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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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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.

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

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].

Setting and data sources

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

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 CIs, 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			
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 standardized difference with aSD > 0.1 indicating meaningful difference between admitted and non-admitted			

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.

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.

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

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)

* - 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

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].

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 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 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[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

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.

Conclusion

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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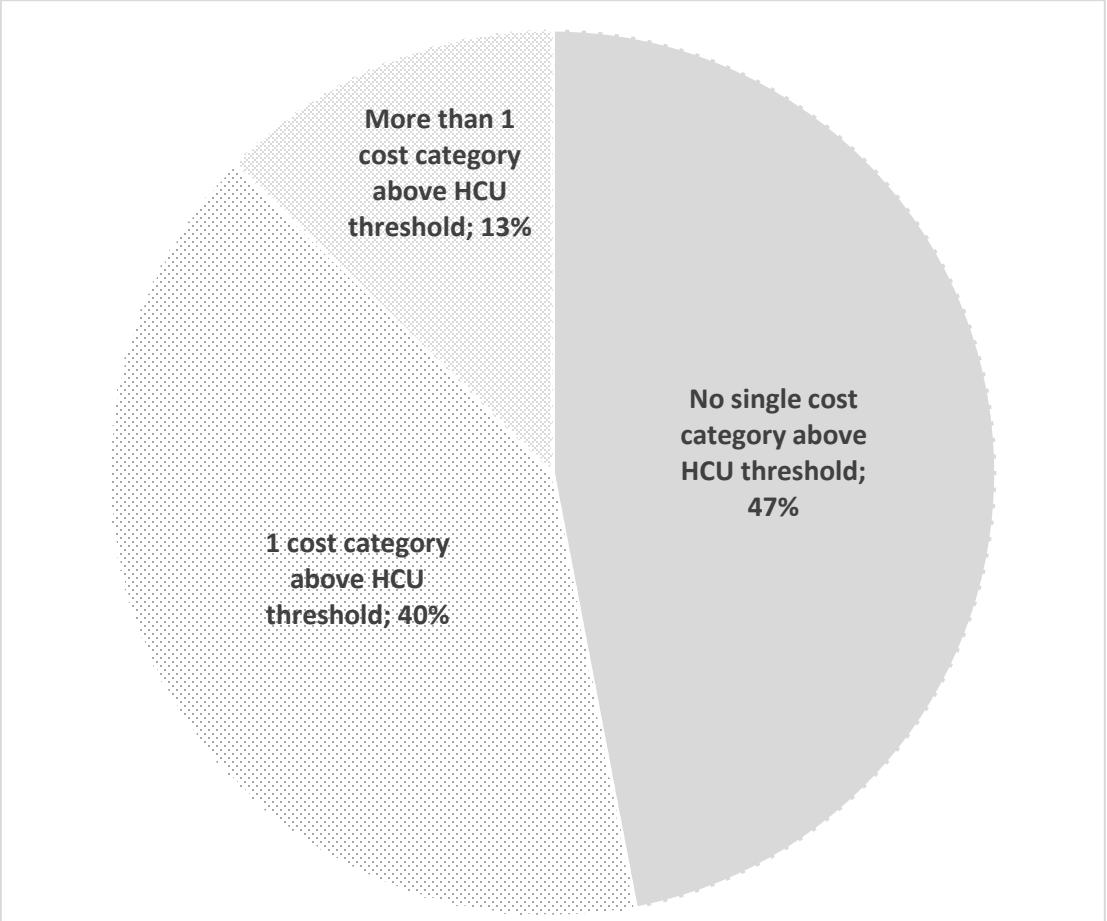
Figure 1

Proportion of new HCUs that made the HCU threshold due to various types of costs



The graph presents the proportion of senior HCU in the context of cost categories that reached the HCU threshold of $10,192.

- **One cost category** (e.g. hospital costs) reached the HCU threshold among 40% of new HCUs (% of patient in Top 5 categories: Hospital (70.7%); Cancer (8.1%); ODB (7.3%); LTC (5.1%); HC: (3.3%))
- **More than 1 cost category** (e.g. hospital and physician costs) reached the HCU threshold among 13% of HCUs (% of patient in Top 5 categories: Hospital (95.1%); Physician (35.5 %); Rehab (27.8%); CCC (18.6%); HC (13.6%))
- **No single cost category** reached the HCU threshold among 47% of new HCUs (% of patient in Top 5 categories: Physician (99.9%, mean $3022); ODB (99.6%, mean $2127); Hospital (88.7%, mean $5611); Laboratory (87.1%, mean $190); ED (70%, mean $654)

CCC - Contunuing Care; ED - Emergency Department; LTC- Long-term care; ODB - Outpatient Drug Benefit

Figure 2

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

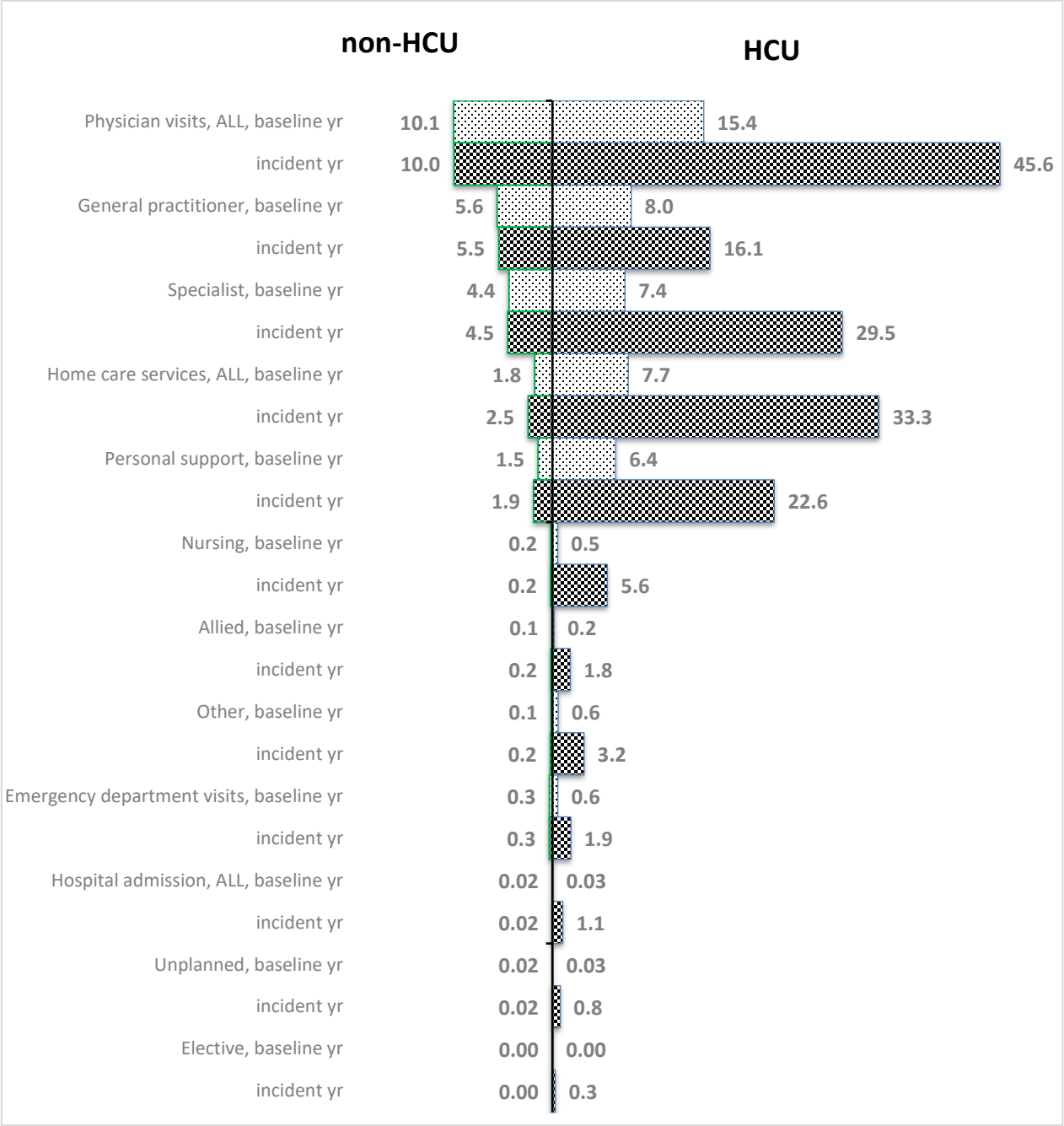
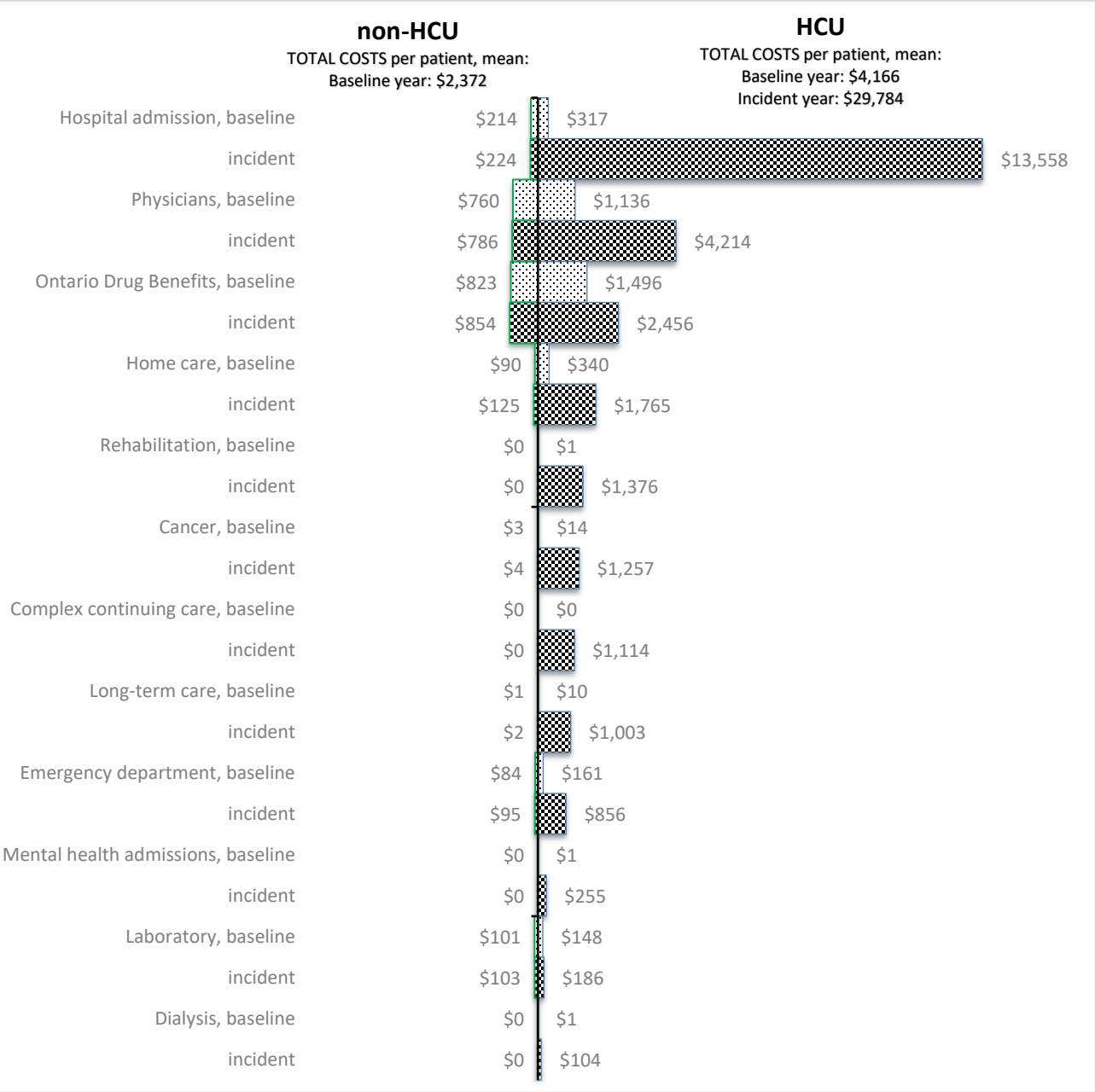


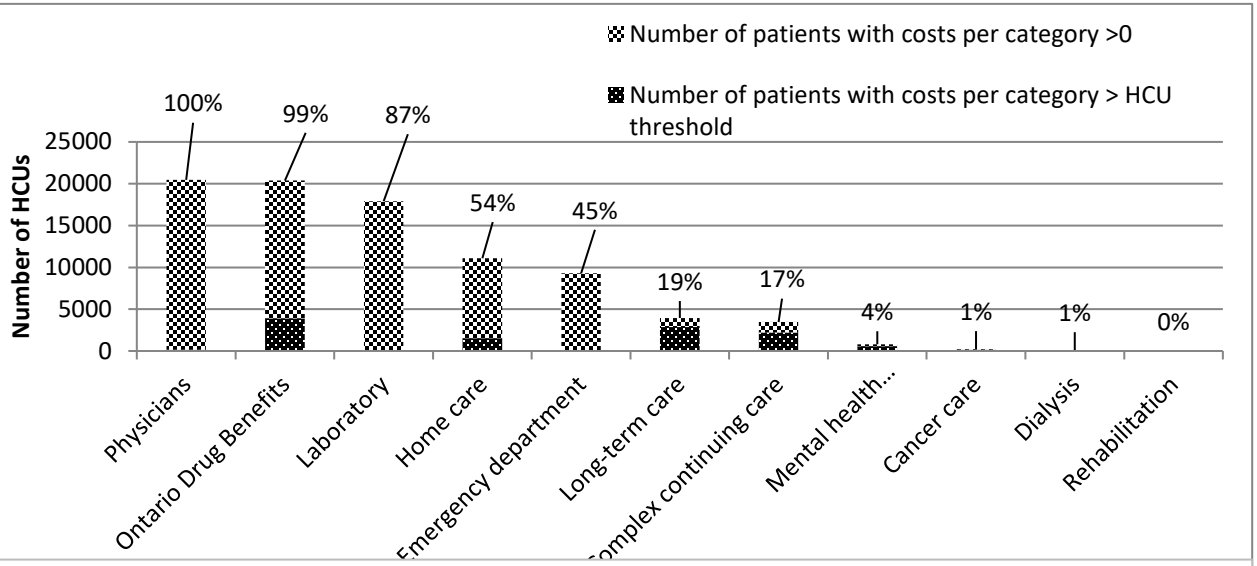
Figure 3

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



Appendix 1

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



Notes:
1. Total number of HCUs with no hospitalization costs in the incident year is **20,501 (11.6% of all HCUs)**
2. The percentages in the figure represent the proportion of patients out of the total number of HCUs without hospitalization expenditures during the incident year that incurred any costs in the corresponding cost category in that year.

Appendix 2

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

Cost components	FY2012 (pre-incident year)			FY2013 (incident year)		
	HCU N=175847	Non-HCU N=527541		HCU N=175847	Non-HCU N=527541	
	Mean, $ (SD)	Mean, $ (SD)	aSD	Mean, $ (SD)	Mean, $ (SD)	aSD
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)	1.4
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

Appendix 3

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

Cost components	FY2012 (pre-incident year)			FY2013 (incident year)		
	HCU N=175847	Non-HCU N=527541		HCU N=175847	Non-HCU N=527541	
	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	1.6
Elective	0.01 ± 0.07	0.01 ± 0.07	0.01	0.3 ± 0.51	0.01 ± 0.07	0.6
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	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	0.5
Other	0.58 ± 2.30	0.14 ± 0.96	0.25	3.22 ± 5.23	0.21 ± 1.09	0.6

aSD- absolute standardized difference;
FY- fiscal year

Appendix 4

Regression coefficients, recycled prediction, costs

Care categories / Covariates	Hospital admission			Physician			Homecare			Ontario Drug benefits			Emergency Department			Mental health admission			Total		
	Coeff	SE	P-value	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(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	5.32	<.0001	-4.95	0.09	<.0001
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	5.18	<.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	0.00	<.0001	-0.01	0.00	<.0001
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	0.01	0.214	-0.47	0.01	<.0001
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	0.00	<.0001	0.08	0.00	<.0001
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	0.05	0	0.10	0.02	<.0001
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	0.06	0.003	0.32	0.02	<.0001
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	0.28	<.0001	6.51	0.01	<.0001
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	<.0001
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	0.00	0.37	0.00	0.00	<.0001
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	0.01	<.0001	0.03	0.00	<.0001
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	0.00	0.002	0.01	0.00	<.0001
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	0.04	0.882	0.04	0.00	<.0001
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	0.05	0.214	0.04	0.00	<.0001
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	0.03	<.0001	0.58	0.00	<.0001

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

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	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	<.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	<.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	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	<.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
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	0.00	<.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	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

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	Hospital admission, All			Hospital admission, urgent			Hospital admission, elective			Physician visits, All			Physician visits, Specialist			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	<.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
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	<.0001	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	<.0001	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	<.0001	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	<.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		0.36	0.00	

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

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

Care categories / Covariates	Emergency department visits			Home care services, All*			Home care services, Personal support			Home care services, Nursing			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	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	<.0001	-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	<.0001	3.07	0.01	<.0001
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	<.0001	0.58	0.00	<.0001
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	<.0001	0.08	0.00	<.0001
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	<.0001	0.05	0.00	<.0001
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	<.0001
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	<.0001
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	<.0001
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	<.0001
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	<.0001	0.03	0.00	<.0001
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	<.0001	0.02	0.00	<.0001
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	<.0001	0.00	0.00	<.0001
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	<.0001	0.00	0.00	0.3217
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	<.0001	0.04	0.00	<.0001
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

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

	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 abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
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 recruitment, exposure, follow-up, and data collection	7
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	7
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6,8,9
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, describe which groupings were chosen and why	8-10
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9-10
		(*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	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	11
		(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) and information on exposures and potential confounders	11
		(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	12-14

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and 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	12-13
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Appendix 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 imprecision. Discuss both direction and magnitude of any potential bias	17-18
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	16,17,18
Generalisability	21	Discuss the generalisability (external validity) of the study results	18
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	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.

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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

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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 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 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.

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 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.

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

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

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].

Setting and data sources

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].

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. 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.

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].

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 looking back for 3 years prior to the incident year[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]. The choice of specific conditions used to describe patients was driven by several factors: 1) chronic conditions that are commonly associated with high economic burden (cardiovascular and pulmonary diseases, malignancy) [31-33]; 2) conditions that are well known risk factors (e.g., hypertension, diabetes); 3) availability of data.

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 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

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 2.5^{th} and 97.5^{th} percentiles were the 95% lower and upper bound CIs, 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 was confirmed by the modified Park test[42]. 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)[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

(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[43, 45]. 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).

Patient and Public Involvement

Patients or public were not involved in the design of this retrospective cohort study.

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			
Age, mean (SD), yr	77.7 ± 7.7	77.7 ± 7.7	0

Sex, female	93,119 (53%)	279,501 (53%)	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 standardized difference with aSD > 0.1 indicating meaningful difference between HCU and non-HCU			

HCU status

The 5% HCU annual 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.

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.

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.

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

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)

* - 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

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)[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 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, 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

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

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[50, 51], limiting the comparability of earlier studies that relied only on Medicare payments[11, 23, 52]. 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[53]. However, when used for comparisons at a provincial level, these estimations are considered acceptable[53]. 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[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. Finally, 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.

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 [57]. 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[58]. Canada has recently made steps to alleviate the burden of drug costs by negotiating lower prices of generic and non-generic drugs with manufacturers[59]. Although there may be room for further savings among generic drugs[60], these may be offset by the growing share of expensive biologics coupled with just a modest uptake of biosimilars[61]. Finally, future cost analysis of senior HCUs could benefit from greater data granularity. Following a patient longitudinally by type of care received in the incident year and time of death, 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 with greater accuracy, including specific clinical conditions (e.g., cognitive impairment among seniors) or conducting joint cost-survival modelling[62, 63].

Conclusion

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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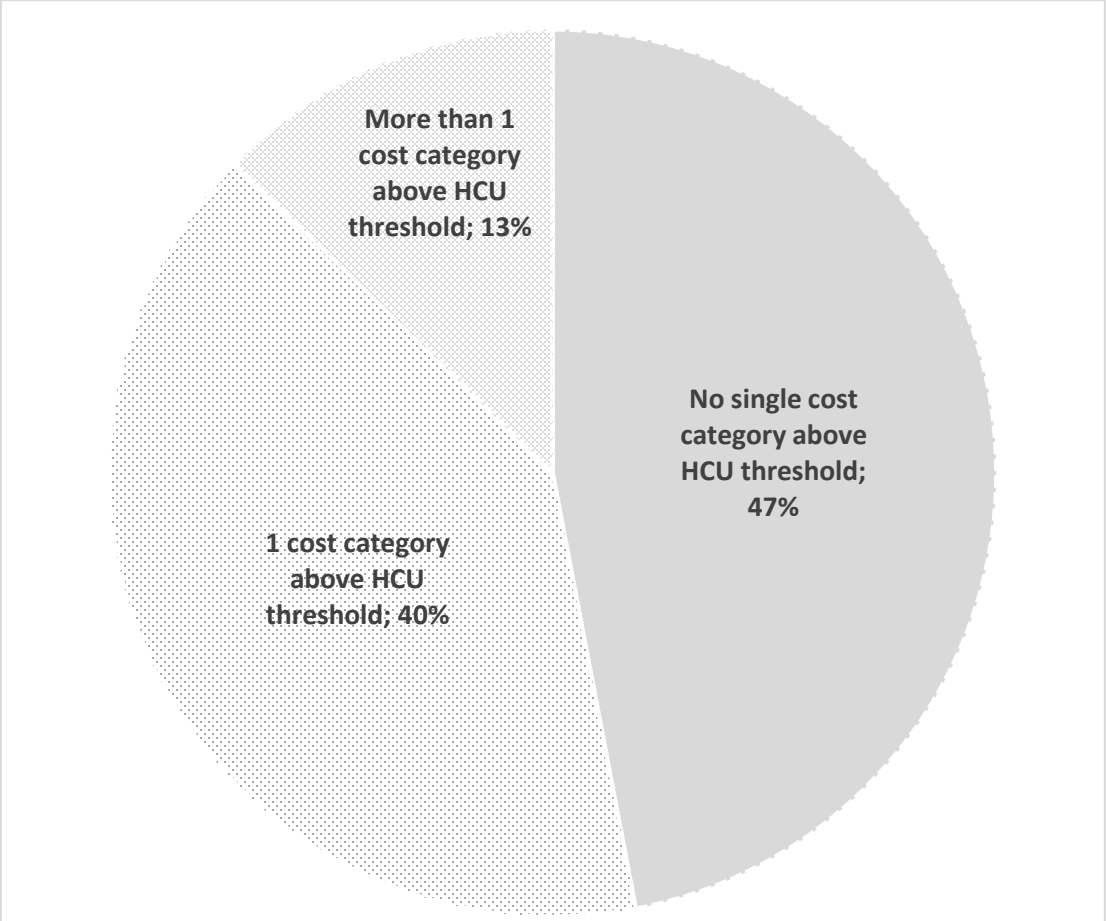
Figure 1

Proportion of new HCUs that made the HCU threshold due to various types of costs



The graph presents the proportion of senior HCU in the context of cost categories that reached the HCU threshold of $10,192.

- **One cost category** (e.g. hospital costs) reached the HCU threshold among 40% of new HCUs (% of patient in Top 5 categories: Hospital (70.7%); Cancer (8.1%); ODB (7.3%); LTC (5.1%); HC: (3.3%))
- **More than 1 cost category** (e.g. hospital and physician costs) reached the HCU threshold among 13% of HCUs (% of patient in Top 5 categories: Hospital (95.1%); Physician (35.5 %); Rehab (27.8%); CCC (18.6%); HC (13.6%))
- **No single cost category** reached the HCU threshold among 47% of new HCUs (% of patient in Top 5 categories: Physician (99.9%, mean $3022); ODB (99.6%, mean $2127); Hospital (88.7%, mean $5611); Laboratory (87.1%, mean $190); ED (70%, mean $654)

CCC - Contunuing Care; ED - Emergency Department; LTC- Long-term care; ODB - Outpatient Drug Benefit

Figure 2

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

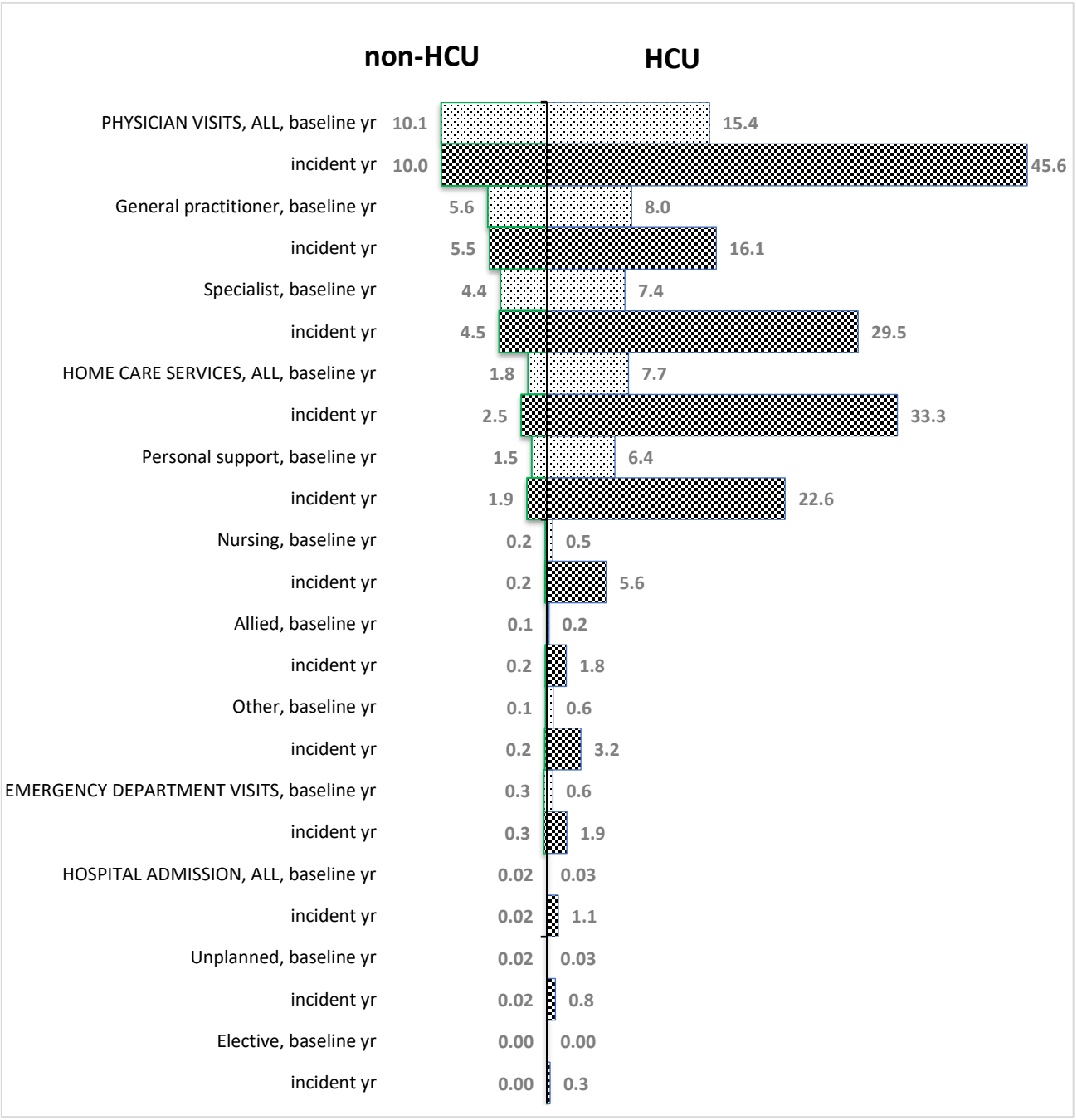
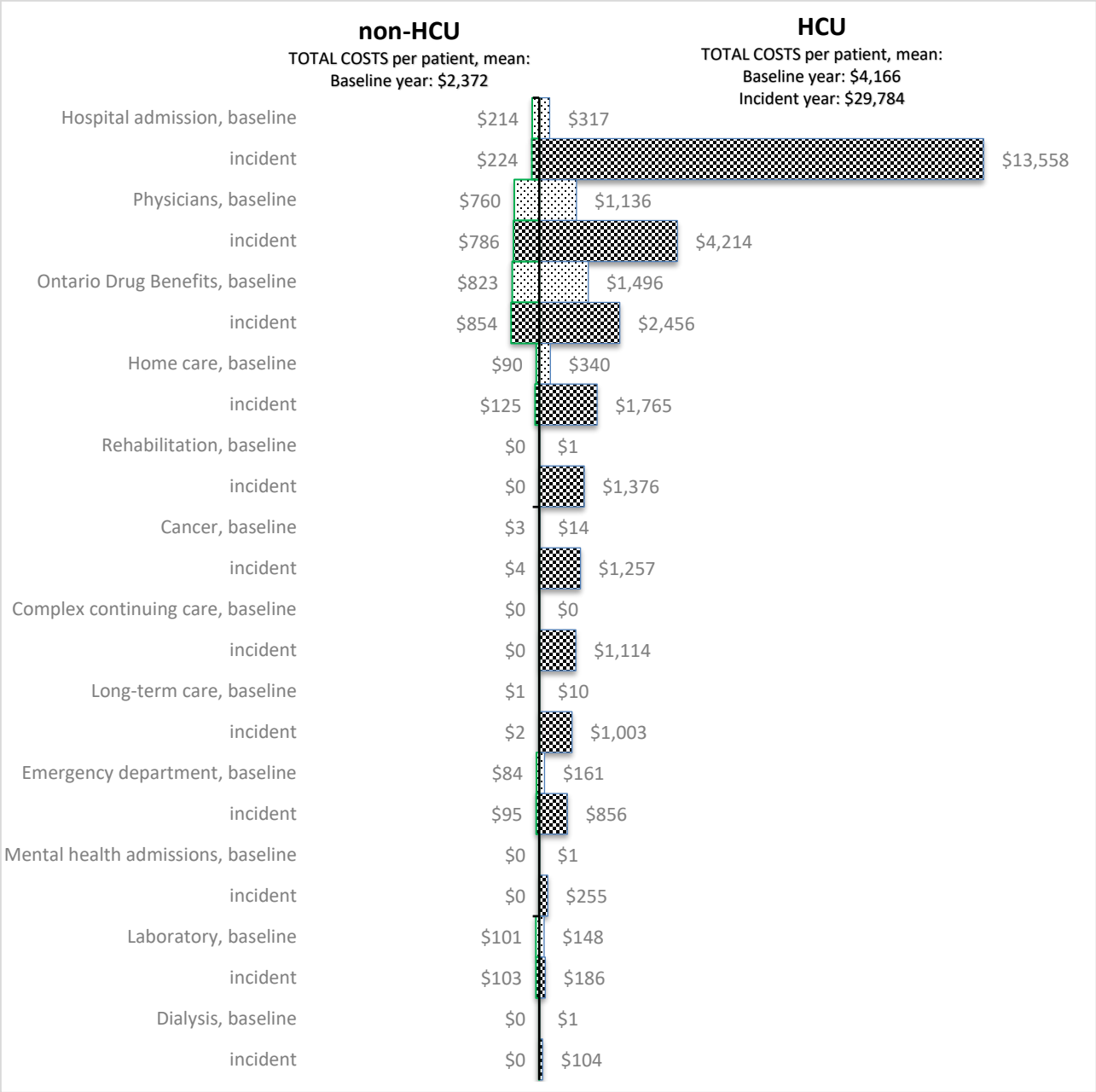


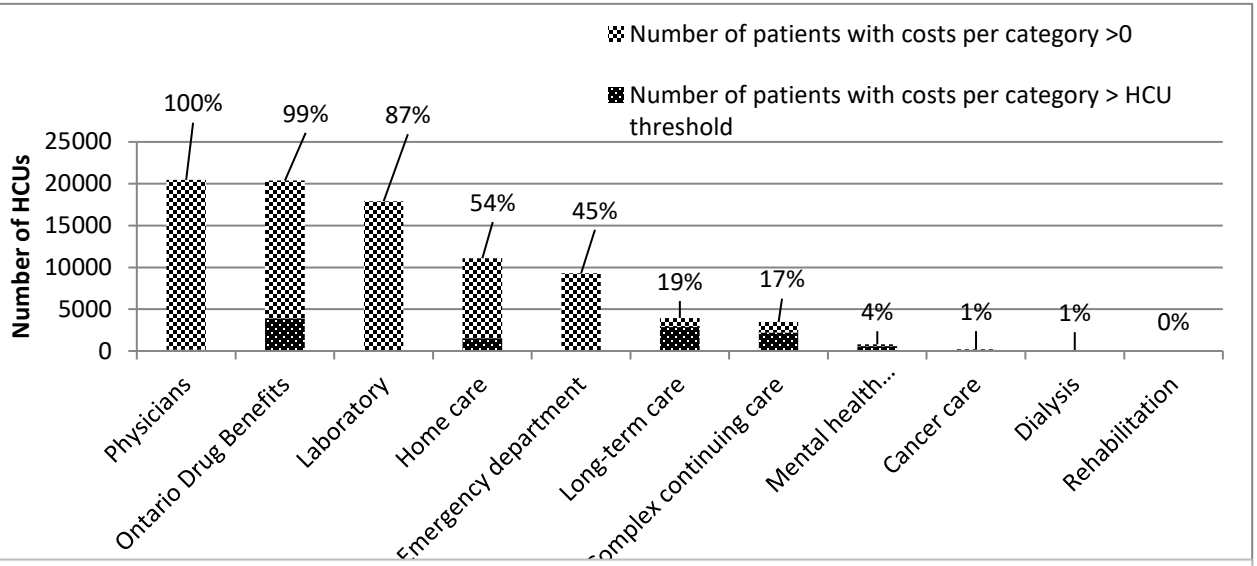
Figure 3

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



Appendix 1

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



Notes:

1. Total number of HCUs with no hospitalization costs in the incident year is **20,501 (11.6% of all HCUs)**
2. The percentages in the figure represent the proportion of patients out of the total number of HCUs without hospitalization expenditures during the incident year that incurred any costs in the corresponding cost category in that year.

Appendix 2

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

Cost components	FY2012 (pre-incident year)			FY2013 (incident year)		
	HCU N=175847	Non-HCU N=527541		HCU N=175847	Non-HCU N=527541	
	Mean, $ (SD)	Mean, $ (SD)	aSD	Mean, $ (SD)	Mean, $ (SD)	aSD
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)	1.4
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

Appendix 3

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

Cost components	FY2012 (pre-incident year)			FY2013 (incident year)		
	HCU N=175847	Non-HCU N=527541		HCU N=175847	Non-HCU N=527541	
	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	1.6
Elective	0.01 ± 0.07	0.01 ± 0.07	0.01	0.3 ± 0.51	0.01 ± 0.07	0.6
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	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	0.5
Other	0.58 ± 2.30	0.14 ± 0.96	0.25	3.22 ± 5.23	0.21 ± 1.09	0.6

aSD- absolute standardized difference;
FY- fiscal year

Appendix 4

Regression coefficients, recycled prediction, costs

Care categories / Covariates	Hospital admission			Physician			Homecare			Ontario Drug benefits			Emergency Department			Mental health admission			Total		
	Coeff	SE	P-value	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(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	5.32	<.0001	-4.95	0.09	<.0001
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	5.18	<.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	0.00	<.0001	-0.01	0.00	<.0001
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	0.01	0.214	-0.47	0.01	<.0001
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	0.00	<.0001	0.08	0.00	<.0001
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	0.05	0	0.10	0.02	<.0001
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	0.06	0.003	0.32	0.02	<.0001
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	0.28	<.0001	6.51	0.01	<.0001
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	<.0001
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	0.00	0.37	0.00	0.00	<.0001
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	0.01	<.0001	0.03	0.00	<.0001
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	0.00	0.002	0.01	0.00	<.0001
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	0.04	0.882	0.04	0.00	<.0001
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	0.05	0.214	0.04	0.00	<.0001
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	0.03	<.0001	0.58	0.00	<.0001

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

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	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	<.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	<.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	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	<.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
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	0.00	<.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	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

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	Hospital admission, All			Hospital admission, urgent			Hospital admission, elective			Physician visits, All			Physician visits, Specialist			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	<.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
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	<.0001	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	<.0001	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	<.0001	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	<.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		0.36	0.00	

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

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

Care categories / Covariates	Emergency department visits			Home care services, All*			Home care services, Personal support			Home care services, Nursing			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	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	<.0001	-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	<.0001	3.07	0.01	<.0001
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	<.0001	0.58	0.00	<.0001
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	<.0001	0.08	0.00	<.0001
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	<.0001	0.05	0.00	<.0001
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	<.0001
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	<.0001
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	<.0001
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	<.0001
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	<.0001	0.03	0.00	<.0001
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	<.0001	0.02	0.00	<.0001
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	<.0001	0.00	0.00	<.0001
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	<.0001	0.00	0.00	0.3217
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	<.0001	0.04	0.00	<.0001
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

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.

A.

```
%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);
```

```
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(ll);
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);
```

```
   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;
```

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

	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 abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
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 recruitment, exposure, follow-up, and data collection	7
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	7
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6,8,9
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, describe which groupings were chosen and why	8-10
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9-10
		(*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	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	11
		(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) and information on exposures and potential confounders	11
		(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	12-14

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and 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	12-13
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Appendix 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 imprecision. Discuss both direction and magnitude of any potential bias	17-18
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	16,17,18
Generalisability	21	Discuss the generalisability (external validity) of the study results	18
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	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.

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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

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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 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 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.

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 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.

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

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

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].

Setting and data sources

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].

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. 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.

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].

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 looking back for 3 years prior to the incident year[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]. The choice of specific conditions used to describe patients was driven by several factors: 1) chronic conditions that are commonly associated with high economic burden (cardiovascular and pulmonary diseases, malignancy) [31-33]; 2) conditions that are well known risk factors (e.g., hypertension, diabetes); 3) availability of data.

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 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

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 2.5^{th} and 97.5^{th} percentiles were the 95% lower and upper bound CIs, 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 was confirmed by the modified Park test[42]. 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)[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

(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[43, 45]. 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). The SAS scripts are available as supplemental material.

Patient and Public Involvement

Patients or public were not involved in the design of this retrospective cohort study.

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			
Age, mean (SD), yr	77.7 ± 7.7	77.7 ± 7.7	0
Sex, female	93,119 (53%)	279,501 (53%)	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 standardized difference with aSD > 0.1 indicating meaningful difference between HCU and non-HCU			

HCU status

The 5% HCU annual 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.

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.

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.

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

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)

* - 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

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)[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 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, 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 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 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[50, 51], limiting the comparability of earlier studies that relied only on Medicare payments[11, 23, 52]. 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[53]. However, when used for comparisons at a provincial level, these estimations are considered acceptable[53]. 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[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 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 [57]. 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[58]. Canada has recently made steps to alleviate the burden of drug costs by negotiating lower prices of generic and non-generic drugs with

manufacturers[59]. Although there may be room for further savings among generic drugs[60], these may be offset by the growing share of expensive biologics coupled with just a modest uptake of biosimilars[61]. Finally, future cost analysis of senior HCUs could benefit from greater data granularity. Following a patient longitudinally by type of care received in the incident year and time of death, 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 with greater accuracy, including specific clinical conditions (e.g., cognitive impairment among seniors) or conducting joint cost-survival modelling[62, 63].

Conclusion

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.

Figure 1: Proportion of new HCUs that made the HCU threshold due to various types of costs

The graph presents the proportion of senior HCU in the context of cost categories that reached the HCU threshold of $10,192. **One cost category** (e.g. hospital costs) reached the HCU threshold among 40% of new HCUs (% of patient in Top 5 categories: Hospital (70.7%); Cancer (8.1%); ODB (7.3%); LTC (5.1%); HC: (3.3%)) **More than 1 cost category** (e.g. hospital and physician costs) reached the HCU threshold among 13% of HCUs (% of patient in Top 5 categories: Hospital (95.1%); Physician (35.5 %); Rehab (27.8%); CCC (18.6%); HC (13.6%)). **No single cost category** reached the HCU threshold among 47% of new HCUs (% of patient in Top 5 categories: Physician (99.9%, mean $3022); ODB (99.6%, mean $2127); Hospital (88.7%, mean $5611); Laboratory (87.1%, mean $190); ED (70%, mean $654)

CCC – Complex Continuing Care; ED - Emergency Department; LTC- Long-term care; ODB - Outpatient Drug Benefit

Figure 2: Dynamics of change in annual healthcare use, before (baseline) and during incident year, by HCU status and cost categories (mean per patient)

The graph shows a dramatic increase in healthcare use among senior HCU during FY2013, while the service consumption among non-HCU remained relatively unchanged from the baseline year

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)

Total costs per patient (mean) among HCUs: $4,166 (baseline year) and $29,784 (incident year)

Total costs per patient (mean) among non-HCUs: $2,372 (baseline year) and $2,471 (incident year)

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Figure 1

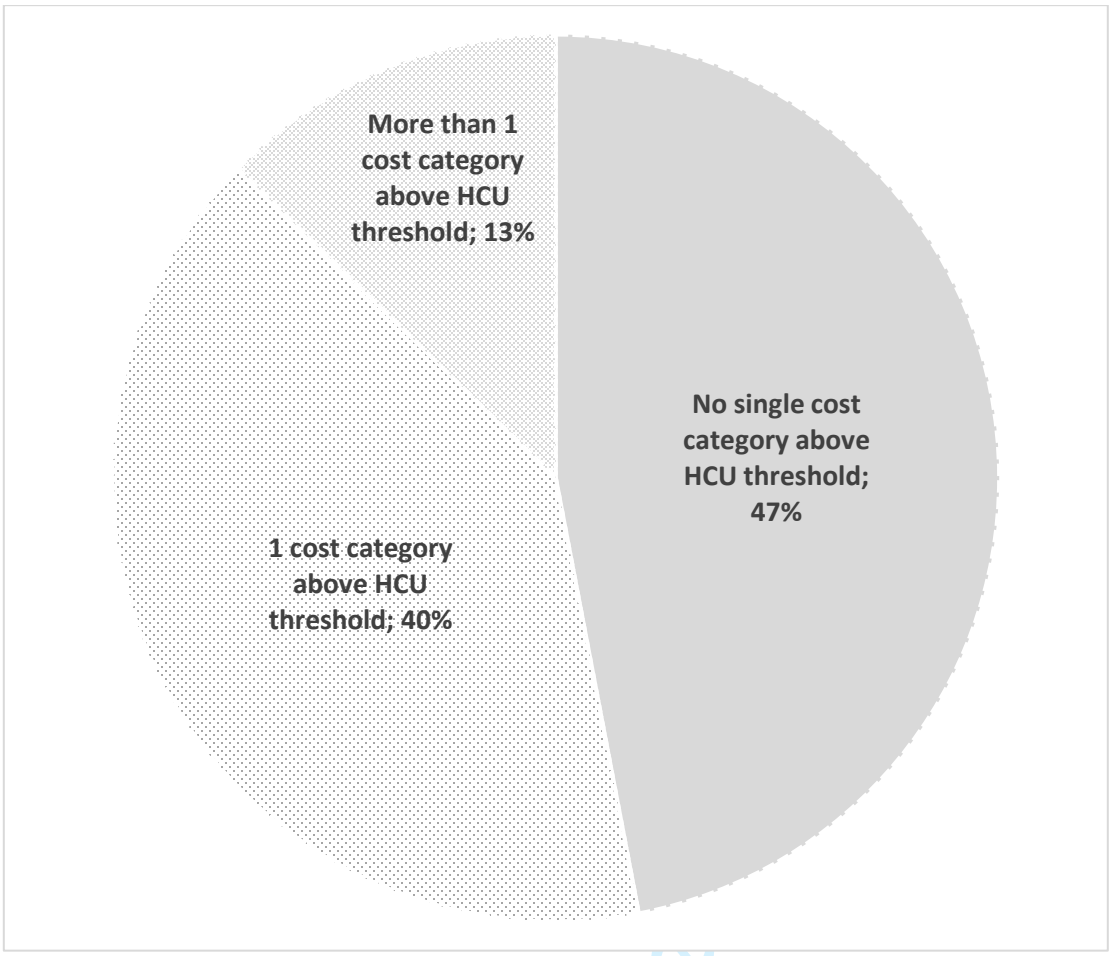


Figure 2

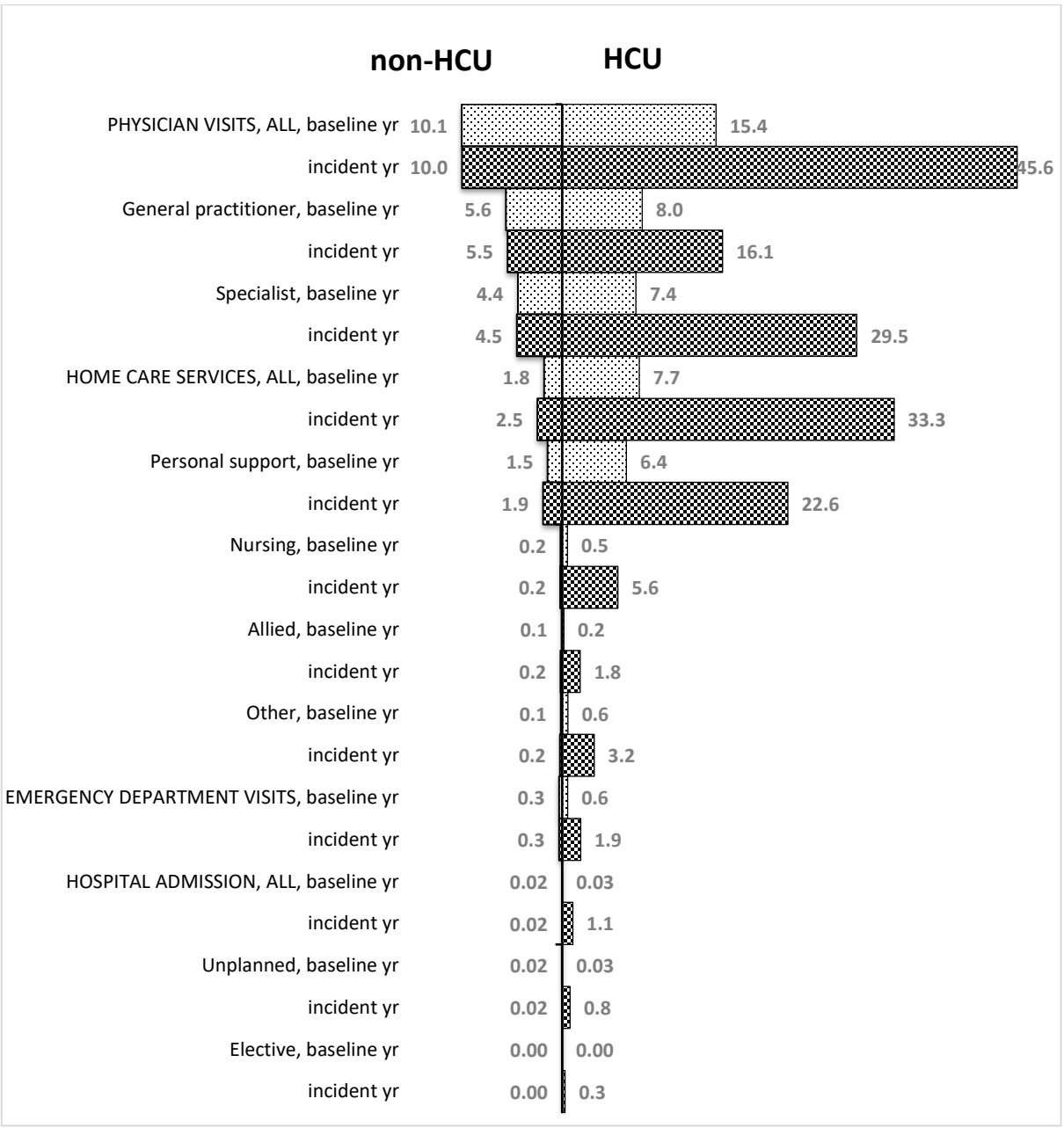
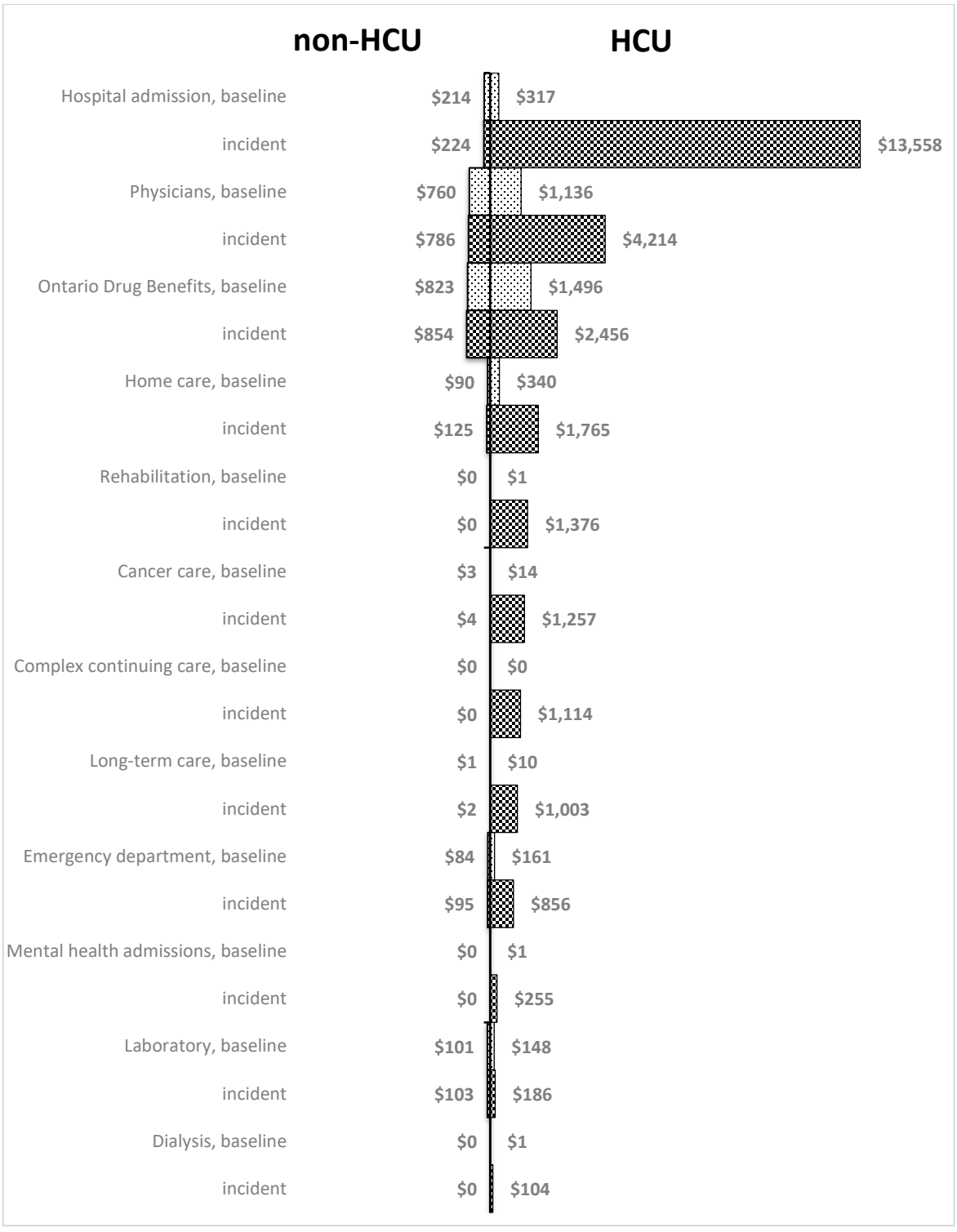
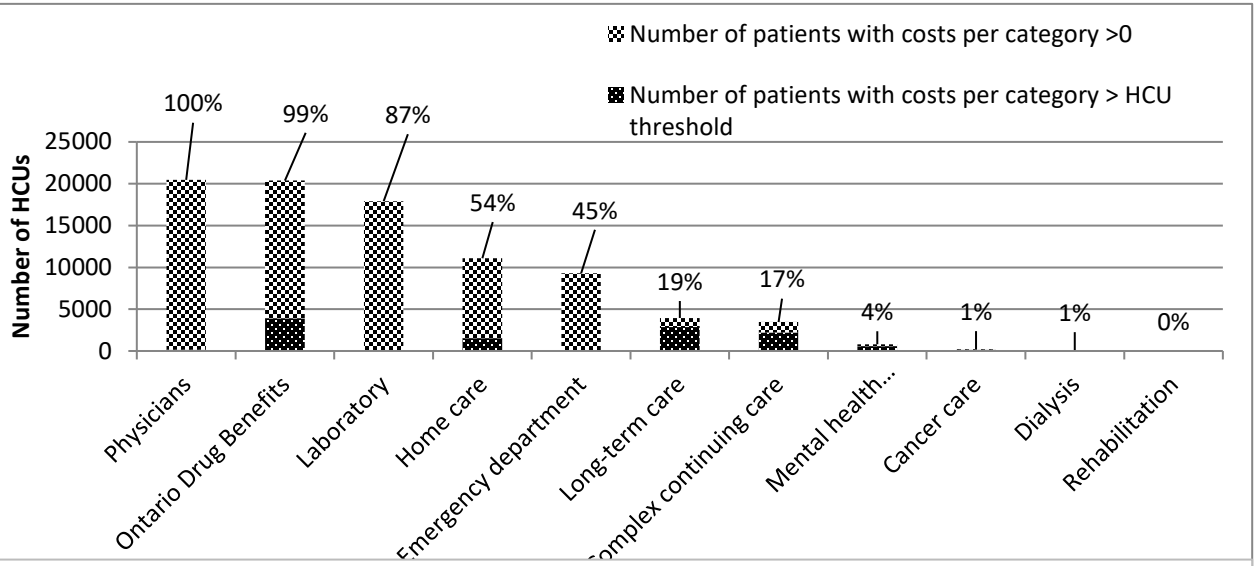


Figure 3



Appendix 1

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



Notes:
1. Total number of HCUs with no hospitalization costs in the incident year is **20,501 (11.6% of all HCUs)**
2. The percentages in the figure represent the proportion of patients out of the total number of HCUs without hospitalization expenditures during the incident year that incurred any costs in the corresponding cost category in that year.

Appendix 2

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

Cost components	FY2012 (pre-incident year)			FY2013 (incident year)		
	HCU N=175847	Non-HCU N=527541		HCU N=175847	Non-HCU N=527541	
	Mean, $ (SD)	Mean, $ (SD)	aSD	Mean, $ (SD)	Mean, $ (SD)	aSD
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)	1.4
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

Appendix 3

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

Cost components	FY2012 (pre-incident year)			FY2013 (incident year)		
	HCU N=175847	Non-HCU N=527541		HCU N=175847	Non-HCU N=527541	
	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	1.6
Elective	0.01 ± 0.07	0.01 ± 0.07	0.01	0.3 ± 0.51	0.01 ± 0.07	0.6
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	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	0.5
Other	0.58 ± 2.30	0.14 ± 0.96	0.25	3.22 ± 5.23	0.21 ± 1.09	0.6

aSD- absolute standardized difference;
FY- fiscal year

Appendix 4

Regression coefficients, recycled prediction, costs

Care categories / Covariates	Hospital admission			Physician			Homecare			Ontario Drug benefits			Emergency Department			Mental health admission			Total		
	Coeff	SE	P-value	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(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	<.0001
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	0.18	<.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	0.00	<.0001	-0.01	0.00	<.0001
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	0.01	0.214	-0.47	0.01	<.0001
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	0.00	<.0001	0.08	0.00	<.0001
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	0.05	0	0.10	0.02	<.0001
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	0.06	0.003	0.32	0.02	<.0001
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	0.28	<.0001	6.51	0.01	<.0001
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	<.0001
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	0.00	0.37	0.00	0.00	<.0001
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	0.01	<.0001	0.03	0.00	<.0001
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	0.00	0.002	0.01	0.00	<.0001
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	0.04	0.882	0.04	0.00	<.0001
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	0.05	0.214	0.04	0.00	<.0001
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	0.03	<.0001	0.58	0.00	<.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;
ADG- Aggregate Diagnosis Group; Coeff- regression coefficient; HCU- high-cost user; SE- standard error

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	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	<.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	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	<.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	0.00	<.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	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;
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	Hospital admission, All			Hospital admission, urgent			Hospital admission, elective			Physician visits, All			Physician visits, Specialist			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
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	<.0001	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	<.0001	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	<.0001	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	<.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		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

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

Care categories / Covariates	Emergency department visits			Home care services, All*			Home care services, Personal support			Home care services, Nursing			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	P-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	<.0001	-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	<.0001	3.07	0.01	<.0001
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	<.0001	0.58	0.00	<.0001
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	<.0001	0.08	0.00	<.0001
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	<.0001	0.05	0.00	<.0001
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	<.0001
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	<.0001
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	<.0001	-0.47	0.01	<.0001
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	<.0001
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	<.0001	0.03	0.00	<.0001
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	<.0001	0.02	0.00	<.0001
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	<.0001	0.00	0.00	<.0001
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	<.0001	0.00	0.00	0.3217
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	<.0001	0.04	0.00	<.0001
Scale parameter	1.09	0.02					115.73	0.00		2.12	0.02		1.01	0.01				

*-models were fit using Poisson distribution

*- 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

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.

A.

```
%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);
```

```
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(ll);
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);
```

```
   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;
```

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

	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 abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	4
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
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 recruitment, exposure, follow-up, and data collection	7
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	7
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6,8,9
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, describe which groupings were chosen and why	8-10
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9-10
		(*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	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	11
		(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) and information on exposures and potential confounders	11
		(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	12-14

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and 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	12-13
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Appendix 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 imprecision. Discuss both direction and magnitude of any potential bias	17-18
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	16,17,18
Generalisability	21	Discuss the generalisability (external validity) of the study results	18
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	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.