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Senior high cost healthcare users' resource utilization and outcomes: a protocol of a retrospective matched cohort study

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ABSTRACT

Introduction

Senior high cost users (HCUs) are estimated to represent 60% of all HCUs in Ontario, Canada's most populous province. To improve our understanding of individual and health system aspects related to senior HCUs, an inquiry will be conducted into incident senior HCUs in terms of their incremental healthcare utilization and costs, characteristics of index hospitalization episodes, mortality and their regional variation across Ontario.

Methods and analysis

A retrospective, population-based cohort study using administrative healthcare records will be used. Incident senior HCUs will be defined as Ontarians age ≥66 years who were in the top 5% of healthcare cost users during fiscal year 2013 but not during fiscal year 2012. Each HCU will be matched to 3 non-HCUs by age, sex and health planning region. Incremental healthcare use and costs will be determined using the 'difference in differences' approach. We will apply multivariable logistic regression to determine patient and care factors associated with index hospitalization and in-hospital mortality during the incident year. The most common causes of admission will be identified and contrasted with the most expensive hospitalized conditions. We will also calculate the ratio of inpatient costs incurred through admissions of ambulatory care sensitive conditions (ACSC) to the total inpatient expenditures. The magnitude of variation in costs and health service utilization will be established by calculating the extremal quotient, the coefficient of variation, and the Gini mean difference for estimates obtained through multilevel regression analyses.

Ethics and dissemination

This study has been approved by Hamilton Integrated Research Ethics Board (ID#1715-C). The results of the study will be distributed widely through peer-reviewed journals. They also will be disseminated at research events in academic settings, national and international conferences as well as with presentations
to provincial health authorities.

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Strengths

- The study provides a focused look at incident, or "new", cases of senior HCUs using a matched cohort design
- The study draws on econometrics methods to calculate incremental values of costs and health service use that have never been reported for HCUs to our knowledge
- Detailed information on every hospitalization is available allowing to compare characteristics of index hospitalizations between HCUs and non-HCUs and to determine the economic contribution of individual conditions, including ACSCs

Limitations

- This study is subject to the limitations inherent in observational design and the use of health administrative databases
- The study is limited by the period of observation of 1-year before and after becoming HCU for most of the variables

INTRODUCTION

Societies worldwide are facing a demographic shift towards a growing proportion of seniors, defined as people aged 65 years and older[1]. The phenomenon is more prominent in developed nations. In 2015, the proportion of seniors in Canada, for instance, exceeded the proportion of young people (i.e., <15 years of age) for the first time in history[2]. From an economic point of view, seniors account for 46% of the national public healthcare expenditures in Canada[3]. This proportion is likely to increase due to the continued ageing of the population, therefore putting additional pressure on the government in the coming years. In addition, the high-cost users (HCUs) of health services[4, 5], commonly defined as individuals in the highest 5% of total expenditures, are often seniors. For example, senior HCUs are estimated to represent 60% of all HCUs in Ontario, Canada's most populous province[4]. Consistent with findings from other jurisdictions [6, 7], a recent Ontario study indicated that 5% of senior HCUs consume 44% of the total measured public healthcare expenditures by the seniors in the province[8].

A number of demographic and clinical characteristics of the senior HCUs have been described internationally and in Canada: high level of comorbidities, functional impairment, and poor social supports at home[8-10]. However, many individual and health system aspects related to senior HCUs are still poorly understood. Filling gaps in our understanding of this HCU subgroup is especially important at a time when policy makers are targeting interventions for HCUs such as complex case management and care coordination models[8, 11-13]. In particular, a closer inquiry is required into the incident, or "new", senior HCUs in terms of their incremental healthcare utilization and costs, characteristics of their hospitalization episodes, including the economic impact of admissions for individual conditions, and regional variation in main outcomes across Ontario.

Incremental costs among incident HCUs

Many disease management programs as well as research efforts focus on persistent HCUs, i.e., those that retain their HCU status in subsequent years[8, 13, 14]. This practice ignores the fact that new HCUs have historically accounted for more than 50% of all the cases annually, including those among senior patients[8, 15]. Incident HCUs may have different characteristics than prevalent HCUs, and more focus on incident HCUs will allow for scrutiny of the factors that influence the transition from non-HCU to HCU, and whether HCU status is maintained versus an individual transitioning back to non-HCU.

The magnitude of incremental healthcare utilization and costs attributable to becoming a HCU is unknown. HCU research in Canada and elsewhere has been conducted predominantly on prevalent HCU cohorts using cross-sectional designs, [4, 7, 8, 11, 16, 17]. These studies provide valuable information on comparisons, for example, of the 1-year costs of HCUs compared to non-HCUs. However, these methods do not explore the change in outcomes associated with becoming a new HCU beyond secular trends in outcomes over time, thus miss the contribution of HCU status. In addition, no study to our knowledge has compared the characteristics, costs and outcomes of incident HCUs to a matched cohort of non-HCUs, which would provide a more detailed assessment of the distinguishing features of HCU status. Finally, HCU related research with a system-wide approach is still limited[4, 8] as studies have largely focused on acute care (e.g. hospitalizations, emergency care, physicians) and have left out other important care categories such as long-term care, rehabilitation, medications. Recently, a population-

based study conducted in Ontario, Canada took a one year look at the cost distribution across a wider range of health sectors among HCUs, including seniors[8]. Although it was applied to prevalent HCUs and was not intended to provide a detailed characterization of the study population and a comparison with non-HCUs, we will be building on their work by using the same cost algorithm.

Analysis of hospitalization episodes among senior incident HCUs compared to non-HCUs

The majority (> 90% in some studies) of senior HCUs have at least one hospital admission in the year they reach HCU status[15]. Considering that hospitalization costs among HCUs account for almost two thirds of direct medical costs[4], it is important to better understand the characteristics associated with hospitalizations among incident HCUs. To date, much of the literature on risk factors and interventions to prevent hospitalization has focused on hospital re-admissions [18-21]. However, as opposed to younger adults in whom hospitalizations often occur due to a sudden event (e.g. trauma) that often resolves without serious permanent cost or care implications[22], re-admissions in senior patients, especially HCUs, may signal a deterioration in health status and mark a point where management interventions are less likely to be effective in preventing recurrent hospitalizations[13].Therefore, focusing on the index hospitalizations associated with becoming an incident senior HCU (i.e., the first admission in the fiscal year when the patient reaches the HCU status) with the goal to reduce or divert them may be a more appropriate target for policy development. Since this subject has received little attention[23], more information is needed on the index hospitalization, including the patient demographic and clinical attributes (e.g. whether the patient is admitted for a newly diagnosed condition or a condition that s/he has received care in preceding years), outpatient care that was provided prior to the admission (e.g. type of home care visits), and the environment within which the care is received (e.g., primary care model).

Determining the most expensive conditions by inpatient costs and identifying patient attributes associated with them is also of great interest to health planners and administrators as a potential target for cost containment strategies. In this respect, the contribution of ambulatory care sensitive conditions (ACSC) to HCU requires clarification. ACSC-related hospital admissions, i.e. those which are theorized to be reducible with high-quality primary care[24, 25], have been long used as an indicator of access to primary care at the population-level[26-28]. In Canada, several chronic ACSC are on a national list of indicators of health system performance reported by health authorities[29]. However, the economic impact of ACSC admissions among HCUs is unclear. A recent US study revealed that no more than 10% of hospitalization costs among the top decile of Medicare HCUs were ACSC-related [30]. The authors commented that if the financial impact of ACSC is low and resource consumption is a target for intervention, it may be worthwhile to shift prevention efforts to other conditions that are financially more burdensome. The only Canadian study of this issue reported that 6% of hospital encounters among HCUs were considered ambulatory sensitive. This study however was different from the US study in that it defined the top 5% percentile as HCUs (versus 10%), investigated a broader population (children and adults up to 75 years of age) admitted to a single tertiary hospital in Ottawa, Ontario, and estimated the ACSC costs focusing on a shorter list of chronic conditions [31]. As such we do not know if these results are generalizable to all hospitalizations in Ontario and to the senior HCUs. None of these studies have focused on incident HCUs in which the economic impact from ACSCs may be different

compared to persistent HCUs or on the relative contribution of ACSCs on the index hospitalizations during the incident year.

Regional variation in health services use, costs and mortality among incident senior HCUs

Finally, evidence on geographic variation in healthcare utilization, costs and mortality among senior HCUs is scarce[4, 32]. In Canada's general population, variation in health service use (e.g., hospital admission rates, surgical procedures or consumption of medications), both at provincial level and when compared to other countries, can be substantial[33-36]. This observation however may be misleading as assessments of variation are commonly adjusted for age and sex only[35-38] despite numerous reports revealing the impact of socio-demographic or healthcare supply factors on this variation[34, 39, 40]. On the other hand, healthcare spending may show a lower level of variability. For example, a recent study conducted in British Columbia, Canada reported a coefficient of variation (CV) for total healthcare spending of 8.6 (4.9 upon adjustment) [39]. This is lower compared to the US and the UK that reported CVs of approximately 12 and 10, respectively[41]. It is unclear how all these findings relate to senior HCUs in the context of Ontario. Further, assessment of variation in individual cost categories has not been reported. Moreover, it is important to understand the association between variation in healthcare spending and service use with outcomes such as mortality[33], which can help identify areas of potential inefficiency.

Geographical units should reflect actual patterns of services use. In Ontario, delivery of care is organized by health planning regions, Local Health Integration Networks (LHIN). LHINs were originally established to reflect local patterns of clinical decision making and use of services. However, inter-region migration to receive health services is common. The proportion of expenses incurred for acute care provided in health facilities outside the LHIN of residence ranged from 3% to 49% depending on the LHIN[32]. While current reforms in Ontario are providing more autonomy to the LHINs to deliver and monitor quality of care[42], the impact of such migration on variation in healthcare use and spending among HCUs has received little attention in the literature, although potential budget planning implications for LHINs can be sizable due to the high costs associated with HCUs.

Here, we propose to answer three inter-related research questions:

1. What is the one-year incremental healthcare utilization and direct financial impact on public payers of becoming an incident HCU among seniors in Ontario?
2. What are the characteristics of hospital admissions and associated costs in senior incident HCUs compared to non-HCUs in Ontario?
3. What is the extent of regional (LHIN-level) specific variation among senior incident HCUs compared to non-HCUs in Ontario in terms of healthcare utilization, costs, and mortality?

METHODS AND ANALYSIS

Study Design

The proposed study is a retrospective population-based matched cohort study using linked administrative health data. Registration number is NCT02815930 (clinicaltrials.gov).

Setting

Ontario is the most populous province in Canada, with almost 14 million residents, representing about 40% of the Canadian population[43]. It is divided into 14 LHINs that are responsible for local health care planning and delivery[42]. The Ontario Ministry of Health and Long-Term Care (MOHLTC), using general taxation revenues (80% provincial and 20% federal transfer), pays for approximately 70% of health care provided in the province. This includes 90% to 100% funding of hospital care, physician costs, public health, and prescription drugs for seniors[3] while contributions to other services (e.g., long-term care facilities) are less.

Study Cohorts

The study population is senior HCUs with annual total healthcare expenditures within the top 5% threshold of all Ontarians in the fiscal year of 2013 (i.e. incident year), who were not in the top 5% in the preceding year. Total health care expenditures will be calculated using the Institute of Clinical Evaluative Sciences (ICES) person-level health utilization costing algorithms[44]. ICES is an independent, non-profit research corporation funded by the Ontario Ministry of Health and Long-Term Care (www.ices.on.ca).

To reduce bias due to confounding the incident HCU cohort will be matched with non-HCU in a ratio of 1:3 according to age at cohort entry (+/- 1 month), sex and LHIN of patient residence. Health services utilization and costs will be captured from April 1, 2013 to March 31, 2014.

Data Set

The patient level dataset will be created using 15 health administrative databases housed at ICES. These databases contain publicly funded administrative health service records for the Ontario population eligible for health coverage. These databases are linked using encrypted patient-specific identifiers. Appendix 1 presents a description of databases that will be used to create the dataset.

Variables

The dataset will include a number of variables related to patient socio-demographic characteristics, healthcare use, and patient outcomes which are briefly described below.

Patient characteristics include age, sex, geographic location, income (in quintiles), immigration status, and comorbidity. Geographical location of residence (urban/suburban/rural) is based on the Rural Index of Ontario(RIO) and LHIN[45]. Multi-morbidity is captured by means of John Hopkins Expanded Diagnosis Clusters (EDCs). EDCs are derived from Johns Hopkins Adjusted Clinical Groups (ACGs, www.hopkinsacg.org)[46], which are used to organize the codes of the International Statistical Classification of Diseases and Related Health Problems, the 10th revision, Canadian version (ICD10-

CA)[47] into 282 clinically similar clusters. EDCs will be based on 3 years of hospitalization and ambulatory data prior to index date.

Care characteristics include the primary care provider payment model. The providers are categorized by several main primary care patient enrolment models: Fee for Service (FFS), Enhanced FFS, Family Health Team (FHT), Capitation, and None. Under enhanced FFS model, provider's compensation is based on FFS billing with enhanced FFS components and incentives for the provision of services for specific patient needs. FHT models consists of two options: the primarily capitation-based Family Health Network (FHN) and the capitation or salaried based Family Health Organization (FHO). If the patient is affiliated with either FHN or FHO but not matched to FHT, then the patient is placed with the Capitation category. The None category refers to patients for whom no primary care provider was identified (i.e., they were not enrolled with a provider through a patient enrollment program and they were not virtually rostered based on claims because they did not have any billing claims with primary care fee codes).

Resource utilization variables include the number of hospitalizations, emergency department (ED) visits, physician encounters, publicly funded home care visits and long-term care. Home care visits are categorized by type of services provided such as nursing, personal support, or allied health. For each hospitalization, the following information is derived: admission type (urgent or elective), length of stay, the type of institution the patient has been transferred from, alternate level of care (ALC) status, discharge destination, date of death while in hospital, whether the hospitalization happened within the LHIN of residence, and hospitalization costs. All health care expenditures are derived using the ICES costing algorithm for each cost category (See Appendix 2 for more detail on the categories). Costs are expressed in 2017 Canadian Dollars.

STUDY PRIMARY OUTCOMES

1. One-year incremental healthcare utilization (rate per 10,000 of study population for hospital admissions, ED, physician and home care visits) and costs (mean) attributable to becoming an HCU at the provincial level (Research Question 1)
2. Determination of patient and care factors associated with a) index hospitalization (odds ratio) and b) its in-hospital mortality (odds ratio) among HCUs and non-HCUs during the incident year (Research Question 2)
3. Proportion (%) of ACSC-related hospitalization costs to annual total inpatient costs during the incident year at the provincial level for the HCU and non-HCU cohorts (Research Question 2)
4. Patterns of variation in healthcare utilization, mortality and costs across LHINs in HCUs compared to non-HCUs during the incident year (Research Question 3)

ANALYSIS PLAN

The two matched cohorts (HCUs and non-HCUs) will be described using descriptive statistics. In addition to standardized differences[48] to compare the baseline characteristics of the two cohorts, regression methods will be used to adjust for differences between the cohorts. Goodness of fit statistics will be

used to evaluate models and guide model selection. A level of significance (α) of 0.05 will be applied to indicate statistical significance (see Appendix 3 for more detail).

Regression models for cost and count data including two-part models to deal with the potential over-representation of zeros in the data will be used to analyze the data. For example, we expect that many members in the non-HCU cohort may have no encounters with the health system (i.e., no hospital admission, physician visits or visits to ED). Ignoring the fact that the data are not normally distributed or utilizing only the portion of the data with the values greater than zero can lead to biased estimates[49]. The following provides more information on the analysis plan for each of the 3 research questions.

Research Question 1:

To estimate the incremental healthcare utilization and costs attributable to becoming an HCU, difference in differences (DID) models will be developed. The HCU dataset containing 1-year pre- and post-values is an example of longitudinal data. Incremental values of the outcome variables (i.e., costs, physician encounters, etc.) represent the difference between the two cohorts over time, sometimes referred to as change analysis[50]. The use of the DID estimator permits inference regarding the incremental values accounting for the outcome trajectories over time and the differences in the outcome values between the two cohorts [50, 51]. DID analysis is accomplished by regressing outcomes for each individual onto time (the year prior to the index date compared to the year after), group (HCU or non-HCU), and their interaction; this last term is the DID that yields an estimate of incremental values. DID models will be adjusted to account for any differences between the cohorts (i.e. comorbidities). Several DID models will be conducted to analyze changes in costs and healthcare utilization.

Originally used in health economics for policy impact evaluations[52], the DID estimator requires that the data meet two key assumptions in order to establish causality of the policy impact: 1) parallel trends assumes that trajectories in outcomes between the groups are the same prior to the exposure and would continue if no exposure occurred[53] and 2) no substantial variation between the groups at baseline[54]. The latter is to a large extent handled by matching the cohorts and adjusting for important covariates through regression. The former is more difficult to meet. However, we can relax this criterion, as it is more important for causal inference, which is not a purpose of our study.

Research Question 2

To describe and compare characteristics of the index hospitalization among senior HCUs vs non-HCUs during the incident year (Fiscal year 2013), we will define an index hospitalization as the first hospitalization in the incident year among subjects without admissions of any type in the preceding year (Fiscal year 2012). We will provide descriptive statistics on hospitalizations by the type of admission (frequency of urgent vs elective), by the total length of stay (mean), including the alternate level of care status and the number of ALC days (mean), by discharge destination (frequency) and in-hospital mortality. We will identify the most common clinical causes of admissions and contrast the list with a list of most expensive hospitalized conditions for both cohorts to distinguish common diagnoses from

diagnoses that drive inpatient spending. To determine patient and care factors associated with index hospitalization and its in-hospital mortality (dependent variables) during the incident year, we will apply multivariable logistic regression using a list of pre-determined demographic, clinical and care factors (Appendix 3). Data preparation before running regression analyses will include identifying co-linearity between the variables.

To investigate the proportion of ACSC-associated hospitalization costs, we will identify patients admitted for ACSCs and calculate for the HCU and the non-HCU cohorts the ratio of inpatient costs incurred through ACSC admissions to the total inpatient expenditures. Our ACSC list will be based on the list originally developed by the Agency for Healthcare Research and Quality (AHRQ)[28]. Chronic conditions on the list (e.g. hypertension, diabetes, and etc.) will be identified using the Canadian Institute of Health Information (CIHI) ACSC algorithm[26] which is based on the AHRQ original list adapted to Canada. The algorithm for 3 other conditions considered acute (e.g., bacterial pneumonia, dehydration and urinary tract infections) and not included in the CIHI algorithm of chronic conditions will be derived by directly converting the original ICD-10-CM codes of the AHRQ original list into ICD-10-CA. Appendix 4 provides more detail on the algorithms.

Consistent with the approach to ACSC identification that was previously used by researchers [26, 31, 55], ACSC related hospitalizations can be identified using the most responsible diagnosis at discharge. However, using the most responsible diagnosis which accounts for the largest portion of consumed resources during the hospitalization may not be able to accurately capture all ACSC-associated admission costs. Applying a ACSC definition to preadmission diagnoses that also add to the use of resources[55] would help clarify the economic impact of ACSCs among incident senior HCUs. Therefore, ACSC diagnosis codes will be included when they are accompanied by diagnosis types of either “M” (major diagnosis responsible for resource use) or “1” (preadmission diagnosis) without an accompanying “2” (postadmission diagnosis)[55]. Of note, no studies have compared these two approaches before to identify ACSC related costs. The ACSC definition will be applied to patients in the incident year. Transfers will be excluded from the definition of hospitalization episode.

Sensitivity analysis will be conducted to assess the impact of several factors on the ACSC related costs. Analysis will be repeated for 3 age subgroups: those age 66 to 74, 75 to 84, and 85 and older. We will also apply the algorithm excluding non-emergent hospitalizations and re-admissions. The ACSC related costs will be compared to non-ACSC inpatient costs in both cohorts.

Research Question 3

To assess regional differences among senior HCUs compared to non-HCUs, we will focus on the incident year and use several approaches. First, we will make a cross-sectional comparison of patients’ clinical, demographic and care characteristics for each LHIN contrasting the two cohorts. Within each LIHN, urban, sub-urban and rural residence characteristics by RIO will be taken into account. Crude HCU rate per LHIN seniors will be derived to identify areas of high and low HCU incidence. The crude rates will be then adjusted through regression to remove the influence of comorbidity, demographic and care factors or RIO status.

Second, we will estimate regional variation in total healthcare spending and health services utilization and contrast these values between the two cohorts. Regression models with LHIN-level fixed effects will be developed using the following as dependent variables: total healthcare expenditures, hospital admission, emergency visits, physician encounters and home care visits. We will also assess the relationship between overall mortality and healthcare spending/utilization across the different LHINs by means of multilevel logistic regression models. Statistical significance of variation (alpha=0.05) will be calculated.

The magnitude of variation will be quantified using the extremal quotient (EQ), the coefficient of variation (CV), and the Gini mean difference (GMD). The EQ is the ratio of the highest LHIN parameter to the lowest. The CV is the ratio of the standard deviation to the mean among the LHINs: the higher the CV, the greater the dispersion. Both are widely used nationally and internationally[36, 37]. The GMD has been commonly used in economics and social sciences to measure inequality and variability and is gaining popularity in health sciences[56]. It calculates the extent to which the distribution of a parameter (e.g., total costs) among individuals across LHINs deviates from an exactly equal distribution.

Third, we will describe inter-LHIN migration patterns to receive acute hospital care and assess its impact on regional variation in total health spending for both cohorts. We will re- run the total healthcare spending regression model described above with the proportion of residents of a LHIN admitted outside the LHIN taken out of the analysis. The EQ, the CV, and the GMD will be used to compare the models and the cohorts.

SIGNIFICANCE AND POLICY IMPLICATIONS OF STUDY RESULTS

This study will generate new knowledge that will assist the Ontario Ministry of Health and Long-Term Care, healthcare administrators, clinicians, citizens and patients to guide policies around senior HCUs in the province of Ontario. The analysis of incremental healthcare utilization and costs will provide a description of the true utilization and economic impact associated with the incident HCU status. By separating index hospitalizations, the analysis of hospitalization patterns in the incident cohort of senior HCUs compared to matched non-HCUs may help identify opportunities for interventions to possibly delay or divert hospitalization episodes and prevent some of these patients from becoming new HCUs. Exploring the contribution of ACSC hospitalization costs toward the total health spending may help clarify the role of interventions directed at these conditions in the management of senior HCUs. Further, more clarity on existing regional variation in healthcare services and spending among senior HCUs may support a new wave of health care reforms in the province that intend to increase the role and authority of health planning regions. Finally, since other jurisdictions outside of Ontario (e.g., in countries with comparable health systems such as Australia, France, the Netherlands) are faced with similar issues, the study results are likely to be generalized to other similar settings in Canada or internationally.

EXPLORATORY ANALYSIS

Explanatory analyses may be conducted to explore study specific populations (COPD, CHF), cost thresholds to determine HCU status (1% vs. 5%), or any other relevant factors.

ETHICS AND DISSEMINATION

This study has been approved by Hamilton Integrated Research Ethics Board (ID#1715-C). The results of the study will be distributed widely through peer-reviewed journals. They also will be disseminated at research events in academic settings, national and international conferences as well as with presentations to the MOHLTC and LHIN administration.

AUTHORS'S CONTRIBUTIONS

AH, JET, JL, JMP, SM conceptualized the study. All authors have contributed to its design. JMP, WK, PP were instrumental in creating datasets. SM prepared the initial draft of the manuscript and revised it based on co- authors' feedback. All authors provided comments to the initial draft, read and approved the final manuscript.

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COMPETING INTERESTS

None declared.

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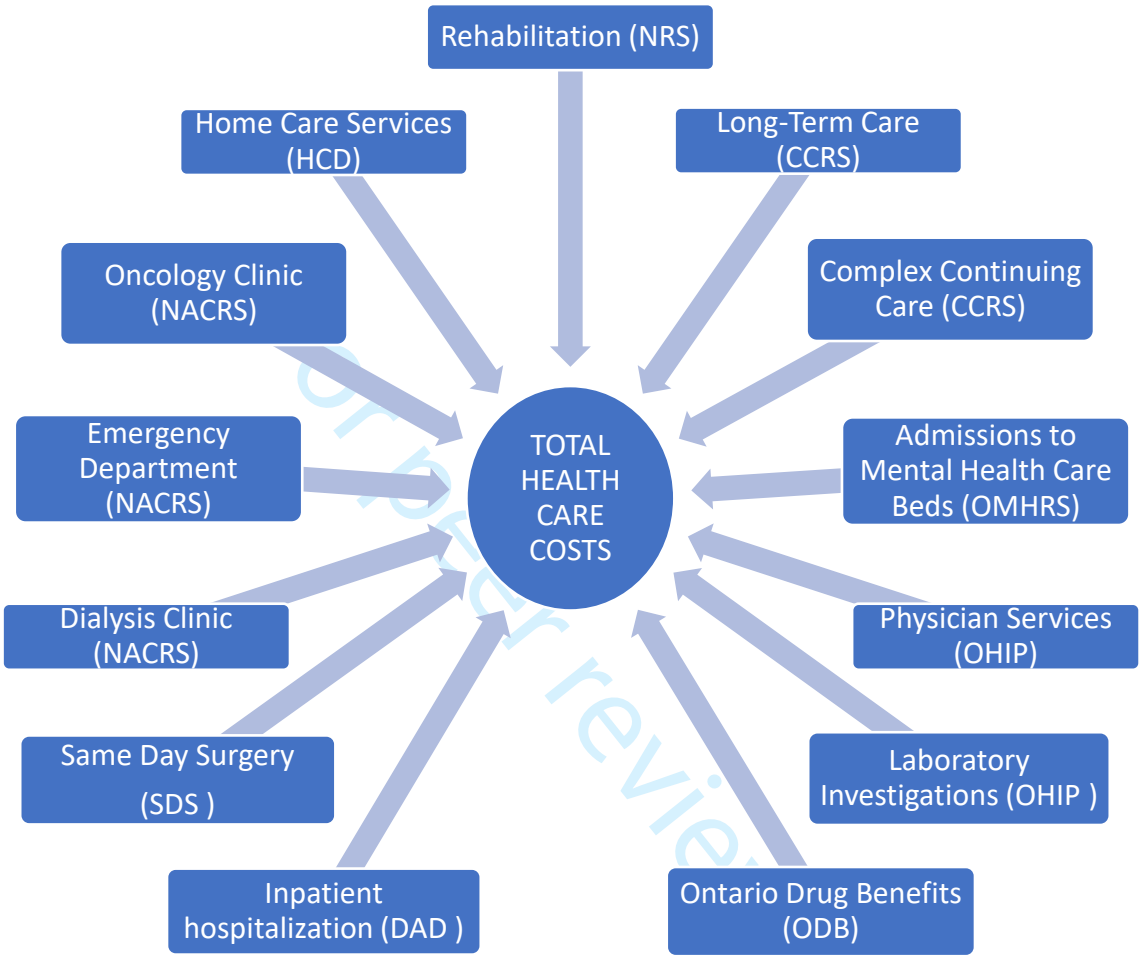
Appendix 1: Description of ICES databases

NAME OF DATABASE	DATABASE CONTENT
Canadian Institute for Health Information–Discharge Abstract Database (CIHI-DAD)	Patient-level demographic, diagnostic, procedural and treatment information on all acute care hospitalizations
CIHI—National Ambulatory Care Reporting System (CIHI-NACRS)	Patient-level demographic, diagnostic, procedural and treatment information for all hospital-based and community-based ambulatory care, including outpatient and community-based clinics and emergency departments
CIHI-National Rehabilitation Reporting System (NRS)	Patient-level demographic, diagnostic, procedural and treatment information from participating adult inpatient rehabilitation facilities and programs
CIHI-Same Day Surgery (CIHI-SDS)	Patient-level demographic, diagnostic, procedural and treatment information on all day surgeries
Citizenship and Immigration Canada (CIC) Database	Landing records for permanent legal immigrants to Ontario
Client Agency Program Enrolment (CAPE)	Information regarding enrollment/rostering of individuals with primary care practitioners, teams and networks
ICES Physician Database (IPDB)	Characteristics of physicians and surgeons licenced to practice in Ontario
ICES-derived cohorts	Validated cohorts of individuals with specific diseases and conditions. These include: Congestive Heart Failure (CHF) database; Chronic Obstructive Pulmonary Disease (COPD) database; Ontario Crohn's and Colitis Cohort Database (OCCD); Ontario Diabetes Database (ODD); Ontario Myocardial Infarction Database (OMID); and the Ontario Rheumatoid Arthritis Database (ORAD)
Ontario Continuing Care Reporting System (CCRS)	Demographic, clinical, functional and resource utilization information on individuals receiving hospital-based complex continuing care services
Ontario Drug Benefit (ODB)	Records of dispensed outpatient prescriptions paid for by the provincial government
Ontario Health Insurance Plan database (OHIP)	Claims for physician services paid for by the provincial government
Ontario Home Care Database (HCD)	Patient-level demographic, diagnostic, procedural and treatment information on all home care visits
Ontario Mental Health Reporting System (OMHRS)	Patient-level demographic, diagnostic, procedural and treatment information on all adult inpatient mental health visits
Ontario Registered Persons Database (RPDB)	Demographic, place of residence and vital status information for all persons eligible to receive insured heath services in the province

Appendix 2: Cost categories and sources of data



Appendix 3: Approach to data analyses and adjusting for covariates

Outcome	Type of response variable	Method of analysis	List of potential covariates, (forward selection)
Incremental costs (total and by care category, province wide)	**Continuous**	Repeated measures linear regression model with gamma distribution	**Socio -demographic factors:** Age (to be used for per LHIN analysis) Sex (to be used for per LHIN analysis) Income Urban/Rural residence Immigration status **Clinical status and care characteristics:** Number of EDCs and specific clinical clusters of interest such mental disease or dementia Access to a geriatrician Primary care group affiliation Number of physician visits (primary care and specialist) Number of home care visits
Costs per LHIN* (total and by care category)		Multi-level generalized linear models with gamma distribution (to be confirmed by modified Park test)	
HCU* rate per LHIN		Ordinary Least Squares regression model with aggregated values of covariates	
Incremental rates of healthcare use (e.g. all cause hospital admission, physician visits and home care visits, province wide)	**Count**	Two-part models with random effects (zero-inflated negative binomial OR Hurdle)	
Rates of healthcare use by LHIN level		Multi-level generalized linear models with negative binomial distribution	
All-cause mortality	**Categorical**	Logistic regression	

**HCU- High Cost Healthcare User; LHIN- Local Health Integration Networks*

Appendix 4: ACSC conditions and codes

	Condition	ICD-10-CA Codes	Exclusions	Source
1	Angina	I20, I23.82, I24.0, I24.8, I24.9	Cardiac procedure admissions	**CIHI[26] AHQR*[28]**
2	Asthma	J45		
3	Chronic Obstructive Pulmonary Disease	J41, J42, J43, J44, J47; J10.0, J11.0, J12–J16, J18, J20, J21, J22 if J44 as a secondary dx		
4	Diabetes	E10.0^^, E10.1^^, E10.63, E10.64, E10.9^^, E11.0^^, E11.1^^, E11.63, E11.64, E11.9^^, E13.0^^, E13.1^^, E13.63, E13.64, E13.9^^, E14.0^^, E14.1^^, E14.63, E14.64, E14.9^^		
5	Grand mal status and other epileptic convulsions	G40, G41		
6	Heart failure and pulmonary edema	I50, J81	Cardiac procedure admissions	
7	Hypertension	I10.0, I10.1, I11	Cardiac procedure admissions	
8	Bacterial pneumonia	J13, J14, J15211, J15212, J153, J154, J157, J159, J160, J168, J180, J181, J188, J189	Immunocompromised states and procedures#	
9	Dehydration	E860; E861, E869; (Hyperosmolality and/or hypernatremia) E870; (Gastroenteritis) A080, A0811, A0819, A082, A0831, A0832, A0839, A084, A088, A09, K5289, K529; (Acute kidney failure) N170-N172, N178, N179, N19, N990	I120, I1311, I132, N185, N186	
10	Urinary tract infection	N10, N119, N12, N151, N159, N16, N2884, N2885, N2886, N3000, N3001, N3090, N3091, N390	Kidney/urinary tract disorder diagnosis codes^; Immunocompromised States and Procedures#	

**AHRQ- Agency for Healthcare Research and Quality; CIHI - Canadian Institute for Health Information*

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Senior high cost healthcare users' resource utilization and outcomes: A protocol of a retrospective matched cohort study in Canada

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ABSTRACT

Introduction

Senior high cost users (HCUs) are estimated to represent 60% of all HCUs in Ontario, Canada's most populous province. To improve our understanding of individual and health system characteristics related to senior HCUs, we will examine incident senior HCUs to determine their incremental healthcare utilization and costs, characteristics of index hospitalization episodes, mortality and their regional variation across Ontario.

Methods and analysis

A retrospective, population-based cohort study using administrative healthcare records will be used. Incident senior HCUs will be defined as Ontarians age ≥66 years who were in the top 5% of healthcare cost users during fiscal year 2013 but not during fiscal year 2012. Each HCU will be matched to 3 non-HCUs by age, sex and health planning region. Incremental healthcare use and costs will be determined using the method of recycled predictions. We will apply multivariable logistic regression to determine patient and health service factors associated with index hospitalization and in-hospital mortality during the incident year. The most common causes of admission will be identified and contrasted with the most expensive hospitalized conditions. We will also calculate the ratio of inpatient costs incurred through admissions of ambulatory care sensitive conditions (ACSC) to the total inpatient expenditures. The magnitude of variation in costs and health service utilization will be established by calculating the extremal quotient, the coefficient of variation, and the Gini mean difference for estimates obtained through multilevel regression analyses.

Ethics and dissemination

This study has been approved by Hamilton Integrated Research Ethics Board (ID#1715-C). The results of the study will be distributed through peer-reviewed journals. They also will be disseminated at research events in academic settings, national and international conferences as well as with presentations to provincial health authorities.

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Strengths

- Focusing on incident senior HCUs and comparing them with non-HCUs in a longitudinal study allows for scrutiny of the factors that are associated with the transition from non-HCU to HCU and for identification of opportunities of pro-active preventive management approaches
- The comparative nature of the study with a matched cohort design reduces bias due to confounding

Limitations

- This study is subject to the limitations inherent in observational design and the use of health administrative databases
- The study is limited by the period of observation of 1-year before and 1-year after becoming HCU for most of the variables

INTRODUCTION

Societies worldwide are facing a demographic shift towards a growing proportion of seniors, defined as people aged 65 years and older[1]. In 2015, the proportion of seniors in Canada, for instance, exceeded the proportion of young people (i.e., <15 years of age) for the first time in history[2]. Seniors account for 46% of the national public healthcare expenditures in Canada[3]. This proportion is likely to increase due to the continued ageing of the population, therefore putting additional pressure on the government's resource allocation decisions in the coming years. The high-cost users (HCUs) of health services[4 5], commonly defined as individuals in the highest 5% of total expenditures, are often seniors. Senior HCUs are estimated to represent 60% of all HCUs in Ontario, Canada's most populous province[4]. Consistent with findings from other jurisdictions [6 7], a recent Ontario study indicated that 5% of senior HCUs consume 44% of the total measured public healthcare expenditures by the seniors in the province[8].

A number of demographic and clinical characteristics of the senior HCUs have been described internationally and in Canada: high level of comorbidities, functional impairment, and poor social supports at home[8-10]. However, many individual and health system characteristics related to senior HCUs are still poorly understood, particularly in the context of their sub-populations. As such, many disease management programs as well as research efforts focus on persistent HCUs, i.e., those that retain their HCU status in subsequent years[8 11 12]. This practice ignores the fact that "new", or incident, HCUs have historically accounted for more than 50% of all the cases annually, including those among senior patients[8 13]. Incident senior HCUs may have different characteristics than prevalent HCUs, and more focus on incident HCUs will allow for scrutiny of the factors that influence the transition from non-HCU to HCU.

Filling gaps in our understanding of this HCU subgroup is especially important at a time when policy makers internationally are targeting interventions for senior HCUs such as complex case management and care coordination models[8 12 14 15]. To inform policy making in identification of opportunities to prevent transition to the HCU status or to improve existing programs, a closer inquiry is required into the incident senior HCUs in terms of their incremental healthcare utilization and costs, characteristics of their hospitalization episodes, including the economic impact of individual conditions, and regional variation in main outcomes.

Incremental costs among incident HCUs

The magnitude of incremental healthcare utilization and costs attributable to becoming a HCU is unknown. HCU research in Canada and elsewhere has been conducted predominantly on prevalent HCU cohorts using cross-sectional designs, [4 7 8 16-18]. These studies provide valuable information on comparisons, for example, of the 1-year costs of HCUs compared to non-HCUs. However, these methods do not explore the change in outcomes associated with becoming a new HCU beyond secular trends in outcomes over time, thus miss the contribution of HCU status. In addition, no study to our knowledge has compared the characteristics, costs and outcomes of incident HCUs to a matched cohort of non-HCUs, which would provide a more detailed assessment of the distinguishing features of HCU status. Finally, HCU related research with a system-wide approach is still limited[4 8] as studies have largely focused on acute care (e.g. hospitalizations, emergency care, physicians) and have left out other

important care categories such as long-term care, rehabilitation, medications. Recently, a population-based study conducted in Ontario, Canada took a one year look at the cost distribution across a wider range of health sectors among HCUs, including seniors[8]. Although it was applied to prevalent HCUs and was not intended to provide a detailed characterization of the study population and a comparison with non-HCUs, we will be building on their work by using the same cost algorithm.

Analysis of hospitalization episodes among senior incident HCUs compared to non-HCUs

The majority (> 90% in some studies) of senior HCUs have at least one hospital admission in the year they reach HCU status[13]. Considering that hospitalization costs among HCUs may account for almost two thirds of direct medical costs[4], it is important to better understand the characteristics associated with hospitalizations among incident HCUs. To date, much of the literature on risk factors and interventions to prevent hospitalization has focused on hospital re-admissions [19-22]. However, as opposed to younger adults in whom hospitalizations often occur due to a sudden event (e.g. trauma) that often resolves without serious permanent cost or care implications[23], re-admissions in senior patients, especially HCUs, may signal a deterioration in health status and mark a point where management interventions are less likely to be effective in preventing recurrent hospitalizations[12].Therefore, focusing on the index hospitalizations associated with becoming an incident senior HCU (i.e., the first admission in the fiscal year when the patient reaches the HCU status) with the goal to reduce or divert them may be a more appropriate target for policy development. Since this subject has received little attention[24], more information is needed on the index hospitalization, including the patient demographic and clinical attributes (e.g. whether the patient is admitted for a newly diagnosed condition or a condition that s/he has received care in preceding years), outpatient care that was provided prior to the admission (e.g. type of home care visits), and the environment within which the care is received (e.g., primary care model).

Determining the most expensive conditions by inpatient costs and identifying patient attributes associated with them is also of great interest to health planners and administrators as a potential target for cost containment strategies. In this respect, the contribution of ambulatory care sensitive conditions (ACSC) to HCU requires clarification. ACSC-related hospital admissions, i.e. those which are theorized to be reducible with high-quality primary care[25 26], have been long used as an indicator of access to primary care at the population-level[27-29]. In Canada, several chronic ACSC are on a national list of indicators of health system performance reported by health authorities[30]. However, the economic impact of ACSC admissions among HCUs is unclear. A recent US study revealed that no more than 10% of hospitalization costs among the top decile of Medicare HCUs were ACSC-related [31]. The authors commented that if the financial impact of ACSC is low and resource consumption is a target for intervention, it may be worthwhile to shift prevention efforts to other conditions that are financially more burdensome. The only Canadian study of this issue reported that 6% of hospital encounters among HCUs were considered ambulatory sensitive. This study however was different from the US study in that it defined the top 5% percentile as HCUs (versus 10%), investigated a broader population (children and adults up to 75 years of age) admitted to a single tertiary hospital in Ottawa, Ontario, and estimated the ACSC costs focusing on a shorter list of chronic conditions [32]. As such we do not know if these results are generalizable to all hospitalizations in Ontario and to the senior HCUs. None of these studies have focused on incident HCUs

in which the economic impact from ACSCs may be different compared to persistent HCUs or on the relative contribution of ACSCs on the index hospitalizations during the incident year.

Regional variation in health services use, costs and mortality among incident senior HCUs

Finally, studying regional variation is needed to understand equality in service provision and identify areas for interventions. Evidence on geographic variation in healthcare utilization, costs and mortality among senior HCUs is scarce[4 33]. In Canada's general population, variation in health service use (e.g., hospital admission rates, surgical procedures or consumption of medications), both at provincial level and when compared to other countries, can be substantial[34-37]. [37]This observation however may be misleading as assessments of variation are commonly adjusted for age and sex only[36-39] despite numerous reports revealing the impact of socio-demographic or healthcare supply factors on this variation[35 40-42]. On the other hand, healthcare spending may show a lower level of variability. For example, a recent study conducted in British Columbia, Canada reported a coefficient of variation (CV) for total healthcare spending of 8.6 (4.9 upon adjustment) [40]. This is lower compared to the US and the UK that reported CVs of approximately 12 and 10, respectively[43]. It is unclear how all these findings relate to senior HCUs in the context of Ontario. Also, assessment of regional variation in individual cost categories has not been reported.

Further, geographical units should reflect actual patterns of services use. In Ontario, delivery of care is organized by health planning regions. These regions were originally established to reflect local patterns of clinical decision making and use of services. However, inter-region migration to receive health services is common. The proportion of expenses incurred for acute care provided in health facilities outside the region of residence ranged from 3% to 49% depending on the region[33]. The impact of such migration on regional variation in healthcare use and spending among HCUs has received little attention in the literature, although potential budget planning implications for health planning regions can be sizable due to the high costs associated with HCUs.

Here, we propose to answer three inter-related research questions:

1. What is the one-year incremental healthcare utilization and direct financial impact on public payers of becoming an incident HCU among seniors in Ontario? Hypothesis: the greatest incremental value in utilization and expenditures will be attributable to hospitalization episodes followed by physician costs.
2. What are the characteristics of hospital admissions and associated costs in senior incident HCUs compared to non-HCUs in Ontario? Hypotheses: a) causes of hospitalization as well as individual and care factors associated with an index hospitalization for senior HCUs differ from those of non-HCUs; b) the contribution of ACSCs will be high (proportion >10% of the total hospitalization costs) in senior HCUs and significantly higher than among non-HCUs
3. What is the extent of regional (health planning level) variation in healthcare utilization, costs, and mortality among senior incident HCUs compared to non-HCUs in Ontario? Hypothesis: regional variation in utilization, sector-specific costs and mortality measured by CV will be significantly higher in the HCU cohort than non-HCUs.

Methods and Analysis

Study Design:

The proposed study is a retrospective population-based matched cohort study using linked administrative health data. Registration number is NCT02815930 (clinicaltrials.gov).

Setting:

Ontario is the most populous province in Canada, with almost 14 million residents, representing about 40% of the Canadian population[44]. It is divided into 14 Local Health Integration Networks (LHIN) that are responsible for local health care planning and delivery[45]. The Ontario Ministry of Health and Long-Term Care (MOHLTC), using general taxation revenues (80% provincial and 20% federal transfer), pays for approximately 70% of health care provided in the province. This includes 90% to 100% funding of hospital care, physician costs, public health, and prescription drugs for seniors[3] while contributions to other services (e.g., long-term care facilities) are less.

Study Cohorts:

The study population is senior HCUs with annual total healthcare expenditures within the top 5% threshold of all Ontarians in the fiscal year of 2013 (i.e. incident year), who were not in the top 5% in the preceding year. Total health care expenditures will be calculated using the Institute of Clinical Evaluative Sciences (ICES) person-level health utilization costing algorithms[46]. ICES is an independent, non-profit research corporation funded by the Ontario Ministry of Health and Long-Term Care (www.ices.on.ca).

To reduce bias due to confounding the incident HCU cohort will be matched with non-HCU in a ratio of 1:3 according to age at cohort entry (+/- 1 month), sex and LHIN of patient residence. Health services utilization and costs will be captured from April 1, 2013 to March 31, 2014.

Data Set

The patient level dataset will be created using 15 health administrative databases housed at ICES. These databases contain publicly funded administrative health service records for the Ontario population eligible for health coverage. These databases are linked using encrypted patient-specific identifiers. Appendix 1 presents a description of databases that will be used to create the dataset.

Variables

The dataset will include a number of variables related to patient socio-demographic characteristics, healthcare use, and patient outcomes which are briefly described below (see Appendix 2 for more detail on key variables).

Patient characteristics include age, sex, geographic location, income (in quintiles), immigration status, and comorbidity. Geographical location of residence (urban/suburban/rural) is based on the Rural Index of Ontario(RIO) and LHIN[47]. Multi-morbidity is captured by means of John Hopkins Expanded Diagnosis Clusters (EDCs). EDCs are derived from Johns Hopkins Adjusted Clinical Groups (ACGs, www.hopkinsacg.org)[48], which are used to organize the codes of the International Statistical

Classification of Diseases and Related Health Problems, the 10th revision, Canadian version (ICD10-CA)[49] into 282 clinically similar clusters. EDCs will be based on 3 years of hospitalization and ambulatory data prior to index date.

Care characteristics include the primary care provider payment model. The providers are categorized by several main primary care patient enrolment models: Fee for Service (FFS), Enhanced FFS, Family Health Team (FHT), Capitation, and None. Under enhanced FFS model, provider's compensation is based on FFS billing with enhanced FFS components and incentives for the provision of services for specific patient needs. FHT models consists of two options: the primarily capitation-based Family Health Network (FHN) and the capitation or salaried based Family Health Organization (FHO). If the patient is affiliated with either FHN or FHO but not matched to FHT, then the patient is placed with the Capitation category. The None category refers to patients for whom no primary care provider was identified (i.e., they were not enrolled with a provider through a patient enrollment program and they were not virtually rostered based on claims because they did not have any billing claims with primary care fee codes).

Resource utilization variables include the number of hospitalizations, emergency department (ED) visits, physician encounters, publicly funded home care visits and long-term care. Home care visits are categorized by type of services provided such as nursing, personal support, or allied health. For each hospitalization, the following information is derived: admission type (urgent or elective), length of stay, the type of institution the patient has been transferred from, alternate level of care (ALC) status, discharge destination, date of death while in hospital, whether the hospitalization happened within the LHIN of residence, and hospitalization costs. All health care expenditures are derived using the ICES costing algorithm for each cost category.

Study Primary Outcomes:

1. One-year incremental healthcare utilization (rate per 10,000 of study population for hospital admissions, ED, physician and home care visits) and costs (mean) attributable to becoming an HCU at the provincial level (Research Question 1)
2. Determination of patient and care factors associated with a) index hospitalization (odds ratio) and b) its in-hospital mortality (odds ratio) among HCUs and non-HCUs during the incident year (Research Question 2)
3. Proportion (%) of ACSC-related hospitalization costs to annual total inpatient costs during the incident year at the provincial level for the HCU and non-HCU cohorts (Research Question 2)
4. Patterns of variation in healthcare utilization, mortality and costs across LHINs in HCUs compared to non-HCUs during the incident year (Research Question 3)

Analysis plan

The two matched cohorts (HCUs and non-HCUs) will be described using descriptive statistics. In addition to standardized differences[50] to compare the baseline characteristics of the two cohorts, regression methods will be used to adjust for important residual differences between the cohorts that remain after

matching. Each subsection below presents more detail on handling confounding. Data preparation before running regression analyses will include identifying co-linearity between covariates. Goodness of fit statistics will be used to evaluate models and guide model selection. A level of $\alpha < 0.05$ will be applied to indicate statistical significance.

Regression models for cost and count data including two-part models to deal with the potential over-representation of zeros in the data will be used to analyze the data. For example, we expect that many members in the non-HCU cohort may have no encounters with the health system (i.e., no hospital admission, physician visits or visits to ED). Ignoring the fact that the data are not normally distributed or utilizing only the portion of the data with the values greater than zero can lead to biased estimates[51]. The following provides more information on the analysis plan for each of the 3 research questions.

Research Question 1:

To estimate the incremental healthcare utilization and costs attributable to becoming an HCU, longitudinal data analysis will be employed[52]. The HCU dataset containing repeated measures on the same subject (i.e., 1-year pre- and post-values) is an example of longitudinal data. Incremental values of the outcome variables (i.e., costs, physician encounters, etc.) represent the difference between the two cohorts over time. An estimate of incremental values will be generated using the method of recycled predictions[53-56]. First, coefficients are obtained from a model regressing the post-values of an outcome on the HCU status, pre-values of the outcome and other covariates as needed. Then, using the calculated coefficients, predicted outcome values are estimated assuming everyone is an HCU and re-estimated assuming every subject is a non-HCU. The difference between the two averaged predictions yields the incremental value. Confidence intervals (CIs) of the incremental values will be obtained with the percentile method (i.e., creating a bootstrap distribution and assigning the 95% lower bound CI to the 2.5th percentile and the 95% upper bound CI to the 97.5th percentile)[56]. The method will be applied to analyze incremental changes in each type of costs and healthcare utilization.

This approach will allow us to account for correlation between the pre- and post values, to adjust for residual confounding by including demographic (i.e., income) and health status (i.e. comorbidities) variables in the model; and, when needed, to properly manage excessive zero values by developing two-part models. Alternative models may also be explored to accommodate the data specifics (e.g., mixed models with random effects).

Research Question 2

To describe and compare characteristics of the index hospitalization among senior HCUs vs non-HCUs during the incident year (Fiscal year 2013), we will define an index hospitalization as the first hospitalization in the incident year among subjects without admissions of any type in the preceding year (Fiscal year 2012). We will provide descriptive statistics on hospitalizations by the type of admission (frequency of urgent vs elective), by the total length of stay (mean), including the alternate level of care status and the number of ALC days (mean), by discharge destination (frequency) and in-hospital

mortality. Using major ICD10-CA diagnosis codes responsible for resource use (abbreviated as MRDX), we will identify the most common clinical causes of admissions and contrast the list with a list of most expensive hospitalized conditions for both cohorts to distinguish common diagnoses from diagnoses that drive inpatient spending. To determine patient and care factors associated with index hospitalization and its in-hospital mortality (dependent variables) during the incident year, we will develop predictive models using multivariable logistic regression based on a list of pre-determined demographic, clinical and care factors (Appendix 3).

To investigate the proportion of ACSC-associated hospitalization costs, we will identify patients admitted for ACSCs and calculate for the HCU and the non-HCU cohorts the ratio of inpatient costs incurred through ACSC admissions to the total inpatient expenditures. Our ACSC list will be based on the list originally developed by the Agency for Healthcare Research and Quality (AHRQ)[29]. Chronic conditions on the list (e.g. hypertension, diabetes, and etc.) will be identified using the Canadian Institute of Health Information (CIHI) ACSC algorithm[27] which is based on the AHRQ original list adapted to Canada. The algorithm for 3 other conditions considered acute (e.g., bacterial pneumonia, dehydration and urinary tract infections) and not included in the CIHI algorithm of chronic conditions will be derived by directly converting the original ICD-10-CM codes of the AHRQ original list into ICD-10-CA. Appendix 4 provides more detail on the algorithms.

Consistent with the approach to ACSC identification that was previously used by researchers [27 32 57], ACSC related hospitalizations can be identified using the most responsible diagnosis at discharge. However, using the most responsible diagnosis which accounts for the largest portion of consumed resources during the hospitalization may not be able to accurately capture all ACSC-associated admission costs. Applying a ACSC definition to preadmission diagnoses that also add to the use of resources[57] would help clarify the economic impact of ACSCs among incident senior HCUs. Therefore, ACSC diagnosis codes will be included when they are accompanied by diagnosis types of either “M” (MRDX) or “1” (preadmission diagnosis) without an accompanying “2” (postadmission diagnosis)[57]. Of note, no studies have compared these two approaches before to identify ACSC related costs. The ACSC definition will be applied to patients in the incident year. Transfers will be excluded from the definition of hospitalization episode.

Sensitivity analysis will be conducted to assess the impact of several factors on hospitalization costs. Analysis will be repeated for 3 age subgroups: those age 66 to 74, 75 to 84, and 85 and older. As sepsis cases (reportedly, ones of the costliest among hospitalized conditions) may go underreported when using MRDX codes alone[58], the case-finding algorithm to capture these cases will include preadmission and postadmission codes that are not MRDX. We will also apply the ACSC algorithm excluding non-emergent hospitalizations and re-admissions. The ACSC related costs will be compared to non-ACSC inpatient costs in both cohorts.

Research Question 3

To assess regional differences among senior HCUs compared to non-HCUs, we will focus on the incident year and use several approaches. First, we will make a cross-sectional comparison of patients’ clinical, demographic and care characteristics for each LHIN contrasting the two cohorts. Within each LIHN,

urban, sub-urban and rural residence characteristics by RIO will be taken into account. Crude HCU rate per LHIN seniors will be derived to identify areas of high and low HCU incidence.

Second, we will estimate regional variation in total healthcare spending and health services utilization and contrast these values between the two cohorts[59]. Regression models with LHIN-level fixed effects will be developed using the following as dependent variables: total and sector healthcare expenditures, count data (i.e., hospital admission, emergency visits, physician encounters and home care visits), and mortality. The crude values will be then adjusted to remove the influence of comorbidity, demographic and care factors or RIO status.

The magnitude of variation will be quantified using the extremal quotient (EQ), the coefficient of variation (CV), and the Gini mean difference (GMD). The EQ is the ratio of the highest LHIN parameter to the lowest. The CV is the ratio of the standard deviation to the mean among the LHINs: the higher the CV, the greater the dispersion. Both are widely used nationally and internationally[37 38]. The GMD has been commonly used in economics and social sciences to measure inequality and variability and is gaining popularity in health sciences[60]. It calculates the extent to which the distribution of a parameter (e.g., total costs) among individuals across LHINs deviates from an exactly equal distribution.

Third, we will describe inter-LHIN migration patterns to receive acute hospital care and assess its impact on regional variation in total health spending for both cohorts. We will re- run the total healthcare spending regression model described above with the proportion of residents of a LHIN admitted outside the LHIN taken out of the analysis. The EQ, the CV, and the GMD will be used to compare the models and the cohorts.

Significance and policy implications of study results

This study will generate new knowledge that will assist Canadian healthcare administrators, clinicians, citizens and patients to guide health policy and program development around senior HCUs. The analysis of incremental healthcare utilization and costs will provide a description of the true utilization and economic impact associated with the incident HCU status. By separating index hospitalizations, the analysis of hospitalization patterns in the incident cohort of senior HCUs compared to matched non-HCUs will help identify potential interventions to prevent or divert hospitalization episodes for high risk groups. Exploring the contribution of disease-specific hospitalization costs toward the total inpatient spending will help determine the potential value expanding care models that target ACSCs and identify opportunities of fund re-allocation to hospitalizations types that are more contributory and more amenable to change. Further, by defining regional variation in healthcare services and spending among senior HCUs we will inform the value of potential benchmarking and regional practice comparisons in HCU management. Finally, since other jurisdictions in developed countries have comparable health systems and are faced with similar HCU challenges, our methods and findings may inform local considerations for HCU prevention and management.

Exploratory analysis

Explanatory analyses may be conducted to explore study specific populations, cost thresholds to determine HCU status (1% vs. 5%), or any other relevant factors. ICES-derived cohorts will be used to facilitate the analysis. These cohorts were created by identifying patients with specific diseases (e.g., COPD, CHF, diabetes) using validated case-finding algorithms[61 62].

Ethics and dissemination

This study has been approved by Hamilton Integrated Research Ethics Board (ID#1715-C). The results of the study will be distributed widely through peer-reviewed journals. They also will be disseminated at research events in academic settings, national and international conferences as well as with presentations to the MOHLTC and LHIN administration.

Authors' contributions:

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

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Competing Interests:

None declared.

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Appendix 1: Description of ICES databases

NAME OF DATABASE	DATABASE CONTENT
Canadian Institute for Health Information–Discharge Abstract Database (CIHI-DAD)	Patient-level demographic, diagnostic, procedural and treatment information on all acute care hospitalizations
CIHI—National Ambulatory Care Reporting System (CIHI-NACRS)	Patient-level demographic, diagnostic, procedural and treatment information for all hospital-based and community-based ambulatory care, including outpatient and community-based clinics and emergency departments
CIHI-National Rehabilitation Reporting System (NRS)	Patient-level demographic, diagnostic, procedural and treatment information from participating adult inpatient rehabilitation facilities and programs
CIHI-Same Day Surgery (CIHI-SDS)	Patient-level demographic, diagnostic, procedural and treatment information on all day surgeries
Citizenship and Immigration Canada (CIC) Database	Landing records for permanent legal immigrants to Ontario
Client Agency Program Enrolment (CAPE)	Information regarding enrollment/rostering of individuals with primary care practitioners, teams and networks
ICES Physician Database (IPDB)	Characteristics of physicians and surgeons licenced to practice in Ontario
ICES-derived cohorts	Validated cohorts of individuals with specific diseases and conditions. These include: Congestive Heart Failure (CHF) database; Chronic Obstructive Pulmonary Disease (COPD) database; Ontario Crohn's and Colitis Cohort Database (OCCD); Ontario Diabetes Database (ODD); Ontario Myocardial Infarction Database (OMID); and the Ontario Rheumatoid Arthritis Database (ORAD)
Ontario Continuing Care Reporting System (CCRS)	Demographic, clinical, functional and resource utilization information on individuals receiving hospital-based complex continuing care services
Ontario Drug Benefit (ODB)	Records of dispensed outpatient prescriptions paid for by the provincial government
Ontario Health Insurance Plan database (OHIP)	Claims for physician services paid for by the provincial government
Ontario Home Care Database (HCD)	Patient-level demographic, diagnostic, procedural and treatment information on all home care visits
Ontario Mental Health Reporting System (OMHRS)	Patient-level demographic, diagnostic, procedural and treatment information on all adult inpatient mental health visits
Ontario Registered Persons Database (RPDB)	Demographic, place of residence and vital status information for all persons eligible to receive insured heath services in the province

Appendix 2: Key variables and sources of data

Key variables	Description	Type	Time period (PRE=1, POST=2)	Data source
Patient and care characteristics				
age_	Age in years	continuous	1	RPDB
sex_	Sex; female or male	categorical	1	RPDB
rio2008_	Rurality Index for Ontario; on a scale of 0 to 100 with 100 being most rural	continuous	1	RPDB
lhin_	LHINs: 1 to 14	categorical	1	RPDB
income_	Income quintiles	categorical	1	RPDB
recent_immigration_	Whether immigrated in the past 15 years	categorical	1	CIC
primarycaregrp_	Primary care model	categorical	1	CAPE
geriatrician_	Whether visited a geriatrician	categorical	1	OHIP
Health status/comorbidity				
n_edc	John Hopkins Expanded Diagnosis Clusters (EDCs) are based on 3 years of hospitalization and ambulatory data	continuous	1	DAD, NACRS, OHIP
ices_cohort_	Cohorts of individuals with the following conditions separately: CHF, COPD, Inflammatory Bowel Disease (Crohn's and Colitis), diabetes, myocardial infarction, or rheumatoid arthritis	categorical	1	CHF, COPD, OCCD, ODD, OMID, ORAD
dth365d_	Mortality at the end of FE2013	categorical	2	RPDB
Healthcare utilization				
ndrugnames_	Number of prescription drugs the patient is on	continuous	1,2	ODB
n_md_visits_	Number of physician visits; reported as total and by categories (family practitioner and specialist)	continuous	1,2	
n_hcd_visits_	Number of home care visists; reported as total and by categories (nursing, personal support, allied health)	continuous	1,2	
nhosp_	Number of hospitalizations; reported as total and by categories (urgent and elective)	continuous	1,2	DAD

admcat_	Admission categories: urgent and elective	categorical	1,2	DAD
los	Length of stay, days	continuous	1,2	DAD
instftyp_	Institution from where admitted	categorical	1,2	DAD
instlhin_	LHIN where admitted	categorical	1,2	DAD
dx10code1-25	Diagnosis ICD10 codes for each admission	categorical	1,2	DAD
ds10type1-25	Type of diagnosis code: "M"-MRDX; "1" - preadmission; "2" - post-admission	categorical	1,2	DAD
dischdisp	Institution where discharged to	categorical	1,2	DAD
Healthcare costs				
inpat_cost_	Inpatient hospitalization Costs	continuous	1,2	DAD
sds_cost_	Same Day Surgery Costs	continuous	1,2	SDS
er_cost_	Emergency Department Costs	continuous	1,2	NACRS
odb_cost_	Costs for Ontario Drug Benefits	continuous	1,2	ODB
hc_cost_	Costs for Home Care Services	continuous	1,2	HCD
md_cost_	Physician expenditures are a combination of the costs for capitation and fees-for -services	continuous	1,2	OHIP
mh_cost_	Costs for Admissions to Mental Health Care Beds (using OMHRS)	continuous	1,2	OMHRS
onc_cost_	Oncology Clinic Costs	continuous	1,2	NACRS
dial_cost_	Dialysis Clinic Costs	continuous	1,2	NACRS
rehab_cost_	Costs for Rehabilitation	continuous	1,2	NRS
ccc_cost_	Costs for Complex Continuing Care	continuous	1,2	CCRS
lab_cost_	Costs for Laboratory investigations	continuous	1,2	OHIP
ltc_cost_	Costs for Long-Term Care	continuous	1,2	CCRS
total_cost_	Total healthcare expenditures	continuous	1,2	

Appendix 3: Approach to data analyses

Outcome	Type of response variable	Method of analysis	List of potential covariates, (forward selection)
Incremental costs (total and by care category, province wide)	**Continuous**	Method of recycled predictions using generalized linear regression models with gamma distribution and the log link (incl. two-part models if needed)	**Socio -demographic factors:** Age (to be used for per LHIN analysis) Sex (to be used for per LHIN analysis) Income Urban/Rural residence Immigration status **Clinical status and care characteristics:** Number of ADGs and specific clinical clusters of interest such mental disease or dementia Access to a geriatrician Primary care group affiliation Number of physician visits (primary care and specialist) Number of home care visits
Costs per LHIN (total and by care category)		Multi-level generalized linear models with gamma distribution	
HCU rate per LHIN		Ordinary Least Squares regression model with aggregated values of covariates	
Incremental rates of healthcare use (e.g. all cause hospital admission, physician visits and home care visits, province wide)	**Count**	Method of recycled predictions using generalized linear regression model with negative binomial distribution and the log link (incl. two-part models if needed)	
Rates of healthcare use by LHIN level		Multi-level generalized linear models with negative binomial distribution	
All-cause mortality	**Categorical**	Logistic regression	

Appendix 4: ACSC conditions and codes

	Condition	ICD-10-CA Codes	Exclusions	Source
1	Angina	I20, I23.82, I24.0, I24.8, I24.9	Cardiac procedure admissions	**CIHI[26] AHQR*[28]**
2	Asthma	J45		
3	Chronic Obstructive Pulmonary Disease	J41, J42, J43, J44, J47; J10.0, J11.0, J12–J16, J18, J20, J21, J22 if J44 as a secondary dx		
4	Diabetes	E10.0^^, E10.1^^, E10.63, E10.64, E10.9^^, E11.0^^, E11.1^^, E11.63, E11.64, E11.9^^, E13.0^^, E13.1^^, E13.63, E13.64, E13.9^^, E14.0^^, E14.1^^, E14.63, E14.64, E14.9^^		
5	Grand mal status and other epileptic convulsions	G40, G41		
6	Heart failure and pulmonary edema	I50, J81	Cardiac procedure admissions	
7	Hypertension	I10.0, I10.1, I11	Cardiac procedure admissions	
8	Bacterial pneumonia	J13, J14, J15211, J15212, J153, J154, J157, J159, J160, J168, J180, J181, J188, J189	Immunocompromised states and procedures#	
9	Dehydration	E860; E861, E869; (Hyperosmolality and/or hypernatremia) E870; (Gastroenteritis) A080, A0811, A0819, A082, A0831, A0832, A0839, A084, A088, A09, K5289, K529; (Acute kidney failure) N170-N172, N178, N179, N19, N990	I120, I1311, I132, N185, N186	
10	Urinary tract infection	N10, N119, N12, N151, N159, N16, N2884, N2885, N2886, N3000, N3001, N3090, N3091, N390	Kidney/urinary tract disorder diagnosis codes^; Immunocompromised States and Procedures#	

**AHRQ- Agency for Healthcare Research and Quality; CIHI - Canadian Institute for Health Information*