (4800)	3 (91)	0	
Mental health admissions	1 (60)	1 (33)	0.03	256 (3924)	1 (29)	1	
Outpatient Drug Benefits	1497 (1441)	824 (1002)	0.01	2456 (3822)	854 (1052)	0	
Physicians	1136 (821)	761 (671)	0.01	4215 (3217)	787 (694)	0	
Rehabilitation	1 (41)	1 (33)	0.01	1376 (6792)	1 (20)	0	
Total cost	4167 (2664)	2372 (2166)	0.74	29785 (29029)	2471 (2252)	1.	
aSD- absolute standardized difference; FY- fiscal year		•			•	•	
						1.	

Description of healthcare use among HCUs and non-HCUs by pre-incident and incident year

Appendix 3 Description of healthcare use amo	ng HCUs and non	-HCUs by pre- inc	BMJ Ope			i sø/pmjopen-zu ie-uzæszi on ze
Cost components	FY20			FY20		011
	(pre-incid	ent year)		(inciden	it year)	
-	HCU N=175847	Non-HCU N=527541		HCU N=175847	Non-HCU N=527541	aSE
	Mean (SD)	Mean (SD)	aSD	Mean (SD)	Mean (SD)	aSĘ
Hospital admission, All	0.04 ± 0.18	0.02 ± 0.14	0.08	1.07 ± 0.87	0.03 ± 0.15	1.6 0.8 1.2
Elective	0.01 ± 0.07	0.01 ± 0.07	0.01	0.3 ± 0.51	0.01 ± 0.07	0.8
Unplanned	0.03 ± 0.17	0.02 ± 0.13	0.08	0.8 ± 0.89	0.02 ± 0.14	1.2
Emergency department visits	0.56 ± 1.13	0.31 ± 0.8	0.26	1.88 ± 2.2	0.32 ± 0.82	0.9
Physician visits, All	15.43 ± 10.69	10.06 ± 8.9	0.55	45.62 ± 32.55	10.03 ± 8.98	1.4
General practitioner	8.03 ± 6.8	5.64 ± 5.59	0.39	16.08 ± 14.74	5.48 ± 5.56	0.9
Specialist	7.4 ± 6.65	4.43 ± 5.13	0.5	29.55 ± 25.97	4.55 ± 5.24	1.3
Home care services, All	7.74 ± 31.92	1.81 ± 14.15	0.24	33.27 ± 82.17	2.47 ± 17.33	1.3 0.5 0.4
Personal support	0.54 ± 4.03	0.16 ± 2.00	0.12	5.60 ± 18.59	0.20 ± 2.26	
Nursing	6.44 ± 30.59	1.46 ± 13.53	0.21	22.62 ± 73.93	1.91 ± 16.39	0.3
Allied	0.18 ± 0.99	0.05 ± 0.52	0.17	1.82 ± 4.27	0.15 ± 1.41	0.5
Other	0.58 ± 2.30	0.14 ± 0.96	0.25	3.22 ± 5.23	0.21 ± 1.09	0.8

aSD- absolute standardized difference; FY- fiscal year

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Appendix 4

ppendix 4																	-2018-(
egression coef	ficient	s, rec	ycled p	redicti	on, co	osts											136/bmjopen-2018-028637 on				
Care categories Covariates	ospital admission			Physician			Homecare			Ontario Drug benefits			Emergency Department			Men Cal health adgrission			Total		
	Coeff	SE	P- value	Coeff	SE	P- value	Coeff	SE	P- value	Coeff	SE	P- value	Coeff	SE	P- value	Coeff	e 影	P- value	Coeff	SE	P- valu
p(costs)=0; Intercept	1.03	0.04	<.0001	-3.52	0.08	<.0001	9.30	0.05	<.0001	-1.85	0.06	<.0001	3.91	0.03	<.0001	5.94	0.32	<.0001	-4.95	0.09	<.00
HCU status	-3.79	0.01	<.0001	-5.16	0.15	<.0001	-3.13	0.01	<.0001	-2.25	0.03	<.0001	-2.39	0.01	<.0001	-5.16	OVABII8	<.0001	- 13.88	14.60	0.3
Cost pre	0.00	0.00	<.0001	-0.01	0.00	<.0001	0.00	0.00	<.0001	-0.01	0.00	<.0001	0.00	0.00	<.0001	0.00	ade d	<.0001	-0.01	0.00	<.0
ADG	-0.09	0.00	<.0001	-0.38	0.00	<.0001	-0.04	0.00	<.0001	-0.34	0.00	<.0001	-0.09	0.00	<.0001	-0.01	fræn	0.214	-0.47	0.01	<.0
Age	0.02	0.00	<.0001	0.06	0.00	<.0001	-0.08	0.00	<.0001	0.04	0.00	<.0001	-0.02	0.00	<.0001	0.05	ntt <mark>p</mark> ://	<.0001	0.08	0.00	<.0
Sex	-0.22	0.01	<.0001	0.13	0.02	<.0001	0.34	0.01	<.0001	0.20	0.01	<.0001	0.04	0.01	<.0001	0.19	ongop	0	0.10	0.02	<.0
Low income	0.18	0.01	<.0001	0.05	0.02	0.011	-0.06	0.01	<.0001	0.59	0.02	<.0001	-0.03	0.01	<.0001	-0.18	60 06	0.003	0.32	0.02	<.0
p(costs)>0; Intercept	6.73	0.02	<.0001	6.26	0.01	<.0001	6.17	0.03	<.0001	5.41	0.01	<.0001	5.46	0.02	<.0001	7.82		<.0001	6.51	0.01	<.0
HCU status	2.27	0.00	<.0001	1.53	0.00	<.0001	0.76	0.01	<.0001	0.79	0.00	<.0001	0.88	0.00	<.0001	1.82	0 16	<.0001	2.34	0.00	<.0
Cost pre	0.00	0.00	<.0001	0.00	0.00	<.0001	0.00	0.00	<.0001	0.00	0.00	<.0001	0.00	0.00	<.0001	0.00	App <u>6</u> 0 2	0.37	0.00	0.00	<.0
ADG	-0.02	0.00	<.0001	0.03	0.00	<.0001	-0.01	0.00	<.0001	0.02	0.00	<.0001	0.01	0.00	<.0001	-0.02	201 001	<.0001	0.03	0.00	<.0
Age	0.01	0.00	<.0001	0.00	0.00	<.0001	0.01	0.00	<.0001	0.01	0.00	<.0001	0.01	0.00	<.0001	0.01	24gy	0.002	0.01	0.00	<.0
Sex	0.08	0.00	<.0001	0.05	0.00	<.0001	0.00	0.01	0.727	0.03	0.00	<.0001	0.02	0.00	<.0001	0.01	guest	0.882	0.04	0.00	<.0
Low income	0.02	0.01	0	-0.03	0.00	<.0001	0.00	0.01	0.749	0.09	0.00	<.0001	0.04	0.00	<.0001	0.07	 0405 0	0.214	0.04	0.00	<.0
log_theta	0.36	0.00	<.0001	0.79	0.00	<.0001	0.34	0.00	<.0001	0.15	0.00	<.0001	0.84	0.00	<.0001	0.24	0 60 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	<.0001	0.58	0.00	<.0

Regression coefficients, recycled prediction, costs (CONT)

Regression coeff	icients	s, recyc	led predi	iction, c	osts (C	CONT)		BW1 (Dpen						36/hminnen-2018-028637 on 28						
Care categories Covariates	Lab			Dialysis			Cancer care			Long-term care			Continuir	Ċ	D	Rehab					
	Coeff	SE	P-value	Coeff	SE	P-value	Coeff	SE	P-value	Coeff	SE	P-value	Coeff	SE SE	P-value	Coeff	SE	P-value			
p(costs)=0; Intercept	- 0.72	0.03	<.0001	7.03	0.33	<.0001	1.96	0.09	<.0001	15.60	0.13	<.0001	15.32	0.23	o .0001	13.08	0.23	<.0001			
HCU status	- 0.52	0.01	<.0001	-2.14	0.07	<.0001	-3.29	0.02	<.0001	-4.60	0.05	<.0001	-6.87	0.19	<.0001	-7.59	0.21	<.000			
Cost pre	- 0.01	0.00	<.0001	-0.03	0.00	<.0001	0.00	0.00	<.0001	0.00	0.00	<.0001	0.00	0.00	<.0001	0.00	0.00	<.000			
ADG	- 0.15	0.00	<.0001	-0.04	0.01	<.0001	0.01	0.00	0	0.03	0.00	<.0001	0.04	0.00	<.0001	0.02	0.00	<.000			
Age	0.02	0.00	<.0001	0.02	0.00	<.0001	0.05	0.00	<.0001	-0.11	0.00	<.0001	-0.07	0.00	<.0001	-0.04	0.00	<.000			
Sex	0.05	0.01	<.0001	-0.60	0.06	<.0001	-0.11	0.02	<.0001	0.42	0.02	<.0001	0.13	0.02	.0001	0.26	0.02	<.000			
Low income	0.08	0.01	<.0001	-0.39	0.07	<.0001	0.22	0.02	<.0001	-0.11	0.02	<.0001	-0.01	0.03	0.763	0.02	0.02	0.364			
p(costs)>0; Intercept	4.41	0.01	<.0001	6.22	0.44	<.0001	8.30	0.10	<.0001	7.54	0.10	<.0001	7.15	0.23	<.0001	7.54	0.19	<.000			
HCU status	0.30	0.00	<.0001	3.99	0.08	<.0001	2.76	0.02	<.0001	1.81	0.04	<.0001	2.47	0.19	<.0001	1.74	0.18	<.000			
Cost pre	0.00	0.00	<.0001	0.00	0.00	0.792	0.00	0.00	<.0001	0.00	0.00	<.0001	0.00	ر 0.00 =	0	0.00	0.00	0.48			
ADG	0.01	0.00	<.0001	-0.05	0.01	<.0001	-0.01	0.00	<.0001	-0.01	0.00	<.0001	-0.01	0.00	0.05	0.00	0.00	0.14			
Age	0.00	0.00	<.0001	0.00	0.01	0.958	-0.02	0.00	<.0001	0.01	0.00	<.0001	0.01	0.00	<.0001	0.01	0.00	<.000			
Sex	0.02	0.00	<.0001	-0.04	0.07	0.547	0.12	0.02	<.0001	-0.06	0.02	0.001	-0.01	0.02	0.665	0.10	0.02	<.000			
Low income	0.03	0.00	<.0001	-0.33	0.08	<.0001	-0.07	0.02	0.003	-0.02	0.02	0.174	0.01	0.03	0.652	0.02	0.02	0.22			
log_theta	0.81	0.00	<.0001	-0.68	0.03	<.0001	-0.07	0.01	<.0001	0.35	0.01	<.0001	0.02	0.01	0.176	0.44	0.01	<.000			

ADG- Aggregate Diagnosis Group; Coeff- regression coefficient; HCU- high-cost user; SE- standard error

Appendix 5

Regression coefficients, recycled prediction, health care use

Care categories Covariates	Hospit	Hospital admission, All			Hospital admission, urgent			Hospital admission, elective			Physician visits, All			Physician vijts, Specialists			Physician visits, General practitioner		
	Coeff	SE	P-value	Coeff	SE	P-value	Coeff	SE	P-value	Coeff	SE	P-value	Coeff	SE	P-value	Coeff	SE	P-value	
p(event) ≠0; Intercept	0.57	0.05	<.0001	-8.08	0.05	<.0001	4.07	0.06	<.0001	7.74	0.15	<.0001	4.80	0.05	01 9 9 9	4.03	0.06	<.0001	
HCU status	5.11	0.01	<.0001	4.48	0.01	<.0001	4.66	0.02	<.0001	5.60	0.14	<.0001	3.78	0.03	0 <.0001	2.71	0.03	<.000	
Pre-incident value	0.78	0.03	<.0001	0.82	0.03	<.0001	0.80	0.07	<.0001	0.40	0.00	<.0001	0.29	0.00	load <.0001	0.62	0.00	<.0002	
Age	0.01	0.00	<.0001	0.05	0.00	<.0001	-0.07	0.00	<.0001	-0.05	0.00	<.0001	-0.03	0.00	0 6 6	-0.04	0.00	<.0002	
ADG	0.00	0.00	0.002	0.00	0.00	<.0001	0.00	0.00	0.006	0.38	0.00	<.0001	0.25	0.00	B <.0001	0.26	0.00	<.0002	
Sex	0.08	0.01	<.0001	0.12	0.01	<.0001	0.05	0.01	<.0001	-0.13	0.01	<.0001	-0.12	0.01	<.0001	-0.12	0.01	<.0002	
Low income	-0.04	0.01	6E-04	0.17	0.01	<.0001	-0.40	0.02	<.0001	-0.20	0.02	<.0001	-0.20	0.01	.0001	-0.16	0.01	<.0001	
p(event) >0; Intercept	-2.16	0.07	<.0001	-6.77	0.19	<.0001	-1.37	0.20	<.0001	3.02	0.01	<.0001	3.10	0.01	- <.0001	1.41	0.01	<.000	
HCU status	4.21	0.13	<.0001	4.62	0.17	<.0001	2.59	0.28	<.0001	1.33	0.00	<.0001	1.63	0.00	e <.0001	0.91	0.00	<.0002	
Pre-incident value	0.39	0.03	<.0001	0.42	0.03	<.0001	0.71	0.11	<.0001	0.03	0.00	<.0001	0.04	0.00	o <.0001	0.06	0.00	<.000	
Age	0.01	0.00	<.0001	0.01	0.00	<.0001	-0.01	0.00	0.041	0.00	0.00	<.0001	0.00	0.00	0.0001	0.01	0.00	<.000	
ADG	0.02	0.00	<.0001	0.03	0.00	<.0001	0.00	0.00	0.268	0.02	0.00	<.0001	0.02	0.00	0 <.0001	0.02	0.00	<.000	
Sex	0.19	0.01	<.0001	0.11	0.01	<.0001	0.29	0.03	<.0001	0.02	0.00	<.0001	0.06	0.00	24 <.0001 P	-0.01	0.00	<.000	
Low income	0.07	0.01	<.0001	0.06	0.02	0.0004	-0.04	0.05	0.45	0.01	0.00	<.0001	-0.02	0.00	<u>4</u> 9 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5	0.05	0.00	<.000	
Scale parameter	1.51	0.08		0.60	0.04	<.0001	0.00	0.00		0.32	0.00		0.49	0.00	<u>4</u>	0.36	0.00		

ADG- Aggregate Diagnosis Group; Coeff- regression coefficient; HCU- high-cost user; SE- standard error

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Regression coefficients, recycled prediction, health care use (CONT)

Care categories Covariates	Emerge	Emergency department visits			Home care services, All*			Home care services, Personal support			e care se Nursin		Home care services, Allied			Home care services, Other*		
	Coeff	SE	P-value	Coeff	SE	P-value	Coeff	SE	P-value	Coeff	SE	P-value	Coeff	SE	다 역 value	Coeff	SE	P-value
p(event) ≠0; Intercept	-1.58	0.03	<.0001	-9.51	0.05	<.0001	-9.22	0.07	<.0001	-3.04	0.05	<.0001	-7.21	0.05	0_<.0001 .00	-9.28	0.05	<.000
HCU status	2.40	0.01	<.0001	3.11	0.01	<.0001	2.97	0.01	<.0001	3.06	0.01	<.0001	2.71	0.01	Q<.0001	3.07	0.01	<.000
Pre-incident value	0.39	0.00	<.0001	0.08	0.00	<.0001	0.09	0.00	<.0001	0.11	0.00	<.0001	0.26	0.00	load	0.58	0.00	<.000
Age	0.02	0.00	<.0001	0.08	0.00	<.0001	0.09	0.00	<.0001	0.02	0.00	<.0001	0.07	0.00	a<.0001 To	0.08	0.00	<.000
ADG	0.09	0.00	<.0001	0.05	0.00	<.0001	0.02	0.00	<.0001	0.02	0.00	<.0001	0.04	0.00		0.05	0.00	<.000
Sex	0.04	0.01	<.0001	-0.34	0.01	<.0001	-0.47	0.01	<.0001	0.12	0.01	<.0001	-0.45	0.01		-0.34	0.01	<.000
Low income	0.04	0.01	<.0001	0.04	0.01	<.0001	0.15	0.01	<.0001	-0.10	0.01	<.0001	-0.01	0.01	0.600	0.08	0.01	<.000
p(event) >0; Intercept	-0.02	0.03	0.658	0.52	0.00	<.0001	-0.70	0.14	<.0001	2.40	0.06	<.0001	0.20	0.05		-0.47	0.01	<.000
HCU status	0.97	0.01	<.0001	0.74	0.00	<.0001	0.62	0.03	<.0001	0.76	0.02	<.0001	0.24	0.01	.0001	0.74	0.00	<.000
Pre-incident value	0.21	0.00	<.0001	0.01	0.00	<.0001	0.01	0.00	<.0001	0.03	0.00	<.0001	0.02	0.00	o <.0001	0.03	0.00	<.00
Age	0.00	0.00	0.179	0.03	0.00	<.0001	0.02	0.00	<.0001	0.00	0.00	<.0001	0.01	0.00	pr:<.0001	0.02	0.00	<.00
ADG	0.03	0.00	<.0001	0.00	0.00	<.0001	-0.01	0.00	0.001	0.00	0.00	0.091	0.02	0.00	0, ,0, ,0001 N 00	0.00	0.00	<.000
Sex	0.09	0.01	<.0001	-0.13	0.00	<.0001	-0.07	0.02	0.006	-0.03	0.01	0.011	-0.11	0.01	24<.0001 5	0.00	0.00	0.32
Low income	0.02	0.01	0.005	0.05	0.00	<.0001	-0.06	0.03	0.026	0.03	0.02	0.061	-0.14	0.01	gue;	0.04	0.00	<.00
Scale parameter	1.09	0.02					115.73	0.00		2.12	0.02		1.01	0.01	. 			

*-models were fit using Poisson distribution

ADG- Aggregate Diagnosis Group; Coeff- regression coefficient; HCU- high-cost user; SE- standard error

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```
2
3
          SAS script for a macro to apply the recycled prediction method. The
4
          script A below is for cost data. For count data, please see Note 1 in
5
          the text as well as subsections A1 and A2 below.
6
7
          Α.
8
          %macro boot(varname= , rep=);
9
10
          %let var1 = &varname. post;
11
          %let var2 = &varname. pre;
12
13
          proc datasets lib=work;
14
                delete rslt all &varname.;
15
          run;
16
17
          %do i=1 %to &rep;
18
19
          ods results off;
20
          ods exclude all;
21
22
          data type.hcu;
          set increment (rename=(hcu=hcustatus));
23
24
          hcu=1;
25
          &var1.=.;
26
          run;
27
          data type.nhcu;
28
          set increment (rename=(hcu=hcustatus));
29
          hcu=0;
30
          &var1.=.;
31
          run;
32
33
          data type.recycled;
34
          set increment type.hcu type.nhcu;
35
          keep ikn &var1. &var2. hcu hcustatus age sex n adg lowinc;
36
          run;
37
38
          proc surveyselect data=type.recycled out=type.boot method=urs
39
          samprate=1 outhits reps=1;
40
          run;
41
42
          /*NOTE 1: Fitting a two-part model for costs using NLMIXED assuming
43
          gamma distribution. This part is replaced when count data is fit,
44
          assuming either negative binomial or Poisson. For additional code,
45
          please see below: A-NB; B-Poisson*/
46
47
          proc nlmixed data=type.boot qpoints=1;
48
          parms a0=0 a1=0 a2=0 a3=0 a4=0 a5=0 a6=0
49
          b0=0 b1=0 b2=0 b3=0 b4=0 b5=0 b6=0 log theta=0;
50
51
          eta=a0+a1*hcu+a2*&var2.+a3*n adg+a4*age+a5*sex+a6*lowinc;
52
          exp eta0=exp(eta);
53
          p0=exp eta0/(1+exp eta0);
54
          etah=b0+b1*hcu+b2*&var2.+b3*n adg+b4*age+b5*sex+b6*lowinc;
55
          mu=exp(etah);
56
          theta=exp(log theta);
57
58
59
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60
```

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```
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```

```
r=mu/theta;
if &var1.=0 then ll=log(p0);
else ll=log(1-p0)-lgamma(theta)+(theta-1)*log(&var1.)-theta*log(r)-
&var1./r;
model &var1.~general(11);
predict (1-p0)*mu out=type.pred (keep=ikn hcu hcustatus &var1. pred);
run;
proc means data=type.pred;
where hcustatus ne .;
class hcu; var pred;
output out=type.rslt mean=;
run;
proc transpose data=type.rslt out=type.rslt tr(rename=(col2=nHCU
col3=HCU) drop= label col1) ;
var pred;
run;
proc append base=rslt all &varname. data=type.rslt tr force; run;
%end;
data type.delta;
set rslt all &varname.;
delta=HCU-nHCU;
run:
ods results on;
ods exclude none;
ods html file="/increment/results/incr.&varname..xls";
title "&varname.&rep";
proc univariate data=type.delta;
var delta;
output out=type.pctl &varname. pctlpre=CI pctlpts=2.5,
                                                        97.5;
run;
proc print data=type.pctl &varname.;
run;ods html close;
%mend boot;
options symbolgen mprint mcompile ;
%boot(varname=type cost, rep=1000);
```

```
1
2
3
4
5
             A1. /*truncated Negative Binomial*/
6
          proc nlmixed data=incr count;
7
          parms a0=0 a1=0 a2=0 a3=0 a4=0 a5=0 a6=0
8
          b0=0 b1=0 b2=0 b3=0 b4=0 b5=0 b6=0 v=1;
9
          eta0=a0+a1*hcu1+a2*&var2.+a3*n adg+a4*age+a5*sex1+a6*lowinc1;
10
          p0=1/(1+exp(-eta0));
11
12
          etap=b0+b1*hcu1+b2*&var2.+b3*n adg+b4*age+b5*sex1+b6*lowinc1;
13
          exp etap=exp(etap);
14
15
          p=1/(1+(1/v) + exp etap);
16
          if &var1. =0 then ll=log(p0);
17
          else ll= \log(1-p0) + \&var1.*\log(1-p) - \log(p**(-1*(v)) - 
18
          1) +lgamma(&var1.+(v)) -lgamma(v) -log(fact(&var1.));
19
          model &var1. ~ general(ll);
20
          predict exp_etap out=admit.pred_trnb (keep=ikn hcu &var1. pred rename
21
22
          = (pred=nb));
23
          ods output parameterestimates=pezph;
24
          ods output fitstatistics=fit1;
25
          run;
26
27
28
             A2. /*truncated Poisson*/
29
          proc nlmixed data=incr count;
30
          parms a0=0 a1=0 a2=0 a3=0 a4=0 a5=0 a6=0
31
          b0=0 b1=0 b2=0 b3=0 b4=0 b5=0 b6=0 ;
32
33
          eta0=a0+a1*hcu1+a2*&var2.+a3*n adg+a4*age+a5*sex1+a6*lowinc1;
34
          p0=1/(1+exp(-eta0));
35
          etap= b0+b1*hcu1+b2*&var2.+b3*n adg+b4*age+b5*sex1+b6*lowinc1;
36
          exp etap=exp(etap);
37
38
          if &var1. =0 then ll=log(p0);
39
          else ll= log(1-p0)-log(1-exp(-exp etap))-exp etap-lgamma(&var1.+1)
40
          +&var1.*log(exp etap);
41
          model &var1. ~ general(ll);
42
          predict exp etap out=gp.pred trp (keep=ikn hcu hcustatus &var1. pred
43
          rename = (pred=poi));
44
          ods output parameterestimates=pezph;
45
          ods output fitstatistics=fit1;
46
47
          run;
48
49
50
51
52
53
54
55
56
57
```

	Item No	Recommendation	Page No
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the	1
		abstract	
		(b) Provide in the abstract an informative and balanced summary of what was	4
		done and what was found	
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being	5
		reported	
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	6-10
Setting	5	Describe the setting, locations, and relevant dates, including periods of	7
		recruitment, exposure, follow-up, and data collection	
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of	7
		participants. Describe methods of follow-up	
		(b) For matched studies, give matching criteria and number of exposed and	
		unexposed	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and	8-9
		effect modifiers. Give diagnostic criteria, if applicable	
Data sources/	8*	For each variable of interest, give sources of data and details of methods of	6,8,9
measurement		assessment (measurement). Describe comparability of assessment methods if	
		there is more than one group	
Bias	9	Describe any efforts to address potential sources of bias	9-10
Study size	10	Explain how the study size was arrived at	6-7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable,	8-10
		describe which groupings were chosen and why	
Statistical methods	12	(a) Describe all statistical methods, including those used to control for	9-10
		confounding	
		(b) Describe any methods used to examine subgroups and interactions	
		(c) Explain how missing data were addressed	
		(d) If applicable, explain how loss to follow-up was addressed	
		(<u>e</u>) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers	11
i urterpunts	15	potentially eligible, examined for eligibility, confirmed eligible, included in the	
		study, completing follow-up, and analysed	
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social)	11
Descriptive data	17	and information on exposures and potential confounders	
		(b) Indicate number of participants with missing data for each variable of	1
		(b) indicate number of participants with missing data for each variable of interest	
		morosi	
		(c) Summarise follow-up time (eg, average and total amount)	

Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and	12-13
		their precision (eg, 95% confidence interval). Make clear which confounders were	
		adjusted for and why they were included	
		(b) Report category boundaries when continuous variables were categorized	
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a	
		meaningful time period	
Other analyses	17	Report other analyses done-eg analyses of subgroups and interactions, and sensitivity	Appendix
		analyses	1
Discussion			
Key results	18	Summarise key results with reference to study objectives	15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or	17-18
		imprecision. Discuss both direction and magnitude of any potential bias	
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations,	16,17,18
		multiplicity of analyses, results from similar studies, and other relevant evidence	
Generalisability	21	Discuss the generalisability (external validity) of the study results	18
Other information	on		
Funding	22	Give the source of funding and the role of the funders for the present study and, if	3
		applicable, for the original study on which the present article is based	

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

BMJ Open

Incremental Healthcare Utilization and Costs Among New Senior High Cost Users in Ontario, Canada: a retrospective matched cohort study

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Secondary Subject Heading:	Health economics, Health policy
Keywords:	Health policy < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, GERIATRIC MEDICINE, HEALTH ECONOMICS

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1		
2	1	Incremental Healthcare Utilization and Costs Among New Senior High Cost Users in
3 4	2	Ontario, Canada: a retrospective matched cohort study
5 6	3	Sergei Muratov ¹ , Justin Lee ^{1,2} , Anne Holbrook ^{1,3} , Jason R Guertin ^{5,6} , Lawrence Mbuagbaw ¹ , J Michael
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39		
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45 46	27	
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Authors' contributions:

SM, JET, AH, JL, JMP, TG, LM, JRG conceptualized the study. SM, JET, AH, JL, JRG, LM, JMP, TG, PP have contributed to its design. JMP, PP, TG were instrumental in creating datasets. PP provided assistance with data analysis. SM prepared the initial draft of the manuscript and revised it based on co- authors' feedback: JET, AH, JL, JMP, TG, JRG, LM, PP provided comments to the initial draft, further revisions, read and approved the final manuscript. The responsibility of study implementation lies with the principal ort investigator (SM) that is supported and supervised primarily by JET.

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Competing Interests:

None declared.

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Data sharing:
The dataset from this study is held securely in coded form at the Institute for Clinical Evaluative Sciences
(ICES). While data sharing agreements prohibit ICES from making the dataset publicly available, access may
be granted to those who meet pre-specified criteria for confidential access, available at
http://www.ices.on.ca/DAS. The full dataset creation plan is available from the authors upon request.
Analytic codes (in SAS) used to conduct the analysis are available as supplemental material.
http://www.ices.on.ca/DAS. The full dataset creation plan is available from the authors upon request. Analytic codes (in SAS) used to conduct the analysis are available as supplemental material.

Objectives: To describe healthcare use and spending before and on becoming a new (incident) senior HCU

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Abstract

compared with senior non-HCUs; to estimate the incremental costs, overall and by service category, attributable to HCU status; and to quantify its monetary impact on the provincial healthcare budget in Ontario, Canada. Design: We conducted a retrospective, population-based comparative cohort study using administrative healthcare records. Incremental healthcare utilization and costs were determined using the method of recycled predictions allowing adjustment for pre-incident and incident year values, and covariates. Estimated budget impact was computed as the product of the mean annual total incremental cost and the number of senior HCUs. **Participants**: Incident senior HCUs were defined as Ontarians aged ≥ 66 years who were in the top 5% of healthcare cost users during fiscal year 2013 (FY2013) but not during fiscal year 2012 (FY2012). The incident HCU cohort was matched with senior non-HCUs in a ratio of 1 HCU :3 non-HCU. Results: Senior HCUs (n=175,847) reached the annual HCU threshold of \$10,192 through different combinations of incurred costs. Although HCUs had higher healthcare utilization and costs at baseline, HCU status was associated with a substantial spike in both, with prolonged hospitalizations playing a major role. Twelve percent of HCUs reached the HCU expenditure threshold without hospitalization. Compared to non-HCUs (n=527,541), HCUs incurred an additional \$25,527 per patient in total healthcare costs; collectively \$4.5 billion or 9% of the 2013 Ontario healthcare budget. Inpatient care had the highest incremental costs: \$13,427, 53% of the total incremental spending. **Conclusions:** Costs attributable to incident senior HCU status accounted for almost one-tenth of the provincial healthcare budget. Prolonged hospitalizations made a major contribution to the total incremental costs. A subgroup of patients that became HCU without hospitalization requires further investigation. For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml

 This population-based study examines incident (new) senior high-cost users (HCU), which provides important information on the driving factors for HCU status Inclusion of all incident senior HCU in the province into the study population allowed us to calculate their monetary impact on the provincial healthcare budget This analysis includes a comprehensive spectrum of the most important cost categories that contribute to total public healthcare expenditures in the province Limitations Despite the comprehensiveness of cost analyses, a few of the cost categories may not have been captured in full, e.g. outpatient intravenous chemotherapy The findings, especially with respect to the total incremental costs and the budget impact, are only comparable to studies with the same HCU threshold and the choice of cost categories 	1 2	1	Strengths
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1 Introduction

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2	Healthcare spending has more than doubled in the countries of the Organization for Economic Cooperation
3	and Development (OECD) over the past two decades[1]. In Canada, where public health and health care are
4	under provincial jurisdiction, health spending accounts for 37% of the total provincial program spending on
5	average [2]. Much of the spending is disproportionately attributed to a small but heterogenous group of
6	patients, commonly referred to as high-cost healthcare users (HCU)[3-5]. The pressing need to control
7	healthcare spending and the inconclusive evidence and varying success of clinical interventions targeting
8	the HCU group[6, 7] have prompted policy makers to revise their management strategies and to seek
9	specific segments of the HCU population who may benefit from certain interventions more than others[4, 8,
10	9].

11 Incident (or new) senior HCUs represent one such segment whose patient care characteristics and spending 12 patterns have not been well studied. A recent systematic review identified 55 studies published over the 13 past two decades that reported HCU characteristics and healthcare utilization[5]. The vast majority (n=42) 14 of the publications originated from the US, 9 were from Canada, 3 were generated by researchers from 15 European countries, and 1 was from Taiwan. Compared to 9 US-based studies of the Medicare (i.e., senior) population, only the study from Taiwan among the others had a specific focus on seniors, even though 16 17 approximately 45-55% of senior healthcare care resources are reportedly consumed by senior HCUs in 18 various jurisdictions[10-12]. Moreover, these studies do not differentiate between prevalent (who retain 19 the HCU status over years) and incident senior HCUs. This is important, as understanding the path to HCU 20 status may identify opportunities for intervention[4]. Further, it is well known that senior HCUs, both 21 prevalent and incident, generally have poor functional status and consume a high level of healthcare 22 resources, including typically reported acute inpatient care and physician services[7, 13, 14]. However, 23 comprehensive descriptions of cost drivers to HCU status are few[10, 15]. A recent example is a study 24 conducted in Ontario, the largest province in Canada, which presented a system-wide assessment of cost

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	1	concentration among HCUs over 3 years using both longitudinal and cross-sectional approaches to their
:	2	analysis[10]. While providing valuable information on the transition of patients between various cost strata,
:	3	their longitudinal analyses focused on the persistence of costs among all HCUs. Their cross-sectional analysis
	4	of expenditures by cost category was limited by only reporting on the top 1% of HCUs and was not stratified
!	5	by age. Another poorly explored aspect of HCU cost analysis is the economic burden associated with HCU
(6	status, which remains largely unknown in Canada and elsewhere. While some international studies have
	7	compared costs between HCUs and non-HCU cohorts in a particular year using a cross-sectional design[3,
:	8	16, 17], these comparative studies did not consider any secular trends over time (e.g. costs in the years
9	9	before the incident year). This limits our understanding of the true incremental costs of becoming a new
10	0	HCU, especially among seniors.
1	1	We recently reported on a cohort of incident senior HCUs compared to matched non-HCUs to examine
1		regional variation in mortality and costs in Ontario using cross-sectional data[18]. Here we aim to
1		determine the incremental healthcare utilization and costs among new senior HCUs in Ontario by looking at
14		the same data longitudinally. The main objectives of this study were to 1) describe healthcare use and
1		spending before and on becoming a senior HCU compared with senior non-HCUs; 2) estimate costs and
1		healthcare use attributable to the incident senior HCU status, and to 3) quantify the monetary impact of
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13	8	Methods
19	9	Ethics Approval
20	0	This study was approved by Hamilton Integrated Research Ethics Board (ID#1715-C).
2	1	Study design
2	2	We conducted a retrospective population-based matched cohort study using administrative healthcare data
2	3	from Ontario, Canada. The protocol for this research has been published[19].
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1 Setting and data sources

2 Ontario is Canada's most populous province, with almost 14 million residents (approximately 40% of the

- 3 Canadian population)[20]. The Ontario Ministry of Health and Long-Term Care (MOHLTC) pays for
- 4 approximately 70% of health care provided in the province. This includes nearly 100% of hospital care,
- 5 physician services, and prescription drugs for seniors[21].
- 6 A patient-level dataset was created by linking 19 health administrative databases[19] using unique encoded
- 7 identifiers at ICES (www.ices.on.ca). ICES is an independent, non-profit research corporation funded by the
- 8 Ontario MOHLTC. The Ontario government fiscal year 2013 (April 1, 2013 and March 31, 2014) was
- 9 considered the incident year (FY2013). Fiscal year 2012 (FY2012: April 1, 2012 and March 31, 2013) was the
- 10 baseline or pre-incident year.

11 Study population

Incident senior HCUs were defined as individuals aged 66 years or above with annual total healthcare expenditures in the top 5% of all Ontarians in FY2013, who were not in the top 5% healthcare users in FY2012. The 5% threshold is commonly reported in HCU studies in Canada and elsewhere[10, 14, 22, 23]. The >66 year age threshold was applied to capture Ontario Drug Benefit (ODB) expenditures for at least one year before the incident year: ODB coverage starts automatically when Ontarians reach 65 years of age[24]. The "non-HCU" cohort included those whose annual total health care expenditures in FY2012 and FY2013 were below the top 5% threshold in both years. The incident HCU cohort was matched with non-HCU in a ratio of 1 HCU :3 non-HCUs by age at the cohort entry (within 1 month), sex and Local Health Integration Network (LHIN) of patient residence. LHINs, Ontario's 14 regional health districts, are responsible for the planning and administration of most of hospital- and community-based health services delivered within their geographic boundaries[25].

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1 2 3	1	Variables
4 5	2	Our dataset included key information on socio-demographic and health status, healthcare utilization and
6 7 8	3	costs. Described in the study protocol[19] in more detail, key variables are briefly summarized below.
9 10 11	4	Socio-demographic status included age, sex, low income status, and geography of residence
12 13	5	(urban/suburban/rural). Low income status was based upon net household income reported to receive ODB
14 15	6	subsidy in FY2012. Rurality was based on the Rurality Index for Ontario (RIO) which is a scale from 0 to 100.
16 17	7	A RIO between 0 and 9 defined an individual from the urban area, between 10 and 40 described a suburban
18 19 20	8	resident, and a resident from a rural area had a RIO score of 40 and above[26].
21 22 23	9	Health status was assessed using several variables. We used two tools derived from Johns Hopkins Adjusted
24 25	10	Clinical Groups (ACG [®]) System, Version 10, a case-mix methodology to describe a population's healthcare
26 27	11	utilization looking back for 3 years prior to the incident year[27]. First, the general degree of comorbidity
28 29	12	was captured by the number of Johns Hopkins Aggregated Diagnosis Groups (ADGs): person-focused,
30 31	13	diagnosis-based method to measure patients' illness by assigning individual ACGs into diagnosis
32 33 34	14	clusters[28]. A higher number of ADGs per patient indicates a greater burden of illness. In addition, we
35 36	15	identified the proportion of patients with a history of hypertension, malignancy, and mental health
37 38	16	condition using John Hopkins Expanded Diagnosis Clusters (EDCs). For each condition, we checked whether
39 40	17	the patient was diagnosed with the condition in the 3 years prior to FY2013. Finally, we used validated
41 42 43	18	administrative data case definitions to identify whether the patient had a history of several common chronic
44 45	19	diseases, including congestive heart failure, diabetes, and chronic obstructive pulmonary disease[29, 30].
46 47	20	The choice of specific conditions used to describe patients was driven by several factors: 1) chronic
48 49	21	conditions that are commonly associated with high economic burden (cardiovascular and pulmonary
50 51 52	22	diseases, malignancy) [31-33]; 2) conditions that are well known risk factors (e.g., hypertension, diabetes);
52 53 54 55 56 57	23	3) availability of data.

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Whereas socio-demographic characteristics and health status were captured at baseline, healthcare utilization and expenditures were obtained for the full two years of study. Utilization variables included the number of hospitalizations (all, elective and unplanned), emergency department (ED) visits, physician encounters, and publicly funded home care services. Home care services were subclassified by type of service: nursing, personal support, and allied health. For each hospitalization, we obtained the total length of stay (TLOS), in days.

Health care expenditures were estimated using ICES person-level health utilization costing algorithms, [34] which report expenditures according to twelve health service cost categories. Hospital costs were the sum of costs associated with acute inpatient care and same-day surgery. Mental health admissions were costed separately. Physician expenditures were the sum of fee-for-service billings and capitation payments. The cost categories also separately included publicly funded long-term homes, inpatient rehabilitations services, community home care, and admissions to complex continuing care. Costs were expressed in 2013 Canadian 2/18 Dollars.

Outcomes

The primary outcome measures were 1) one-year incremental healthcare utilization for hospital admissions (total and by types such as unplanned and elective), emergency visits, physician encounters (total and separately for specialists and general practitioners [GP]), and home care services (total and by type); 2) one-year incremental costs attributable to becoming an HCU (total healthcare expenditures and by cost category); and 3) provincial budget impact of new senior HCUs in FY2013. Incremental healthcare use and costs were calculated as the difference between the two cohorts over one-year period. They represent additional mean visits made or costs incurred by a HCU in the incident year compared with a non-HCU and the baseline year. Statistical analysis

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Baseline patient socio-demographic and health status characteristics of the two cohorts in FY2012 were compared using the absolute standardised difference (aSD), with aSD>0.1 indicating a meaningful difference[35]. We then described the HCU cohort in the context of cost categories and their contribution to the HCU status by calculating the proportion (%) of HCU in each cost category. Since we expected hospitalizations to be a frequent cause of new HCU status, we repeated this analysis for HCUs who were not hospitalized during the incident year to evaluate the contributions of cost drivers other than hospital admission. This was followed by a longitudinal comparison of the unadjusted healthcare use and costs in both cohorts for both the incident year and the preceding year. Incremental healthcare use and costs were estimated using the recycled predictions method [36-39]. Commonly used to evaluate the marginal effect of a covariate on the response variable, the method uses fitted regression models to predict incremental values of the outcomes in two hypothetical populations: one where all subjects are HCU and another where all are non-HCU, all the other covariates being the same. The difference in predicted means between the two populations indicates the incremental value. The method allows for correlation between outcome values in the year before the index year (FY2012) and after the index year (FY2013), while comparing HCU with non-HCU. Confidence intervals (CI) of the incremental values was obtained through the percentile method: random bootstrap resampling with 1000 iterations created a distribution where the 2.5th and 97.5th percentiles were the 95% lower and upper bound Cls, respectively [39]. We used generalized linear regression to model the study outcomes. Costs were modeled with gamma distribution and log-link function to handle the right-skewed data[40, 41]. The choice of gamma distribution

- 21 was confirmed by the modified Park test[42]. For count data (e.g., hospital admissions or home care visits),
 - 22 a negative binomial (NB) distribution was specified as the leading option to better account for
- 23 overdispersion (i.e., observed variance is greater than the assumed variance)[43, 44]. In cases of a NB model
- 24 not converging, Poisson distribution was used. For both costs and count data, we used two-part models

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1	(Hurdle regression) to manage zero values in the response variables: the first part used a logistic regression
2	to predict the probability of positive values of the outcome, while a gamma or a negative binomial model
3	was applied in the second stage for positive costs and counts, respectively[43, 45]. All the models were
4	adjusted for previous resource use (e.g., costs or healthcare use in FY2012), age, sex, ADGs, and low-income
5	status. Because our dataset included all senior HCU subjects in the province at the time of the study, we
6	were able to estimate the total provincial public healthcare expenditures attributable to HCU status among
7	Ontario seniors by multiplying the total incremental costs by the total number of senior HCU. Statistical
8	analyses were conducted using SAS version 9.4.3 (SAS Institute Inc., Cary, NC). The SAS scripts are available
9	as supplemental material.
10	Patient and Public Involvement
11	Patients or public were not involved in the design of this retrospective cohort study.
12	Results
13	Patient characteristics
14	The total study population consisted of 703,388 seniors, of which 175,847 were incident HCUs. This
15	population of incident HCUs represents 46% of all HCUs in FY2013 (n= 383,257) but only 9.4% of the Ontario
16	senior population and 1.4% of the total population in the province[20]. As expected, the mean ages of the
17	HCU and non-HCU cohorts were identical at 77.7 years (standard deviation (SD) 7.7); 53% were women; and
18	most resided in suburban areas (12.2 vs. 11.8, aSD=0.02) (Table 1). Compared to non-HCUs, HCUs had
19	poorer health status as defined by both the number of aggregated diagnosis groups (10.2 vs. 7.9, aSD=0.54)
20	and higher prevalence of chronic diseases. A relatively greater percentage of HCU cohort members had a
21	primary care provider (97% vs. 88.6%, aSD=0.33).
22	Table 1 Patient characteristics

CharacteristicHCU (N=175,847)	Non-HCU (N=527,541)	aSD
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Age, mean (SD), yr	77.7 ± 7.7	77.7 ± 7.7	(
Sex, female	93,119 (53%)	279,501 (53%)	(
Rural Index of Ontario score, mean (SD)	12.2 ± 18.2	11.8 ± 18.2	0.
Low income	31,843 (18.1%)	92,566 (17.5%)	0.
Health Status			
# Adjusted Diagnostic Groups, mean (SD)	10.2 ± 4.0	7.9 ± 4.5	0.
Hypertension ^{\$}	110,692 (63.0%)	282,867 (53.6%)	0.
Congestive Heart Failure [#]	25,195 (14.3%)	36,877 (7.0%)	0.
Chronic Obstructive Disease Pulmonary#	48,738 (27.7%)	96,513 (18.3%)	0.
Diabetes#	62,014 (35.3%)	138,794 (26.3%)	0
Myocardial infarction#	12,892 (7.3%)	24,024 (4.6%)	0.
Rheumatoid Arthritis [#]	5,607 (3.2%)	9,334 (1.8%)	0.
Malignancy ^{\$}	56,855 (32.3%)	123,932 (23.5%)	0
Mental Health condition ^{\$}	67,441 (38.4%)	144,377 (27.4%)	0.

#- ICES-derived cohort

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

2 <u>HCU status</u>

3 The 5% HCU annual threshold for this study was \$10,192. As shown in Figure 1, patients could become HCU

4 through different combinations of incurred costs. Approximately 40% of the HCU became a HCU (i.e.,

5 incurred at least \$10,192 in total annual healthcare expenditures) due to a single cost category,

6 predominantly hospital admissions (70.1%). For 13% of the HCUs, more than one cost category was above

7 the threshold (e.g., hospital admission and rehabilitation costs). Among the remaining 47%, no single cost

8 category was sufficient to meet the expenditure threshold for HCU status: HCU status was achieved through

9 expenditures in several cost categories. In this case, the most common contributing categories were

10 physician compensation, drug benefits, and hospitalization.

11 As many as 11.7% (N=20,501) of the HCU were not hospitalized during the incident year (Appendix 1). Their

new HCU status was mainly due to a combination of physician compensation (99.8%), ODB (99.4%), and

13 laboratory test costs (87.3%), home care (54.1%) and emergency department visits (45.3%). Of note, some

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of the patients within several cost categories had costs high enough for the patient to become a HCU.
Examples include 72.3% of patients in long-term care, 63.4% of patients with cancer care, and 19.1% of
patients with drug costs.

4 Dynamics of change in healthcare use and costs

Analysis of observed healthcare utilization in the two cohorts identifies an upward trajectory in health
services consumption among senior HCU. As shown in Figure 2, compared to non-HCU, the HCU consumed
more services in the pre-incident year across all care categories: physician encounters (mean per patient:
15.4 vs. 10.1, aSD=0.55), home care visits (mean per patient: 7.7 vs. 1.8; aSD=0.24), emergency department
(ED) visits (mean per patient: 0.6 vs. 0.3; aSD=0.26), and hospital admissions (mean per patient: 0.04 vs.
0.02; aSD=0.08). This was followed by a dramatic increase in healthcare use among senior HCU during

11 FY2013, while the service consumption among non-HCU remained relatively unchanged.

Similarly, the total public healthcare expenditures among senior HCU were higher in the pre-incident year compared to non-HCU (mean per patient: \$4,166 vs. \$2,372, aSD=0.74), followed by a substantial spike during the incident year (\$29,784 vs. \$2,471; aSD=1.33) (Figure 3). While the major drivers of total costs were analogous in the two cohorts in the year before (in descending order: drug benefits, physician costs, hospital admissions or home care), the top contributors in the HCU cohort changed during the incident year. With an annual mean of 1.07 of hospital admissions (mean TLOS: 8.8 (SD 14.8)) among senior HCU compared to a mean of 0.03 admissions (mean TLOS: 2.8 (SD 9.6)) for non-HCUs in FY2013, prolonged hospitalizations were the major driver of total healthcare expenditures (\$13, 558) in the incident year. These were followed by physician (\$4,214) and ODB costs (\$2,456). In categories such as rehabilitation, complex continuing care, dialysis, and mental health admissions, the costs incurred by senior HCUs at baseline and non-HCUs across both years were approximating zero: these categories were almost exclusively associated with the HCU status. Little change in the list of major cost drivers and the trajectory of costs over time was noticeable among non-HCU seniors. More detail is provided in Appendices 2 and 3.

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2	Incremental costs and healthcare use	
3	Table 2 shows the magnitude of incremental healthcare	e use by senior HCU during the incident year
4	adjusting for the pre-incident values and other covariat	es. Compared to the year before becoming an HCU,
5	unplanned hospitalizations accounted for 74% of all inc	remental admissions at an additional mean of 0.77
6	hospitalizations per HCU (95%CI: 0.77-0.78) annually. S	imilarly, specialist visits constituted 75% of the
7	incremental physician encounters at an additional mea	n of 22.8 visits (95%CI: 22.7-22.9), whereas personal
8	support worker visits contributed the most to the incre	mental home care use at additional mean of 15.6
9	visits (95%CI: 15.3-15.9) per HCU patient.	
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11 12	Table 2: Incremental healthcare use associated	with HCU status. by healthcare type
11	Table 2: Incremental healthcare use associated Healthcare type	
11 12	Table 2: Incremental healthcare use associated Healthcare type	with HCU status, by healthcare type Annual incremental utilization, mean (95% CI)
11 12		Annual incremental utilization,
11 12	Healthcare type	Annual incremental utilization, mean (95% CI)
11 12	Healthcare type Hospital admission, All Hospital admission, elective Hospital admission, unplanned	Annual incremental utilization, mean (95% Cl) 1.04 (1.04 -1.05) 0.29 (0.29 -0.3) 0.77 (0.77 -0.78)
11 12	Healthcare type Hospital admission, All Hospital admission, elective Hospital admission, unplanned Emergency department visits	Annual incremental utilization, mean (95% Cl) 1.04 (1.04 -1.05) 0.29 (0.29 -0.3) 0.77 (0.77 -0.78) 1.4 (1.4 -1.4)
11 12	Healthcare typeHospital admission, AllHospital admission, electiveHospital admission, unplannedEmergency department visitsPhysician visits, All	Annual incremental utilization, mean (95% Cl) 1.04 (1.04 -1.05) 0.29 (0.29 -0.3) 0.77 (0.77 -0.78) 1.4 (1.4 -1.4) 32.1 (31.9 -32.3)
11 12	Healthcare typeHospital admission, AllHospital admission, electiveHospital admission, unplannedEmergency department visitsPhysician visits, AllGeneral practitioner visits	Annual incremental utilization, mean (95% Cl) 1.04 (1.04 -1.05) 0.29 (0.29 -0.3) 0.77 (0.77 -0.78) 1.4 (1.4 -1.4) 32.1 (31.9 -32.3) 9.3 (8.7 -9.5)
11 12	Healthcare type Hospital admission, All Hospital admission, elective Hospital admission, unplanned Emergency department visits Physician visits, All General practitioner visits Specialist visits	Annual incremental utilization, mean (95% Cl) 1.04 (1.04 -1.05) 0.29 (0.29 -0.3) 0.77 (0.77 -0.78) 1.4 (1.4 -1.4) 32.1 (31.9 -32.3) 9.3 (8.7 -9.5) 22.8 (22.7 -22.9)
11 12	Healthcare type Hospital admission, All Hospital admission, elective Hospital admission, unplanned Emergency department visits Physician visits, All General practitioner visits Specialist visits Home care services, All*	Annual incremental utilization, mean (95% Cl) 1.04 (1.04 -1.05) 0.29 (0.29 -0.3) 0.77 (0.77 -0.78) 1.4 (1.4 -1.4) 32.1 (31.9 -32.3) 9.3 (8.7 -9.5) 22.8 (22.7 -22.9) 25.1 (24.4 -25.7)
11 12	Healthcare typeHospital admission, AllHospital admission, electiveHospital admission, unplannedEmergency department visitsPhysician visits, AllGeneral practitioner visitsSpecialist visitsHome care services, All*Personal support	Annual incremental utilization, mean (95% Cl) 1.04 (1.04 -1.05) 0.29 (0.29 -0.3) 0.77 (0.77 -0.78) 1.4 (1.4 -1.4) 32.1 (31.9 -32.3) 9.3 (8.7 -9.5) 22.8 (22.7 -22.9) 25.1 (24.4 -25.7) 15.6 (15.3 -15.9)
11 12	Healthcare type Hospital admission, All Hospital admission, elective Hospital admission, unplanned Emergency department visits Physician visits, All General practitioner visits Specialist visits Home care services, All* Personal support Nursing	Annual incremental utilization, mean (95% Cl) 1.04 (1.04 -1.05) 0.29 (0.29 -0.3) 0.77 (0.77 -0.78) 1.4 (1.4 -1.4) 32.1 (31.9 -32.3) 9.3 (8.7 -9.5) 22.8 (22.7 -22.9) 25.1 (24.4 -25.7) 15.6 (15.3 -15.9) 5.3 (4.9 -6.0)
11 12	Healthcare type Hospital admission, All Hospital admission, elective Hospital admission, unplanned Emergency department visits Physician visits, All General practitioner visits Specialist visits Home care services, All* Personal support Nursing Allied	Annual incremental utilization, mean (95% Cl) 1.04 (1.04 -1.05) 0.29 (0.29 -0.3) 0.77 (0.77 -0.78) 1.4 (1.4 -1.4) 32.1 (31.9 -32.3) 9.3 (8.7 -9.5) 22.8 (22.7 -22.9) 25.1 (24.4 -25.7) 15.6 (15.3 -15.9) 5.3 (4.9 -6.0) 1.5 (1.5 -1.6)
11 12	Healthcare type Hospital admission, All Hospital admission, elective Hospital admission, unplanned Emergency department visits Physician visits, All General practitioner visits Specialist visits Home care services, All* Personal support Nursing Allied Other** * - fit using Poisson distribution; all other are fit using Nega * - "Other" includes social services, case management, and particular distribution is an additional mean number	Annual incremental utilization, mean (95% Cl) 1.04 (1.04 -1.05) 0.29 (0.29 -0.3) 0.77 (0.77 -0.78) 1.4 (1.4 -1.4) 32.1 (31.9 -32.3) 9.3 (8.7 -9.5) 22.8 (22.7 -22.9) 25.1 (24.4 -25.7) 15.6 (15.3 -15.9) 5.3 (4.9 -6.0) 1.5 (1.5 -1.6) 2.8 (2.7 -2.9)
11 12 13	Healthcare type Hospital admission, All Hospital admission, elective Hospital admission, unplanned Emergency department visits Physician visits, All General practitioner visits Specialist visits Home care services, All* Personal support Nursing Allied Other*# * - fit using Poisson distribution; all other are fit using Nega # - "Other" includes social services, case management, and no Annual incremental utilization is an additional mean number compared with a non-HCU and the baseline year	Annual incremental utilization, mean (95% Cl) $1.04 (1.04 - 1.05)$ $0.29 (0.29 - 0.3)$ $0.77 (0.77 - 0.78)$ $1.4 (1.4 - 1.4)$ $32.1 (31.9 - 32.3)$ $9.3 (8.7 - 9.5)$ $22.8 (22.7 - 22.9)$ $25.1 (24.4 - 25.7)$ $15.6 (15.3 - 15.9)$ $5.3 (4.9 - 6.0)$ $1.5 (1.5 - 1.6)$ $2.8 (2.7 - 2.9)$
11 12	Healthcare type Hospital admission, All Hospital admission, elective Hospital admission, unplanned Emergency department visits Physician visits, All General practitioner visits Specialist visits Home care services, All* Personal support Nursing Allied Other** * - fit using Poisson distribution; all other are fit using Nega * - "Other" includes social services, case management, and particular distribution is an additional mean number	Annual incremental utilization, mean (95% Cl) $1.04 (1.04 - 1.05)$ $0.29 (0.29 - 0.3)$ $0.77 (0.77 - 0.78)$ $1.4 (1.4 - 1.4)$ $32.1 (31.9 - 32.3)$ $9.3 (8.7 - 9.5)$ $22.8 (22.7 - 22.9)$ $25.1 (24.4 - 25.7)$ $15.6 (15.3 - 15.9)$ $5.3 (4.9 - 6.0)$ $1.5 (1.5 - 1.6)$ $2.8 (2.7 - 2.9)$ tive Binomialrespite career of services received by a HCU in the incident yearCU status were \$25,527 (95%CI: \$25,383 - \$25,670)

16 (95%CI: \$13,333 - \$13,533) per HCU. Details of the regression analyses are provided in Appendices 4-5.

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1	Given the size of the senior incident HCU population (n=175,847), the estimated provincial budget impact of
т	Given the size of the senior incident neo population (n=175,647), the estimated provincial budget impact of

2 the senior incident HCU status was \$4.5 billion (CAD). This accounts for approximately 9% of the 2013 total

- 3 provincial healthcare expenditures (\$51 billion)[46].

Table 3: Incremental expenditures associated with HCU status, by cost component and total

Cost component	Annual incremental costs*,
	mean (95% CI)
Hospital admission	\$ 13,428 (13,334 -13,534)
Physicians	\$ 3,150 (3,134 -3,168)
Outpatient Drug Benefits	\$ 1,493 (1,462 -1,523)
Rehabilitation	\$ 1,430 (1,392 -1,467)
Home care	\$ 1,363 (1,347 -1,378)
Cancer care	\$ 1,226 (1,200 -1,253)
Complex continuing care	\$ 1,213 (1,168 -1,257)
Long-term care	\$ 1,021 (995 -1,046)
Emergency department	\$ 684 (679 -687)
Mental health admissions	\$ 258 (238 -278)
Dialysis	\$ 89 (79 -99)
Laboratory tests	\$ 51 (50 -52)
Total incremental cost	\$ 25,527 (25,383 -25,670)
*- Costs were modelled to follow gamma distribution with	log-link function
Annual incremental costs are additional mean expenditure	s incurred by a HCU in the incident year compared
with a non-HCU and the baseline year	

7 Discussion

The study has examined a cohort of new senior HCU patients compared with matched non-HCUs focusing on the absolute and incremental comparative healthcare use and expenditures before and after HCU conversion. We determined that although senior HCUs were already on an upward trajectory during the year before HCU status, showing higher healthcare utilization and costs in the pre-incident year, the HCU status was associated with a spike in healthcare expenditures. We found that seniors became HCU through incurring costs in various combinations, although half of the senior HCU could reach the HCU status by incurring costs from only one or two categories, mainly prolonged hospitalization. Approximately 12% of HCUs had no hospitalization in the incident year: they achieved HCU status by incurring costs largely on physician services and prescription medications. Compared to non-HCU, senior HCU incurred an additional

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\$25,527 per patient in total incremental public healthcare expenditures and cost almost one-tenth of the
provincial budget in the incident year. Hospitalizations, physician compensation and ODB were responsible
for the highest incremental costs.

4

5 This study fills a current gap in the HCU economic literature, especially Canadian HCU studies where few of 6 them have focused on seniors or used a comparative group of non-HCUs. Also, as opposed to cross-7 sectional studies that are common in the area of HCU research, we were able to capture the economic 8 burden attributable to HCU status among senior Ontarians using longitudinal data. Our approach of the 9 recycled predictions has allowed us to compare the healthcare use and costs between HCUs and a matched 10 cohort of non-HCUs while taking account of the correlation between the pre- and post values, managing 11 excessive zero values by developing two-part models, and adjusting for confounding by including important 12 socio-demographic and health status covariates in the models. Another option we considered was the 13 difference in differences (DID) estimator [47, 48]. Frequently employed by economists to assess the impact 14 of introducing a policy or a change in the system, its use is however conditional on two major assumptions 15 that need to be met: parallel trends and no group variation at baseline. While the latter could be dealt with 16 using statistical adjustment, the former assumes that trajectories in outcomes (i.e., costs and use) between 17 the groups are the same prior to the exposure (i.e., HCU conversion). Because we only had access to one 18 year of data prior to the incident year (i.e., the baseline year) by design, it was not possible to determine the 19 trajectories between the cohorts.

20

Consistent with 9 studies of senior HCUs identified by Wammes et al., our results confirm the high burden of common conditions among senior HCUs, the important impact of inpatient care costs, the increasing role of home and long-term care in the HCU cost profile. Some studies also mention non-hospitalized senior HCUs without providing their detailed description[10, 49]. Our findings are however challenging to compare with these for several reasons. First, in addition to the incremental values, we provide a comprehensive

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1	assessment of costs and healthcare utilization for a specific segment of the HCU population: senior incident
2	cases. To our knowledge, no other studies have examined this specific patient population, especially in such
3	detail[5]. Second, as Wammes et el show, the HCU threshold used in the US and other countries (e.g.,
4	Denmark and Germany) is often 10%, while Canadian studies commonly apply the 5% threshold[5]. Third,
5	the spectrum of cost categories included in analysis may vary between countries and even provinces in
6	Canada. Prescription drug costs, for example, the source of one of the highest incremental values in our
7	study, were not covered by the US Medicare program (which covers senior patients) until 2003, although
8	the launch of a fully developed program was delayed until mid-2000s[50, 51], limiting the comparability of
9	earlier studies that relied only on Medicare payments[11, 23, 52]. In this respect, our efforts to standardize
10	cost analyses by using a costing methodology that allows obtaining patient-level expenditures from multiple
11	sources in one standard way is a step toward higher comparability of future studies.
12	
13	Strengths and limitations
14	Our study has several strengths. First, the study is population-based, including all incident senior HCU in the
15	province. Second, the study examines incident HCU, which provides important information on the driving
16	factors for HCU status. Third, we included a comprehensive spectrum of the most important cost categories
17	that contribute to total public healthcare expenditures in the province.
18	
19	The study also has important limitations. The nature of methodology applied to calculate the costs was
20	different across various cost categories. As opposed to the nominal costs per visit (e.g., physician or home
21	care) or prescription claim, some of the costs were estimations, e.g. a provincial average cost per case of
22	inpatient care weighted for resource intensity[53]. However, when used for comparisons at a provincial
23	level, these estimations are considered acceptable[53]. Also, despite our comprehensive coverage of cost
24	categories, some public healthcare expenditures are not accounted for. Examples include community
25	services (e.g., community services for elderly) and public health costs. In addition, a few of the cost

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categories included the analysis may not be captured in full. Most notably, we did not have access to the costs of outpatient intravenous chemotherapy, which can be costly[54]. Also, long-term care residents pay a portion of the costs out of pocket[55]. Despite these limitations, it is unlikely that the unaccounted costs for individual healthcare services amount to more than 5-8% of total public expenditures on healthcare[10, 56]. At the same time, the true hospitalization expenses may be underestimated as physician billings for inpatient services are currently captured by a separate cost category which makes our estimates of the hospital costs conservative. Further, different HCU thresholds may yield different estimations of the incremental costs. Although ours is the most commonly used HCU threshold in Canada[5], our findings are largely comparable to studies with the same threshold and the choice of cost categories. Finally, since our study by design focuses on incident senior HCUs, we did not examine other senior HCU population groups such as prevalent HCUs (i.e., those who have been HCU both in FY2012 and FY2013) or those individuals who were HCUs in FY2012 but not in FY2013. Despite these limitations, our findings have policy and research implications. There is currently no clear internationally accepted definition of the HCU[7]. They are also referred to by many names (e.g., heavy, frequent or high needs users) that are used interchangeably with HCU[7]. However, our data shows that

18 be distinguished. One prolonged hospital stay, for example, can drive a senior patient to become a HCU.

frequent users of healthcare may not be synonymous with high-cost users of healthcare and both need to

19 Although interventions have been introduced to either prevent or divert such hospitalizations, their success

20 is unclear[7]. Further efforts are needed to examine predictors at the pre-hospital level and to identify

21 actionable cost drivers during admission [57]. At the same time, more than one tenth of senior HCUs had no

22 hospital costs. The latter subset of HCUs requires further investigation. Reducing ODB expenditures by

- 23 exploring pharmaceutical policy or pricing strategies (e.g. generic drug tendering) stands out as a promising
- but challenging area to achieve potential cost reductions[58]. Canada has recently made steps to alleviate
- 25 the burden of drug costs by negotiating lower prices of generic and non-generic drugs with

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1 2 3	1	manufacturers[59]. Although there may be room for further savings among generic drugs[60], these may be
4 5	2	offset by the growing share of expensive biologics coupled with just a modest uptake of biosimilars[61].
6 7	3	Finally, future cost analysis of senior HCUs could benefit from greater data granularity. Following a patient
8 9	4	longitudinally by type of care received in the incident year and time of death, for example, it may be
10 11 12	5	possible to more precisely identify the point of HCU conversion, differentiate between outpatient and
13 14	6	inpatient costs that contribute to it, and allocate costs more with greater accuracy, including specific clinical
15 16	7	conditions (e.g., cognitive impairment among seniors) or conducting joint cost-survival modelling[62, 63].
17 18	8	
19 20 21 22	9	Conclusion
23 24	10	Costs attributable to incident senior HCU status accounted for almost one-tenth of the provincial budget.
25 26 27	11	Prolonged hospitalizations made a major contribution to the total incremental costs. However, categories
27 28 29	12	such as physician billings, drug benefits and other, in various combinations, also were important. A
30 31	13	subgroup of patients that became HCU without hospitalization requires further investigation.
32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56	14	
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2 3	1	Figure 1: Proportion of new HCUs that made the HCU threshold due to various types of costs
4 5	2	The graph presents the proportion of senior HCU in the context of cost categories that reached the HCU
6	3	threshold of \$10,192. One cost category (e.g. hospital costs) reached the HCU threshold among 40% of new
7 8	4	HCUs (% of patient in Top 5 categories: Hospital (70.7%); Cancer (8.1%); ODB (7.3%); LTC (5.1%); HC: (3.3%))
9 10	5	More than 1 cost category (e.g. hospital and physician costs) reached the HCU threshold among 13% of
11	6	HCUs (% of patient in Top 5 categories: Hospital (95.1%); Physician (35.5%); Rehab (27.8%); CCC (18.6%); HC
12 13	7	(13.6%)). No single cost category reached the HCU threshold among 47% of new HCUs (% of patient in Top
14 15	8	5 categories: Physician (99.9%, mean \$3022); ODB (99.6%, mean \$2127); Hospital (88.7%, mean \$5611);
16	9	Laboratory (87.1%, mean \$190); ED (70%, mean \$654)
17 18	10	CCC – Complex Continuing Care; ED - Emergency Department; LTC- Long-term care; ODB - Outpatient Drug
19 20	11	Benefit
21 22	12	
23 24	13	Figure 2: Dynamics of change in annual healthcare use, before (baseline) and during incident year, by HCU
25	14	status and cost categories (mean per patient)
26 27	15	The graph shows a dramatic increase in healthcare use among senior HCU during FY2013, while the service
28 29	16	consumption among non-HCU remained relatively unchanged from the baseline year
30 31	17	
32	18	Figure 3: Dynamics of change in annual healthcare care expenditures before and after index year, by HCU
33 34	19	status and cost categories (annual, mean per patient)
35 36	20	Total costs per patient (mean) among HCUs: \$4,166 (baseline year) and \$29,784 (incident year)
37	21	Total costs per patient (mean) among non-HCUs: \$2,372 (baseline year) and \$2,471 (incident year)
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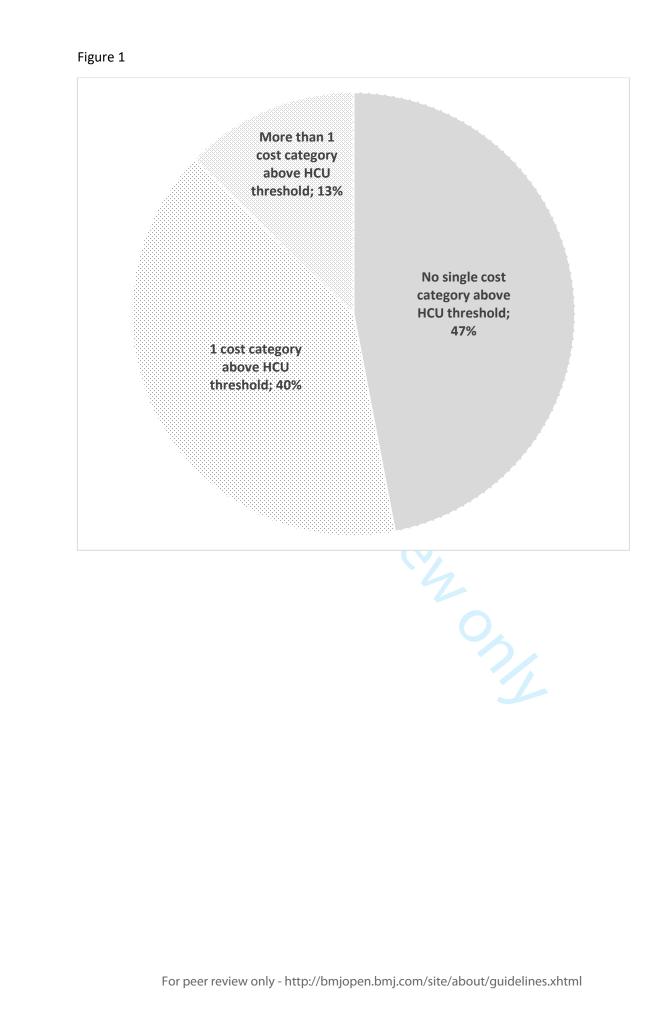
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4 5 6		no
7 8	PHYSICIAN VISITS, ALL,	baseline yr
9		incident yr
10 11	General practitioner,	baseline yr
12		incident yr
13 14	Specialist,	baseline yr
15		incident yr
16 17	HOME CARE SERVICES, ALL,	baseline yr
18		incident yr
19 20	Personal support,	baseline yr
21		incident yr
22 23	Nursing,	baseline yr
23		incident yr
25 26	Allied,	baseline yr
27		incident yr
28	Other,	baseline yr
29 30		incident yr
31	EMERGENCY DEPARTMENT VISITS,	baseline yr
32 33		incident yr
34	HOSPITAL ADMISSION, ALL,	baseline yr
35 36		incident yr
37	Unplanned,	baseline yr
38 39		incident yr
40	Elective,	baseline yr
41 42		incident yr
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HCU on-HCU 10.1 15.4 10.0 8.0 5.6 16.1 5.5 4.4 7.4 4.5 29.5 7.7 1.8 2.5 33.3 1.5 6.4 22.6 1.9 0.5 0.2 5.6 0.2 0.1 0.2 0.2 1.8 0.1 0.6 0.2 3.2 0.3 0.6 0.3 1.9 0.03 0.02 1.1 0.02 Ш 0.02 0.03

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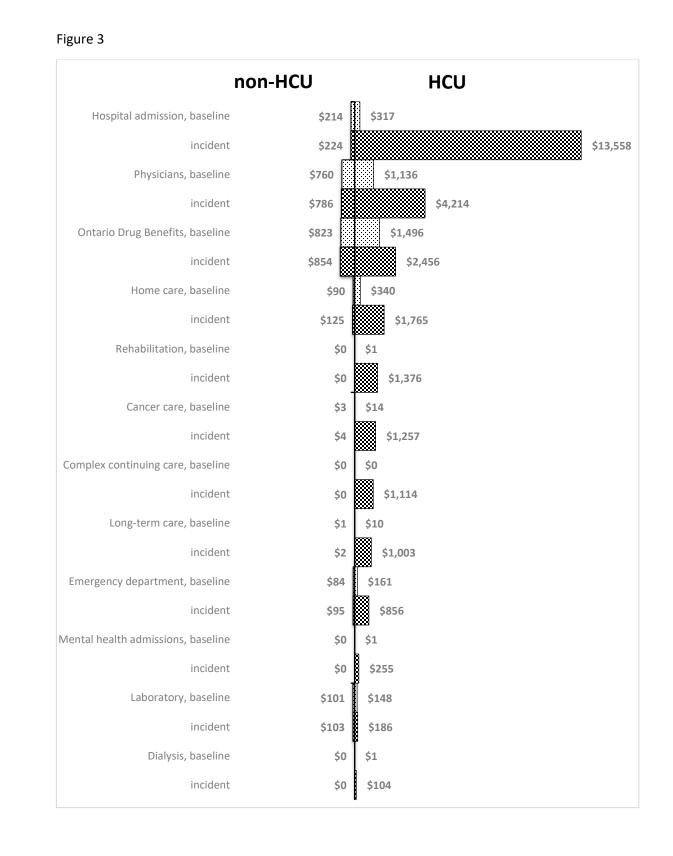
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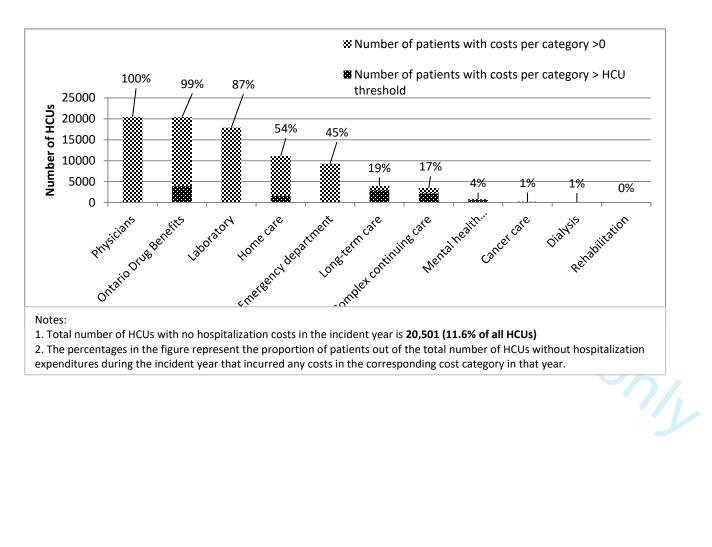
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Appendix 1

HCUs with no hospitalization costs during incident year: contribution of cost categories



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Appendix 2

Description of cost components among HCUs and non-HCUs by pre-incident and incident year

				ind incident year				
Cost components	FY20 pre-incido)			FY2013 (incident year)				
	HCU N=175847	Non-HCU N=527541		HCU N=175847	Non-HCU N=527541	aS		
	Mean, \$ (SD)	Mean, \$ (SD)	aSD	Mean, \$ (SD)	Mean, \$ (SD)	aS		
Cancer clinics	14 (196)	4 (90)	0.54	1258 (5234)	4 (92)	0.		
Complex continuing care	1 (36)	1 (17)	0.50	1114 (7685)	1 (24)	1.		
Dialysis	2 (40)	1 (15)	0.31	104 (2166)	1 (12)	0.		
Emergency department	162 (327)	84 (226)	0.13	857 (881)	96 (249)	0.		
Home care	341 (1023)	90 (498)	0.28	1765 (3667)	125 (589)	0.		
Hospital admission	318 (864)	215 (714)	0.33	13558 (20529)	225 (743)	0.		
_aboratory	149 (160)	102 (123)	0.07	187 (192)	104 (125)	0.		
_ong-term care	11 (192)	1 (45)	0.07	1003 (4800)	3 (91)	0.		
Vental health admissions	1 (60)	1 (33)	0.03	256 (3924)	1 (29)	1.		
Outpatient Drug Benefits	1497 (1441)	824 (1002)	0.01	2456 (3822)	854 (1052)	0.		
Physicians	1136 (821)	761 (671)	0.01	4215 (3217)	787 (694)	0.		
Rehabilitation	1 (41)	1 (33)	0.01	1376 (6792)	1 (20)	0.		
Fotal cost	4167 (2664)	2372 (2166)	0.74	29785 (29029)	2471 (2252)	1.		
aSD- absolute standardized difference; -Y- fiscal year								
						1.		

Appendix 3

0 Appendix 3 Description of healthcare use amo	ng HCUs and non	-HCUs by pre- inc	BMJ Ope			136/bmjopen-2018-028637
Cost components	FY20	-		FY2(on
	(pre-incid	ent year)		(inciden	t year)	28 C
-	HCU N=175847	Non-HCU N=527541		HCU N=175847	Non-HCU N=527541	3 October 20 aSD
	Mean (SD)	Mean (SD)	aSD	Mean (SD)	Mean (SD)	aSD
Hospital admission, All	0.04 ± 0.18	0.02 ± 0.14	0.08	1.07 ± 0.87	0.03 ± 0.15	1.68
Elective	0.01 ± 0.07	0.01 ± 0.07	0.01	0.3 ± 0.51	0.01 ± 0.07	0.8
Unplanned	0.03 ± 0.17	0.02 ± 0.13	0.08	0.8 ± 0.89	0.02 ± 0.14	1.24
Emergency department visits	0.56 ± 1.13	0.31 ± 0.8	0.26	1.88 ± 2.2	0.32 ± 0.82	0.94
Physician visits, All	15.43 ± 10.69	10.06 ± 8.9	0.55	45.62 ± 32.55	10.03 ± 8.98	1.49
General practitioner	8.03 ± 6.8	5.64 ± 5.59	0.39	16.08 ± 14.74	5.48 ± 5.56	0.95
Specialist	7.4 ± 6.65	4.43 ± 5.13	0.5	29.55 ± 25.97	4.55 ± 5.24	1.3
Home care services, All	7.74 ± 31.92	1.81 ± 14.15	0.24	33.27 ± 82.17	2.47 ± 17.33	0.5
Personal support	0.54 ± 4.03	0.16 ± 2.00	0.12	5.60 ± 18.59	0.20 ± 2.26	0.44
Nursing	6.44 ± 30.59	1.46 ± 13.53	0.21	22.62 ± 73.93	1.91 ± 16.39	0.39
Allied	0.18 ± 0.99	0.05 ± 0.52	0.17	1.82 ± 4.27	0.15 ± 1.41	0.52
Other	0.58 ± 2.30	0.14 ± 0.96	0.25	3.22 ± 5.23	0.21 ± 1.09	0.8 9

FY- fiscal year

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Appendix 4 **Regression coefficients, recycled prediction, costs**

opendix 4 egression coeffi	cients	. recv	cled pre	edictio	n. cos	its			BM	IJ Oper	ı						136/bmjopen-2018-02863				Ρ
Care categories		al admis		[Physicia		1	Homeca	re	Ontari	io Drug	benefits		Emerger Departm	•		863 ler∰al ho adjojissi			Total	
	Coeff	SE	P- value	Coeff	SE	P- value	Coeff	SE	P- value	Coeff	SE	P- value	Coeff	SE	P- value	Coeff	8 Otto	P- value	Coeff	SE	P- value
Part 1*: p(costs)=0; Intercept	1.03	0.04	<.0001	-3.52	0.08	<.0001	9.30	0.05	<.0001	-1.85	0.06	<.0001	3.91	0.03	<.0001	5.94	0 8 8 32	<.0001	-4.95	0.09	<.0002
HCU status	-3.79	0.01	<.0001	-5.16	0.15	<.0001	-3.13	0.01	<.0001	-2.25	0.03	<.0001	-2.39	0.01	<.0001	-5.16		<.0001	- 13.88	14.60	0.342
Cost pre	0.00	0.00	<.0001	-0.01	0.00	<.0001	0.00	0.00	<.0001	-0.01	0.00	<.0001	0.00	0.00	<.0001	0.00	Dom 100	<.0001	-0.01	0.00	<.000
ADG	-0.09	0.00	<.0001	-0.38	0.00	<.0001	-0.04	0.00	<.0001	-0.34	0.00	<.0001	-0.09	0.00	<.0001	-0.01		0.214	-0.47	0.01	<.000
Age	0.02	0.00	<.0001	0.06	0.00	<.0001	-0.08	0.00	<.0001	0.04	0.00	<.0001	-0.02	0.00	<.0001	0.05		<.0001	0.08	0.00	<.000
Sex	-0.22	0.01	<.0001	0.13	0.02	<.0001	0.34	0.01	<.0001	0.20	0.01	<.0001	0.04	0.01	<.0001	0.19	05	0	0.10	0.02	<.000
Low income	0.18	0.01	<.0001	0.05	0.02	0.011	-0.06	0.01	<.0001	0.59	0.02	<.0001	-0.03	0.01	<.0001	-0.18		0.003	0.32	0.02	<.000
Part 2*: p(costs)>0; Intercept	6.73	0.02	<.0001	6.26	0.01	<.0001	6.17	0.03	<.0001	5.41	0.01	<.0001	5.46	0.02	<.0001	7.82	8 28	<.0001	6.51	0.01	<.000
HCU status	2.27	0.00	<.0001	1.53	0.00	<.0001	0.76	0.01	<.0001	0.79	0.00	<.0001	0.88	0.00	<.0001	1.82	0.16	<.0001	2.34	0.00	<.000
Cost pre	0.00	0.00	<.0001	0.00	0.00	<.0001	0.00	0.00	<.0001	0.00	0.00	<.0001	0.00	0.00	<.0001	0.00	8,00	0.37	0.00	0.00	<.000
ADG	-0.02	0.00	<.0001	0.03	0.00	<.0001	-0.01	0.00	<.0001	0.02	0.00	<.0001	0.01	0.00	<.0001	-0.02	April Pil	<.0001	0.03	0.00	<.000
Age	0.01	0.00	<.0001	0.00	0.00	<.0001	0.01	0.00	<.0001	0.01	0.00	<.0001	0.01	0.00	<.0001	0.01	2 07:00 2	0.002	0.01	0.00	<.000
Sex	0.08	0.00	<.0001	0.05	0.00	<.0001	0.00	0.01	0.727	0.03	0.00	<.0001	0.02	0.00	<.0001	0.01	02 4 4 b	0.882	0.04	0.00	<.000
Low income	0.02	0.01	0	-0.03	0.00	<.0001	0.00	0.01	0.749	0.09	0.00	<.0001	0.04	0.00	<.0001	0.07	V gn⊒e	0.214	0.04	0.00	<.000
log_theta	0.36	0.00	<.0001	0.79	0.00	<.0001	0.34	0.00	<.0001	0.15	0.00	<.0001	0.84	0.00	<.0001	0.24	<u>਼</u> ਉ03	<.0001	0.58	0.00	<.000

*- A 2-part regression model (Hurdle regression) consisted of part 1 (Logistic regression) to predict the probability of positive values of the outcome and part 2 (generalized linear regression for gamma distribution) for positive costs; ADG- Aggregate Diagnosis Group; Coeff- regression coefficient; HCU- high-cost user; SE- standard error

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Regression coefficients, recycled prediction, costs (CONT)

Care categories Covariates		Lab			Dialysis		c	ancer ca	re	Loi	ng-term o	are	Continui		, ,	Reha	ıb	
	Coeff	SE	P-value	Coeff	SE	P-value	Coeff	SE	P-value	Coeff	SE	P-value	Coeff	SE N	P-value	Coeff	SE	P-value
Part 1*: p(costs)=0; Intercept	0.72	0.03	<.0001	7.03	0.33	<.0001	1.96	0.09	<.0001	15.60	0.13	<.0001	15.32	0.23	<.0001	13.08	0.23	<.0001
HCU status	- 0.52	0.01	<.0001	-2.14	0.07	<.0001	-3.29	0.02	<.0001	-4.60	0.05	<.0001	-6.87	0.19 N	<.0001	-7.59	0.21	<.0001
Cost pre	- 0.01	0.00	<.0001	-0.03	0.00	<.0001	0.00	0.00	<.0001	0.00	0.00	<.0001	0.00	۔ بن 0.00	<.0001	0.00	0.00	<.0001
ADG	- 0.15	0.00	<.0001	-0.04	0.01	<.0001	0.01	0.00	0	0.03	0.00	<.0001	0.04	0.00	<.0001	0.02	0.00	<.0001
Age	0.02	0.00	<.0001	0.02	0.00	<.0001	0.05	0.00	<.0001	-0.11	0.00	<.0001	-0.07	0.00 eC	<.0001	-0.04	0.00	<.0001
Sex	0.05	0.01	<.0001	-0.60	0.06	<.0001	-0.11	0.02	<.0001	0.42	0.02	<.0001	0.13	0.02	<.0001	0.26	0.02	<.0001
Low income	0.08	0.01	<.0001	-0.39	0.07	<.0001	0.22	0.02	<.0001	-0.11	0.02	<.0001	-0.01	0.03	0.763	0.02	0.02	0.364
Part 2*: p(costs)>0; Intercept	4.41	0.01	<.0001	6.22	0.44	<.0001	8.30	0.10	<.0001	7.54	0.10	<.0001	7.15	0.23	.0001	7.54	0.19	<.0001
HCU status	0.30	0.00	<.0001	3.99	0.08	<.0001	2.76	0.02	<.0001	1.81	0.04	<.0001	2.47	0.19	<.0001	1.74	0.18	<.0001
Cost pre	0.00	0.00	<.0001	0.00	0.00	0.792	0.00	0.00	<.0001	0.00	0.00	<.0001	0.00	0.00	0	0.00	0.00	0.486
ADG	0.01	0.00	<.0001	-0.05	0.01	<.0001	-0.01	0.00	<.0001	-0.01	0.00	<.0001	-0.01	0.00	0.05	0.00	0.00	0.143
Age	0.00	0.00	<.0001	0.00	0.01	0.958	-0.02	0.00	<.0001	0.01	0.00	<.0001	0.01	ג 10.00 10.00	<.0001	0.01	0.00	<.0001
Sex	0.02	0.00	<.0001	-0.04	0.07	0.547	0.12	0.02	<.0001	-0.06	0.02	0.001	-0.01	0.02	0.665	0.10	0.02	<.0001
Low income	0.03	0.00	<.0001	-0.33	0.08	<.0001	-0.07	0.02	0.003	-0.02	0.02	0.174	0.01	0.03 4	0.652	0.02	0.02	0.228
log_theta	0.81	0.00	<.0001	-0.68	0.03	<.0001	-0.07	0.01	<.0001	0.35	0.01	<.0001	0.02	0.01	0.176	0.44	0.01	<.0001

*- A 2-part regression model (Hurdle regression) consisted of part 1 (Logistic regression) to predict the probability of positive values of the outcome and part 2 (generalized linear regression for gamma distribution) for positive costs; copyright.

ADG- Aggregate Diagnosis Group; Coeff- regression coefficient; HCU- high-cost user; SE- standard error

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Appendix 5

 Regression coefficients, recycled prediction, health care use

Care categories Covariates	Hospit	al admis	sion, All	Hosp	ital adm urgent		Hosp	ital adm elective	,	Phys	sician vis	its, All		ysician vi Specialis	J		an visits ractitio	, General 1er
	Coeff	SE	P-value	Coeff	SE	P-value	Coeff	SE	P-value	Coeff	SE	P-value	Coeff	SE	P-value	Coeff	SE	P-value
Part 1*: p(event) ≠0; Intercept	0.57	0.05	<.0001	-8.08	0.05	<.0001	4.07	0.06	<.0001	7.74	0.15	<.0001	4.80	0.05	0001	4.03	0.06	<.0001
HCU status	5.11	0.01	<.0001	4.48	0.01	<.0001	4.66	0.02	<.0001	5.60	0.14	<.0001	3.78	0.03	<.0001	2.71	0.03	<.0001
Pre-incident value	0.78	0.03	<.0001	0.82	0.03	<.0001	0.80	0.07	<.0001	0.40	0.00	<.0001	0.29	0.00	<.0001	0.62	0.00	<.0001
Age	0.01	0.00	<.0001	0.05	0.00	<.0001	-0.07	0.00	<.0001	-0.05	0.00	<.0001	-0.03	0.00	<.0001	-0.04	0.00	<.0001
ADG	0.00	0.00	0.002	0.00	0.00	<.0001	0.00	0.00	0.006	0.38	0.00	<.0001	0.25	0.00	<.0001	0.26	0.00	<.0001
Sex	0.08	0.01	<.0001	0.12	0.01	<.0001	0.05	0.01	<.0001	-0.13	0.01	<.0001	-0.12	0.01	<.0001	-0.12	0.01	<.0001
Low income	-0.04	0.01	6E-04	0.17	0.01	<.0001	-0.40	0.02	<.0001	-0.20	0.02	<.0001	-0.20	0.01	<.0001	-0.16	0.01	<.0001
Part 2*: p(event) >0; Intercept	-2.16	0.07	<.0001	-6.77	0.19	<.0001	-1.37	0.20	<.0001	3.02	0.01	<.0001	3.10	0.01	<.0001	1.41	0.01	<.0001
HCU status	4.21	0.13	<.0001	4.62	0.17	<.0001	2.59	0.28	<.0001	1.33	0.00	<.0001	1.63	0.00	<.0001	0.91	0.00	<.0001
Pre-incident value	0.39	0.03	<.0001	0.42	0.03	<.0001	0.71	0.11	<.0001	0.03	0.00	<.0001	0.04	0.00		0.06	0.00	<.0001
Age	0.01	0.00	<.0001	0.01	0.00	<.0001	-0.01	0.00	0.041	0.00	0.00	<.0001	0.00	0.00		0.01	0.00	<.0001
ADG	0.02	0.00	<.0001	0.03	0.00	<.0001	0.00	0.00	0.268	0.02	0.00	<.0001	0.02	0.00	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	0.02	0.00	<.0001
Sex	0.19	0.01	<.0001	0.11	0.01	<.0001	0.29	0.03	<.0001	0.02	0.00	<.0001	0.06	0.00	<u>ج</u> <.0001	-0.01	0.00	<.0001
Low income	0.07	0.01	<.0001	0.06	0.02	0.0004	-0.04	0.05	0.45	0.01	0.00	<.0001	-0.02	0.00	<.0001	0.05	0.00	<.0001
Scale parameter	1.51	0.08		0.60	0.04	<.0001	0.00	0.00		0.32	0.00		0.49	0.00	<u>v</u>	0.36	0.00	

*- A 2-part regression model (Hurdle regression) consisted of part 1 (Logistic regression) to predict the probability of positive values of the outcome and part 2 (negative binomial or Poisson model) for positive counts; ADG- Aggregate Diagnosis Group; Coeff- regression coefficient; HCU- high-cost user; SE- standard error

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Regression coefficients, recycled prediction, health care use (CONT)

Care categories	Emergency department visits			Home o	are serv	ices, All*		care sei onal sup	-	Home	e care se Nursing	-	rvices, Home care se			N N		-
	Coeff	SE	P-value	Coeff	SE	P-value	Coeff	SE	P-value	Coeff	SE	P-value	Coeff	SE	O C OP-value	Coeff	SE	P-value
Part 1*: p(event) ≠0; Intercept	-1.58	0.03	<.0001	-9.51	0.05	<.0001	-9.22	0.07	<.0001	-3.04	0.05	<.0001	-7.21	0.05	0 9 9 9 1 20 1	-9.28	0.05	<.0001
HCU status	2.40	0.01	<.0001	3.11	0.01	<.0001	2.97	0.01	<.0001	3.06	0.01	<.0001	2.71	0.01		3.07	0.01	<.000
Pre-incident value	0.39	0.00	<.0001	0.08	0.00	<.0001	0.09	0.00	<.0001	0.11	0.00	<.0001	0.26	0.00	00 10 00 00 00 00 00 00 00 00 00 00 00 0	0.58	0.00	<.000
Age	0.02	0.00	<.0001	0.08	0.00	<.0001	0.09	0.00	<.0001	0.02	0.00	<.0001	0.07	0.00	0 0 0 0 0 0 0 0 0	0.08	0.00	<.000
ADG	0.09	0.00	<.0001	0.05	0.00	<.0001	0.02	0.00	<.0001	0.02	0.00	<.0001	0.04	0.00	frog <.0001	0.05	0.00	<.000
Sex	0.04	0.01	<.0001	-0.34	0.01	<.0001	-0.47	0.01	<.0001	0.12	0.01	<.0001	-0.45	0.01	.0001	-0.34	0.01	<.000
Low income	0.04	0.01	<.0001	0.04	0.01	<.0001	0.15	0.01	<.0001	-0.10	0.01	<.0001	-0.01	0.01	0.600	0.08	0.01	<.000
Part 2*: p(event) >0; Intercept	-0.02	0.03	0.658	0.52	0.00	<.0001	-0.70	0.14	<.0001	2.40	0.06	<.0001	0.20	0.05	en <.0001	-0.47	0.01	<.000
HCU status	0.97	0.01	<.0001	0.74	0.00	<.0001	0.62	0.03	<.0001	0.76	0.02	<.0001	0.24	0.01	J.<.0001	0.74	0.00	<.000
Pre-incident value	0.21	0.00	<.0001	0.01	0.00	<.0001	0.01	0.00	<.0001	0.03	0.00	<.0001	0.02	0.00	0 <.0001 0	0.03	0.00	<.000
Age	0.00	0.00	0.179	0.03	0.00	<.0001	0.02	0.00	<.0001	0.00	0.00	<.0001	0.01	0.00	л А<.0001 рг	0.02	0.00	<.000
ADG	0.03	0.00	<.0001	0.00	0.00	<.0001	-0.01	0.00	0.001	0.00	0.00	0.091	0.02	0.00	<u>-i:</u> 20<.0001 .0	0.00	0.00	<.000
Sex	0.09	0.01	<.0001	-0.13	0.00	<.0001	-0.07	0.02	0.006	-0.03	0.01	0.011	-0.11	0.01	2024 2024	0.00	0.00	0.321
Low income	0.02	0.01	0.005	0.05	0.00	<.0001	-0.06	0.03	0.026	0.03	0.02	0.061	-0.14	0.01	F by <.0001 g	0.04	0.00	<.000
Scale parameter	1.09	0.02					115.73	0.00		2.12	0.02		1.01	0.01	ues			

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```
SAS script for a macro to apply the recycled prediction method. The
script A below is for cost data. For count data, please see Note 1 in
the text as well as subsections A1 and A2 below.
Α.
%macro boot(varname= , rep=);
%let var1 = &varname. post;
%let var2 = &varname. pre;
proc datasets lib=work;
     delete rslt all &varname.;
run;
%do i=1 %to &rep;
ods results off;
ods exclude all;
data type.hcu;
set increment (rename=(hcu=hcustatus));
hcu=1;
&var1.=.;
run;
data type.nhcu;
set increment (rename=(hcu=hcustatus));
hcu=0;
&var1.=.;
run;
data type.recycled;
set increment type.hcu type.nhcu;
keep ikn &var1. &var2. hcu hcustatus age sex n adg lowinc;
run;
proc surveyselect data=type.recycled out=type.boot method=urs
samprate=1 outhits reps=1;
run;
/*NOTE 1: Fitting a two-part model for costs using NLMIXED assuming
gamma distribution. This part is replaced when count data is fit,
assuming either negative binomial or Poisson. For additional code,
please see below: A-NB; B-Poisson*/
proc nlmixed data=type.boot qpoints=1;
parms a0=0 a1=0 a2=0 a3=0 a4=0 a5=0 a6=0
b0=0 b1=0 b2=0 b3=0 b4=0 b5=0 b6=0 log theta=0;
eta=a0+a1*hcu+a2*&var2.+a3*n adg+a4*age+a5*sex+a6*lowinc;
exp eta0=exp(eta);
p0=exp eta0/(1+exp eta0);
etah=b0+b1*hcu+b2*&var2.+b3*n adg+b4*age+b5*sex+b6*lowinc;
mu=exp(etah);
theta=exp(log theta);
```

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3
          r=mu/theta;
4
          if &var1.=0 then ll=log(p0);
5
          else ll=log(1-p0)-lgamma(theta)+(theta-1)*log(&var1.)-theta*log(r)-
6
          &var1./r;
7
          model &var1.~general(11);
8
          predict (1-p0)*mu out=type.pred (keep=ikn hcu hcustatus &var1. pred);
9
          run;
10
11
          proc means data=type.pred;
12
          where hcustatus ne .;
13
          class hcu; var pred;
14
          output out=type.rslt mean=;
15
          run;
16
17
          proc transpose data=type.rslt out=type.rslt tr(rename=(col2=nHCU
18
          col3=HCU) drop= label col1) ;
19
          var pred;
20
          run;
21
22
          proc append base=rslt all &varname. data=type.rslt tr force; run;
23
24
25
          %end;
26
27
          data type.delta;
28
          set rslt all &varname.;
29
          delta=HCU-nHCU;
30
          run;
31
          ods results on;
32
          ods exclude none;
33
34
          ods html file="/increment/results/incr.&varname..xls";
35
          title "&varname.&rep";
36
          proc univariate data=type.delta;
37
          var delta;
38
          output out=type.pctl &varname. pctlpre=CI pctlpts=2.5,
                                                                      97.5;
39
          run;
40
          proc print data=type.pctl &varname.;
41
          run;ods html close;
42
43
          %mend boot;
44
45
          options symbolgen mprint mcompile ;
46
          %boot(varname=type cost, rep=1000);
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```
A1. /*truncated Negative Binomial*/
proc nlmixed data=incr count;
parms a0=0 a1=0 a2=0 a3=0 a4=0 a5=0 a6=0
b0=0 b1=0 b2=0 b3=0 b4=0 b5=0 b6=0 v=1;
eta0=a0+a1*hcu1+a2*&var2.+a3*n adg+a4*age+a5*sex1+a6*lowinc1;
p0=1/(1+exp(-eta0));
etap=b0+b1*hcu1+b2*&var2.+b3*n adg+b4*age+b5*sex1+b6*lowinc1;
exp etap=exp(etap);
p=1/(1+(1/v) + exp etap);
if &var1. =0 then ll=log(p0);
else ll= \log(1-p0) + \&var1.*\log(1-p) - \log(p**(-1*(v)) - 
1) +lgamma(&var1.+(v)) -lgamma(v) -log(fact(&var1.));
model &var1. ~ general(ll);
predict exp_etap out=admit.pred_trnb (keep=ikn hcu &var1. pred rename
= (pred=nb));
ods output parameterestimates=pezph;
ods output fitstatistics=fit1;
run;
  A2. /*truncated Poisson*/
proc nlmixed data=incr count;
parms a0=0 a1=0 a2=0 a3=0 a4=0 a5=0 a6=0
b0=0 b1=0 b2=0 b3=0 b4=0 b5=0 b6=0 ;
eta0=a0+a1*hcu1+a2*&var2.+a3*n adg+a4*age+a5*sex1+a6*lowinc1;
p0=1/(1+exp(-eta0));
etap= b0+b1*hcu1+b2*&var2.+b3*n adg+b4*age+b5*sex1+b6*lowinc1;
exp etap=exp(etap);
if &var1. =0 then ll=log(p0);
else ll= log(1-p0)-log(1-exp(-exp etap))-exp etap-lgamma(&var1.+1)
+&var1.*log(exp etap);
model &var1. ~ general(ll);
predict exp etap out=gp.pred trp (keep=ikn hcu hcustatus &var1. pred
rename = (pred=poi));
ods output parameterestimates=pezph;
ods output fitstatistics=fit1;
run;
```

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STROBE Statement—Checklist of items that should be included in reports of cohort studies

	Item No	Recommendation	Pag No
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the	1
		abstract	
		(b) Provide in the abstract an informative and balanced summary of what was	4
		done and what was found	
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being	5
		reported	
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	6-10
Setting	5	Describe the setting, locations, and relevant dates, including periods of	7
-		recruitment, exposure, follow-up, and data collection	
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of	7
		participants. Describe methods of follow-up	
		(b) For matched studies, give matching criteria and number of exposed and	
		unexposed	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and	8-9
		effect modifiers. Give diagnostic criteria, if applicable	
Data sources/	8*	For each variable of interest, give sources of data and details of methods of	6,8,
measurement		assessment (measurement). Describe comparability of assessment methods if	
		there is more than one group	
Bias	9	Describe any efforts to address potential sources of bias	9-10
Study size	10	Explain how the study size was arrived at	6-7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable,	8-10
		describe which groupings were chosen and why	
Statistical methods	12	(a) Describe all statistical methods, including those used to control for	9-10
		confounding	
		(b) Describe any methods used to examine subgroups and interactions	
		(c) Explain how missing data were addressed	
		(d) If applicable, explain how loss to follow-up was addressed	
		(<i>e</i>) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers	11
		potentially eligible, examined for eligibility, confirmed eligible, included in the	
		study, completing follow-up, and analysed	
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social)	11
L		and information on exposures and potential confounders	
		(b) Indicate number of participants with missing data for each variable of	
		interest	
		(c) Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	Report numbers of outcome events or summary measures over time	12-1

Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and	12-13
		their precision (eg, 95% confidence interval). Make clear which confounders were	
		adjusted for and why they were included	
		(b) Report category boundaries when continuous variables were categorized	
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a	
		meaningful time period	
Other analyses	17	Report other analyses done-eg analyses of subgroups and interactions, and sensitivity	Appendix
		analyses	1
Discussion			
Key results	18	Summarise key results with reference to study objectives	15
Limitations 1	19	Discuss limitations of the study, taking into account sources of potential bias or	17-18
		imprecision. Discuss both direction and magnitude of any potential bias	
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations,	16,17,18
		multiplicity of analyses, results from similar studies, and other relevant evidence	
		Discussed and an english the (antennal uslidity) of the study negative	18
Generalisability	21	Discuss the generalisability (external validity) of the study results	
Generalisability Other informati		Discuss the generalisability (external validity) of the study results	
•		Give the source of funding and the role of the funders for the present study and, if	3

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.