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Multi-level Analysis for Geographical Inequalities on Ambulatory Care Sensitive Hospitalizations

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A thesis submitted in partial fulfillment of the requirements for the Master of Science degree in Epidemiology and Biostatistics
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Abstract

Background: Ambulatory care sensitive conditions (ACSC) hospitalizations are potentially preventable events and considered as indicator of the efficiency of the primary healthcare system. Therefore, a high level of geographic variation in ACSC hospitalizations warrants more research.

Objectives: To assess the variation in odds of ACSC-related hospitalizations across Canadian communities and health regions.

Methods: The Discharge Abstract Database (DAD) from the Canadian Institute of Health Information (CIHI), was linked to the long-form census by Statistics Canada. Data from three fiscal years (FY), (2006 to 2009), were pooled. Statistical analysis included hierarchical three-level mix modeling.

Results: Between 2006 and 2009, out of 4305400 Canadian population aged below 75 years age, 29130 individuals were hospitalised because of ACSC diseases. This study indicates that up to 14.62 % of variation in the odds of ACSC-related hospitalization was attributable to general contextual factors at the Census Subdivision (CSD)-level, 1.13% was accounted by health regions and the remaining 84% was related to individual-level variations.

Conclusion: The results suggest high geographic variation in the odds of ACSC hospitalization across CSDs and health regions. Beyond urbanicity characteristics, the place of residence (CSDs) appeared as a more influential attribute for the odds of ACSC compared to the place within which primary or acute healthcare services were received (health regions).

Keywords

Ambulatory care sensitive conditions, preventable hospitalization, health region, census, Discharge Abstract Database, Canadian Institute of Health Information, hierarchical three-level mix modeling, census subdivision

Summary for lay audience

Limiting preventable hospital admissions is a goal for the healthcare system, in Canada and around the world. The underlying motivations for reducing preventable hospitalizations can be addressed from three perspectives: a) cost (i.e., to avoid the financial waste of healthcare spending on hospital events that could be avoided); b) patient safety (i.e., there are increased risks of poor health outcomes for hospitalized patients regardless of their primary reason of hospital admission); and c) process disruptions (i.e., the disruption it causes to elective healthcare processes such as inpatient waiting lists). According to global evidence, including evidences from Canada, a disproportionate number of preventable hospital admissions occur among individuals with chronic conditions referred to as ambulatory care sensitive conditions (ACSC). The definition of ACSC from the Canadian Institute of Health Information (CIHI) includes the following conditions: grand mal status and other epileptic convulsions, chronic obstructive pulmonary disease (COPD), asthma, heart failure and pulmonary edema, hypertension, angina, and diabetes. According to the CIHI's definition, ACSC hospitalizations are a relevant indicator of healthcare performance for non-elderly population (under 75 years of age). The overall goal of this study was to assess the geographic variation in the odds of ACSC hospitalizations and the factors associated with this variation. To achieve this goal, the census cohort comprised of the 2006 long-form census respondents was employed and this cohort was followed prospectively over a three-year follow-up interval (May 16, 2006 to March 31, 2009) for detecting their ACSC hospitalization events. Using this cohort, I found out that: the individual's odds of hospital admission for ACSC was not the same across Canada. I found significant geographic variation in odds of ACSC hospitalization across Community (CSD) and health regions. Also results of my study showed that age, sex, visible minority status, marital status, income, educational attainment, immigration status, community-level socioeconomic status (SES) characteristics (i.e., median household income), and urbanicity of ACSC patients were strongly associated with the odds of ACSC hospitalization and its geographic variation. However, I found that these risk factors could not completely explain the geographic disparities and there should be other important, risk factors that need to be explored in future studies.

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Preface

Chapter 1

1 Introduction

1.1 Overview

Eliminating preventable hospital admissions is considered a goal for the healthcare system, in Canada and around the world.[1–3] Limiting the number of preventable hospitalizations is one target for reducing resource consumption in the acute care system. The underlying motivations for reducing preventable hospitalizations can be addressed from three perspectives: a) cost (i.e., to avoid the financial waste of healthcare spending on hospital events that could be avoided); b) patient safety (i.e., there are increased risks of poor health outcomes for hospitalized patients regardless of their primary reason of hospital admission);[4] and c) process disruptions (i.e., the disruption it causes to elective healthcare processes such as inpatient waiting lists).[5] According to global evidence, including evidence from Canada, a disproportionate number of preventable hospital admissions occur among individuals with chronic conditions referred to as ambulatory care sensitive conditions (ACSC).[6,7]

ACSC are a growing area of interest in primary healthcare research, both in Canada[8–10] and internationally.[11–16] The definition of ACSC from the Canadian Institute of Health Information (CIHI) includes the following conditions: grand mal status and other epileptic convulsions, chronic obstructive pulmonary disease (COPD), asthma, heart failure and pulmonary edema, hypertension, angina, and diabetes.[17] According to the CIHI definition, ACSC hospitalizations are a relevant indicator of healthcare performance for non-elderly populations (<75 years of age).[18] While not all hospital admissions are preventable, Billings et al., propose that ACSC are a group of acute or chronic diseases that with timely and effective prevention, monitoring, and early treatment may not require hospitalization under most circumstances.[11] Therefore, rates of ACSC hospitalization are indicative of a potentially suboptimal healthcare system.[18–22] Effective treatment for patients with ACSC outside of acute care facilities is necessary, not only to reduce healthcare spending but also to free up space within hospitalizations for unavoidable hospitalization events. Management of these conditions in primary care before they result in hospitalizations will be of greater necessity given that chronic disease conditions, including ACSC, are on the rise globally.[23–27]

1.2 Study Objectives

The overall goal of this study was to assess the geographic variation in the risk of ACSC hospitalizations and the factors associated with this variation. To achieve this goal, the census cohort comprised of the 2006 census respondents was employed and this cohort was used to observe hospitalization events between fiscal years (FY) 2006 and 2009, specifically, to identify ACSC hospitalization events. Using this cohort, the following primary objectives were addressed:

1) To assess sources of geographic variation in the odds of ACSC hospitalization across Canada, both across communities and across health regions, and to estimate the magnitude of this variation at each level of geography.

2) To assess whether individual-level characteristics (e.g., age, sex, visible minority, marital status, income, educational attainment, and immigration status) are associated with the odds of ACSC hospitalization, and whether these factors account for geographic variation in ACSC hospitalization at each level of geography.

3) To assess if community-level socioeconomic status (SES) characteristics (e.g., median household income), and urbanicity explain the individual-level odds of ACSC hospitalization, and whether these factors account for geographic variation in ACSC hospitalization at each level of geography.

By addressing these objectives, the current study can help Canadian public health policy makers to identify high risk groups, as well as high risk communities, for ACSC hospitalization events. Moreover, estimates of preventable hospitalization rates at the community level can be used as an indicator of healthcare efficiency. This, in turn, can assist policy makers to more accurately evaluate the performance of local primary healthcare facilities, to improve their management of patients with ACSC, and to have a better response to their local needs.

1.3 Outline of Thesis

The following chapter contains a detailed review of the impact of ACSC hospitalizations on the Canadian healthcare system, the geographic variation in ACSC hospitalization across Canada, as well as the associated risk factors for ACSC hospitalization. Chapter 3 outlines the methods employed in this thesis; Chapter 4 outlines the results of this study; and Chapter 5 presents a discussion of the study's findings, strengths and limitations, conclusions, as well as suggestions for the future research.

Chapter 2

2 Background

2.1 ACSC hospitalizations and the Canadian healthcare system

2.1.1 Hospitalization costs and utilization in Canada

ACSC hospitalizations have negative consequences for Canada's health service budget and resources.[28–30] To understand the negative impact of ACSC hospitalization, one needs to have a clear image of the share of costs and resource consumption in the Canadian healthcare system that are related to ACSC hospitalizations.

In Canada, total healthcare expenditures reached $253.5 billion in 2018, which equates to $6,839 per person.[31] Across all healthcare sectors, hospitalizations have accounted for the largest share of costs since 1997, and comprised 28.3% of the total healthcare costs in 2018.[31]

Patients admitted to hospitals for ACSC are not regular consumers of acute health care services, but rather fall mostly among the category of patients referred to as "high-users".[32] Hospitalization expenses are not distributed evenly across all individuals in Canada, but rather are skewed towards the so-called "high-users", representing 5 to 10% of healthcare users who consume over 50% of resources.[33,34] High-users are a growing topic of investigation in Canada[35–42] and globally.[43–48] From a decision-making perspective, CIHI defines several indicators for "high-users" based on a range of criteria including: a) the frequency of service utilization b) the length of stay in hospital per visit, and c) estimated cost.[28] Specifically, the following six criteria are used to identify high-users: [28]

Indicators for frequency of use

1) *3+ Stays:* Patients with 3 or more hospital stays per year

2) *5+ Stays:* Patients with 5 or more hospital stays per year

Indicator for length of stay

3) *30+ Days:* Patients with cumulative length of stay of 30 days or more

Combinational indicator for frequency and length of stay

4) *3+ Stays, 30+ Days:* Patients with the frequency of 3 or more hospital stays and cumulative length of stay of 30 days or more

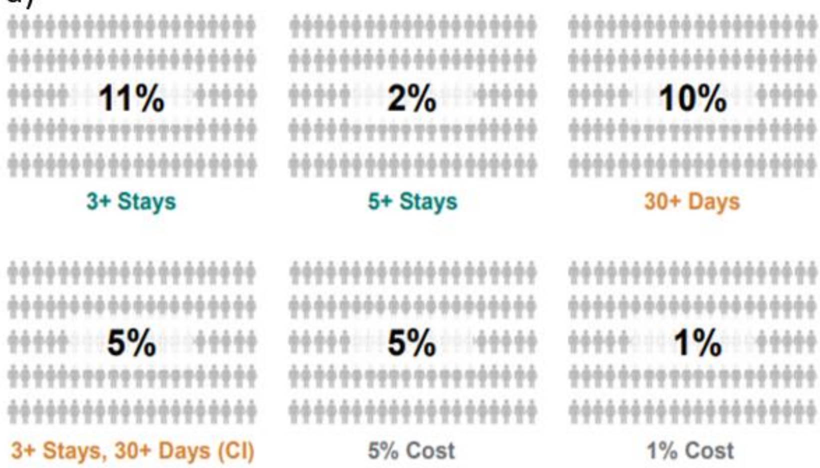
Indicator for cost estimation

5) *5% Cost:* Patients who make the up top 5% of hospitalization costs

6) *1% Cost:* Patients who make up the top 1% of hospitalization costs

As illustrated in Figure 2.1, each of the six indicators of "high-users" may include a different proportion and type of patient. For instance, "high-frequency" users are not always "high-cost" users of acute care services. According to a CIHI report, the "top 1%" group, which makes up 1% of the proportion of the acute care population, leads to an estimated hospitalization cost per average "high-user" of $172,000. On the other hand, for the "3+ Stays" group that comprise 11% of the "high-user" population, cost per average "high user" is reported as $39,000.[28] From a demographic perspective, these categorizations do not include the same type of patients; for example, "high-user" groups defined by length of stay contain the largest proportion of seniors (75 years and older).[28]

a)



b)

Definition	Estimated cost of high user group ($ millions, % of total cost)	Estimated cost per average high user ($ thousands)
3+ Stays	$8,057 (31%)	**$39**
5+ Stays	$2,355 (9%)	**$60**
30+ Days	$10,779 (42%)	**$57**
3+ Stays, 30+ Days (CI)	$5,503 (21%)	**$63**
5% Cost	$8,548 (33%)	**$88**
1% Cost	$3,347 (13%)	**$172**

Average cost per patient: $13,000

Figure 2-1 a) Percentage of acute care population captured by different definitions of "high-users", b) Estimated acute care costs captured by different definitions of "high-users". Source: CIHI. *Defining High Users in Acute Care: An Examination of Different Approaches*, 2015.[28]

2.1.2 Common characteristics among "high-users"

Evidence from across Canada reveals a common disease and sociodemographic profile among this small group of "high-user" patients. "High-users" are more likely to be patients with: 1) greater morbidity and comorbidity burdens; 2) higher likelihood of having chronic conditions, many of which are ACSC (e.g., COPD, congestive heart failure, and diabetes); 3) seniors; and 4) people of low SES (e.g., poverty, homelessness).[36,42,49–51]

2.1.2.1 ACSC hospitalizations and different "high-user" indicators

Patients with ACSC fall into "high-user" categories. They can be considered as "high-users" from the perspective of frequency of visits, length of stay, and/or cost of acute care services.

a) *Prevalence of hospitalization*

Results from the literature indicate that patients with ACSC have been persistently among the most frequently hospitalized group of individuals.[28,52,53] For instance, compared to the non-high user population, "high users" with multiple stays ("3+ Stays"; "5+ stays group"; 30+ Days") have been reported to be 3 times as likely to have COPD and 3.5 times as likely to have heart failure.[28]Also, a recent report by the CIHI confirmed that COPD and heart failure held the second and the fifth most prevalent reason for hospitalization, respectively, during 2017-2018 (FY).[54]

b) *Length of stay*

Collectively, by volume and average length of stay, ACSC have been identified among leading hospitalization diagnoses across Canada.[52,53] According to a report from the CIHI, in 2017-2018 (FY), ACSC-related hospital admissions were associated with the longest average length of stay among the top five most common reasons of hospitalization. For instance, ACSC conditions heart failure and COPD were associated with the longest hospital stays, with an average of 8.9 and 7.2 acute length of stay (days), respectively.[54]

c) *Cost burden*

The cost of hospitalization for ACSC have been on the rise over the recent years, but also these conditions are reported to fall among top most expensive hospitalization diagnoses.[55,56] For instance, in 2017-2018, COPD was one of the most costly hospitalization expenditures at $753.3 million, which was followed by heart failure as the second most expensive acute care expenses at $575.2 million.[30]

2.2 Temporal and geographic patterns of ACSC hospitalizations

2.2.1 Overall trend in ACSC hospitalizations in Canada

Chronic disease is on the rise in Canada,[57] yet reports from the CIHI demonstrate an overall decline in age-adjusted rates of ACSC hospitalization.[58] The overall rate dropped from 349 hospitalizations per 100,000 population in 2010 to 327 hospitalizations per 100,000 population in 2017-2018.[58]

Despite the decreasing trend in national rates, considerable variation in ACSC hospitalization still remains across provinces.[14,52] In 2017-2018, Nunavut (with 751 per 100,000), Northwest Territories (710 per 100,000), Saskatchewan (463 per 100,000), Newfoundland and Labrador (443 per 100,000), New Brunswick (434 per 100,000), Prince Edward Island (416 per 100,000), Nova Scotia (341 per 100,000), and Alberta (338 per 100,000) had higher rates than the national rate (327 per 100,000). Whereas, Ontario (314 per 100,000), Manitoba (314 per 100,000), and British Columbia (294 per 100,000), had lower rates compared to the Canadian average, with British Columbia having the lowest rate of all provinces.[58]

2.2.2 Variation in ACSC hospitalizations across health regions

In addition to cross-provincial variations, substantial intra-province heterogeneity in rates of ACSC hospitalization have been reported since 2001, mostly across health regions such as Local Health Integration Networks (LHINs) in Ontario or regional health authorities in British Columbia.[9,60–62] Health regions are provincially legislated administrative areas with the responsibility of delivering public healthcare services to residents via hospital boards or regional health authorities.[17] According to the recent estimates by the CIHI, in British Columbia, the Vancouver Coastal Health Region had a rate of 222 ACSC hospitalizations per 100,000 whereas the Northern Health Region had a rate of 503 per 100,000.[58]

Saskatchewan is another example of a province which has very dispersed rates of ACSC hospitalization across its health regions.[58] The rates vary from 1,383 hospitalizations per 100,000 populations in the Athabasca Health Authority to 310 hospitalizations per 100,000 populations in the Saskatoon Health Region.

Overall, comparing health regions across Canada, a seven-fold difference in rates of ACSC hospitalization was observed in 2017-2018 (FY), ranging from 195 per 100,000 in the Central LHIN in Ontario to 1,383 per 100,000 in the Athabasca Health Authority Health Region in Saskatchewan.[58]

2.2.3 Variation in ACSC hospitalizations within health regions

In Canada, there are limited data on intra-health region or community-level variation in the rates of ACSC hospitalization. However, from available literature, marked geographic disparities have been identified within smaller geographic areas.[36,63–66]

In 2006, an Ontario-based study reported a threefold difference in age and sex adjusted rates of hospitalizations for asthma across seven hospital sites.[63] Additionally, a study carried out in Nova Scotia found rate disparities in high cost users, among which the most prevalent cases were ACSC such as diabetes, respiratory diseases (predominantly - COPD), ischemic heart disease, and heart failure across.[36] Analysis carried out at Forward Sortation Areas (FSA) level which varied from 2.5% (half the provincial average) to 7.4% (50% higher than the provincial average).[36]

Geographic variation in the rate of ACSC hospitalization across communities was also identified in other countries, which in most cases were defined by local administrative boundaries responsible for delivery of primary healthcare services.

In Switzerland, a study conducted at the zip code-level for 59 service areas indicated an up to 3.6-fold regional difference in the rate of preventable hospitalizations (per 100000 population) over the three-years follow up (RR=274-982).[12] Substantial geographic variation has also been reported in a national-level study in England.[67] Investigating ACSC hospitalization admission data from 151 primary care trusts between 2011 to 2012, revealed a 26% difference in rates per 100,000 residents, across high risk and low risk geographic units (RR=1.26; 95% CI: 1.23-1.30). Similarly, a nationwide study by Mercier and colleagues in France found an overall crude rate of potentially preventable hospitalizations of 1140 episodes per 100,000 people.[68] However zip code-level analyses unveiled significant geographic disparities in these rates. The variation in rates had a north-south gradient in the range of 10 to 4440 cases per 100,000 inhabitants. In Tuscany, Italy, Arandelovic et al. conducted a retrospective cohort study on the rate of preventable hospitalizations for twelve local health authorities.[69] Using individual-level information, findings suggest a considerable difference in the incidence rate ratio (IRR) of preventable hospitalizations between local health authorities when compared to the regional average. Out of twelve local health authorities, three had a significantly lower IRR calculated as Per 100,000 person-days (IRR=24; 40; and 67), whereas one had a significantly higher rate (IRR: 195), compared to the regional average. In Spain, hospitalization data from 34 health districts within the Community of Madrid were investigated in terms of rates for ACSC hospitalization.[22] According to this cross-sectional ecologic study, even after adjusting for sex and age, a wide variability was observed in the rate of ACSC hospitalization; per 100,000 population (Ratio of variation(RV) = 5.6; P5-P95: 2.13 ; and P25-P75: 5.26); with lower rates belong to the regions closer to the center of the Community of Madrid.

Outside of Europe, reports from an ecological study by Magalhães and colleagues demonstrated a distinctive difference in magnitude, profile, and geographic distribution in the rate of ACSC hospitalization across health districts of the municipality of Goiânia in Brazil.[70] Compared to the average rate of ACSC hospitalization (R=1527; 95% CI: 1570-1620) per 100,000 population, the age-adjusted rates of hospitalization at the districts level could be clustered into four groups, with the highest rate observed in the South District (R= 2328; 95% CI: 2247-2411), and the lowest rates in Southeast District (R=1488; 95% CI: 1432-1545). In Australia, an observational cohort study collected ACSC hospitalization data at the Statistical Local Areas level, which is one of the smallest geographic units in the Australian.[71] The magnitude of geographic variation was reported to be highly significant across these small-scale geographic units.

ACSC list of diseases are not defined uniformly across Canadian-international studies and compared to the CIHI's definition of ACSC, broader list of diseases are included in studies (e.g. International:[22,68,69,72–74] within Canada:[75–77]). Also, sociodemographic profiles of patients are not always similar across studies. Therefore, result from different researches across the globe, must be compared with extreme caution.

2.3 Factors associated with geographic variation in ACSC hospitalization

2.3.1 Self-selection

Differential patterns in the rate of ACSC hospitalization across provinces, health regions, and communities may be a consequence of "self-selection" processes, which refers to a process in which people may choose to reside in certain provinces, health regions, or communities that support their lifestyle.[78] Besides self-selection processes, characteristics of the healthcare system can also account for some of the observed geographic variations in ACSC hospitalization.

2.3.2 Healthcare system factors

Geographic heterogeneity in ACSC hospitalizations can arise from different healthcare needs in each region but can also be related to the structure of primary healthcare services and how people use these services. In other words, regional heterogeneity in ACSC hospitalization rates, can reflect the regional barriers associated with access, availability, and quality of primary healthcare resources.[79] These barriers can be related to healthcare policies and their corresponding differences in healthcare management plans for service delivery quantity, quality, and continuity, as well as operationalizing preventative care programs.[20] These characteristics of primary healthcare are often discussed in the context of ACSC hospitalization events,[19,68,79–84] and are discussed briefly in the following section.

a) Access and availability of primary healthcare

Family physician supply, number of visits to primary care, and wait times for specialized services have been used as a surrogate of access and availability of primary healthcare services, and these attributes of healthcare system have shown to be highly variable across Canadian communities.[85–90] There is a growing body of literature that suggests a significant negative association between the degree of access to primary healthcare and the rate of ACSC hospitalization.[11,12,19,20,81–84,91–97] However, there are also mixed results from other studies which vary across countries and healthcare systems:

Some studies report no association between the access to primary health care access and the risk of ACSC hospitalization[72,98] Ansari et al. found a significant negative association between primary healthcare supply and ACSC hospitalization in unadjusted models for Australian population.[99] However, after adjusting for potential confounders, the negative association was no longer statistically significant.

In Canada, Sanmartin and colleagues also reported that access to primary care services was not significantly associated with the risk of ACSC hospitalization for Canadian patients (excluding Québec residents), after adjusting for other factors.[8]

In USA, analysis for 642 urban counties and 306 rural areas showed that for urban areas, primary care physician supply had positive association with reduced risk of ACSC hospitalization. The strength of association was strongly dependent on the age categories. However, results did not support any significant association between risk of ACSC hospitalization and residing in rural areas.[82]

some studies have found negative associations between low to moderate primary care supply and the risk of ACSC hospitalization, but no association at higher levels of supply.[100,101]

In contrast, there are also studies that have found a significant positive relationship between the number of primary care practitioners and the rate of ACSC hospitalization.[102–106]

Studies varying widely in terms of the hosting country healthcare system, the demographic of the included population and geographic boarders within which researches were carried out. Therefore, results may not be comparable with each other and accessibility dimension of primary healthcare remains questionable. In specific, studies that analyzed the risk of ACSC hospitalization in relates with accessibility of primary healthcare by adjusting for sociodemographic indicators have showed the most contradicting results against the protective effect of primary healthcare accessibility.[79] Within Canadian context, some studies suggest that socially disadvantage individuals who had higher risk of ACSC hospitalization did not show lower rate of access to primary healthcare facilities.[8,103]

From a geographic perspective, the link between healthcare attributes and the risk of ACSC hospitalization has shown strong rural/urban association globally.[12,107–109] For instance, in Brazil, local physician supply was reported to be positively associated with the rate of hospitalization in urban areas, but not in rural regions.[106] In Australia, urbanicity and area of residence were significantly associated with increased rates of ACSC hospitalization.[73] However, in some studies urbanicity was reported to be a stronger predictor of ACSC hospitalization events, relative to poor access to primary healthcare.[19]

In Canada, rural patients are reported to have less access to after-hours care than those living in urban areas (69% versus 58%, respectively),[110] and have more challenges accessing specialist services.[111,112] Furthermore, Canadian patients with ACSC living in rural areas have been found to be more frequent users of hospital services, compared to their urban counterparts.[10] The rate of ACSC hospitalizations in Canada has been reported to be higher in rural areas (510 per 100,000 population) compared to urban regions (318 per 10,000 population).[9]

b) Quality of primary healthcare

Access and availability are not the only attributes of the healthcare system that affect ACSC hospitalization. In particular, in a universally funded healthcare context such as the Canadian system, quality of primary healthcare is suggested to be a more relevant system attribute as compared to the accessibility or availability of health services.[114] Globally, it has been debated whether the "quality of healthcare" relates to the risk of ACSC hospitalization.[99,101,114,115] This attribute of healthcare typically relies on surrogate markers or characteristics, such as physician practice behaviors (e.g., physician's adherence to guidelines, communication skills, physician's practice style specifically for chronic conditions,[116,117] or other aspects pertaining to the patient-physician relationship),[95,105,106] and continuity of care.[13,83,94,120,121]

The quality of primary care has an impact on health outcomes such as ACSC hospitalization, not only across large scale geographic areas (such as provinces in Canada), but also in smaller communities. Misalignment of primary care resources with local needs[122] may include one of the following: lack of allocation of alternatives to emergency departments (e.g., walk-in centers, crisis teams),[13] a lack of culturally competent care for some racial and ethnic sub-groups,[123] or ignoring local social conditions.[102] Also, applying intervention programs to decrease preventable hospitalizations may be effective for some conditions and among certain sub-populations, but not for the others.[67,69] Therefore, local-level decision making processes related to the local healthcare system may partially explain geographic difference in ACSC hospitalization rates.[13,124]

In Canada, large-scale variation across provinces, and to some degree health regions, is expected given that each of the ten Canadian provinces has its own healthcare system with a different and complex set of social programs and healthcare policies.[125] These differences may cause disparities in the quality of disease management for residents with chronic conditions and a greater reliance on hospital utilization in some provinces. However, it is challenging to explain the intra-health region inequalities within the universally funded Canadian health system context. The healthcare system promises equity to access, availability, and quality of health for Canadian residents, regardless of their location and their social status.[126] Disparities in the rate of ACSC hospitalizations across communities may imply that even within the same health region, primary healthcare centers do not provide the same level of accessibility or service quality for the population. Therefore, persistent community-level heterogeneity in the rates of ACSC hospitalization deserves a more comprehensive assessment. It can also be argued that there are additional contributing factors to geographic variation in ACSC rates other than those related to healthcare system.[102,103] Determinants related to individual- and community-level characteristics may explain part of the heterogeneity in the regional rates of ACSC hospitalization.[72,93,104]

2.3.3 Individual-level determinants

An Australian assessment of risk factors for ACSC hospitalization reported that more than 36.9% of geographic variation stemmed from sociodemographic composition, health status, and behaviors of individuals, whereas only 2.9% of this variation was related to general practitioner supplies within health service centers.[71] In addition, these individual-level characteristics showed strong associations with the risk of ACSC hospitalization, compared to acute or vaccine-preventable health conditions. International studies suggest that an individual’s demographic, socioeconomic, health behavior, and health status are independent risks for ACSC hospitalization, beyond healthcare system attributes.[8,99,127,128] Some of the most important individual-level determinants are discussed in the following section.

Age

Age has been shown to be a risk factor for health outcomes in general, but it also remains a consistent predictor of ACSC hospitalization. Older people (60 years and older) are at a higher risk of ACSC hospitalization, compared to younger individuals.[8,82,92,129–134]

According to a cross-sectional Canadian study, men and women over the age of 60, experienced a 2.4 to 3.5-fold increase in the odds of ACSC hospitalization events, respectively, compared to people under the age of 60.[8]

Older people comprise a more vulnerable and fragile population in terms of their health status.[135] Age-related living arrangements, such as living alone with a serious disability, may result in reduced access to continued primary healthcare services.[130] Even for institutionalized seniors, there are barriers to timely and effective access to the required primary healthcare.[136] Multimorbidity, the co-occurrence of two or more chronic conditions, is also significantly associated with age.[137,138] The ability to adhere to a prescribed treatment for multiple conditions may be more challenging for older individuals due to the complex or possibly mutually exclusive treatment recommendations by different physicians.[139–141]

Gender

Gender is identified as another major determinant of health,[142] and is associated with ACSC hospitalization. In particular, a growing body of research suggests that women and men do not share the same degree of risk in relation to ACSC hospitalization; this risk has been frequently reported to be higher for men than women.[8,12,71] This may be a result of differences in the way men and women use primary care services, the experience they report from healthcare providers, differences in their health behaviors, and their biomedical factors.[143,144]

Individual-level SES

It is well accepted that in addition to age and gender, SES is a critical driver of health inequalities for a number of diseases, and is influential on health service utilization.[95,145,146] According to Winkleby et al., SES markers are "causes of the cause" for most of health outcomes, including chronic disease.[147] SES is a complex construct evaluated by a broad spectrum of interrelated dimensions, including wealth (financial) and social (e.g., occupational, and educational) factors.[147,148] Various combinations of SES markers are used; however, among all dimensions of SES, income and education are more prevalent in the literature. In general, the burden of ACSC hospitalization are reported to be disproportionately high among people with low SES, and this inverse association has been observed globally across countries with various types of healthcare systems and social conditions (e.g., United States[119,147,149,150], Australia[19,71], Italy[97], Brazil[151], Taiwan[152]).

In Canada, despite the universally-funded healthcare system, an individual's SES has also been found to be significantly associated with an increased risk of chronic disease, as well as ACSC hospitalization events.[8,36,37,65,95,103,153–156] For example, a cross-sectional analysis of a population in Saskatchewan showed that the risk of diabetes mellitus has a marked association with an individual's level of education.[65] Compared to individuals with postsecondary education, people who have not completed high school had the highest odds of diabetes (OR=1.51, 95% CI: 1.49-1.54), whereas those with a high school diploma had lower odds of diabetes (OR=1.08, 95% CI: 1.06-1.10). A study conducted in Winnipeg, found that after adjusting for individuals' demographic and healthcare system attributes, people with lower income were still three times more likely to have an ACSC hospitalization, compared to their counterparts with higher income.[102]

Generally speaking, evidence suggests that lower educational attainment and/or having lower income are associated with higher risk of ACSC hospitalization. However, in some cases these markers are reported to have a different magnitude of effect when they are all included in a single model. For instance, Gonçalves et al., showed that in an adjusted model, an individual's education remains an important risk of hospitalization compared to the effect of income.[129] A study of associated risk factors for cardiovascular disease examined the contribution of each SES dimension including education, income, and occupation.[147] The results suggest that among these three SES components, individual-level educational attainment is the most consistent predictor for the burden of cardiovascular disease.[147]

Race and ethnicity

Race and ethnicity are additional individual-level factors that may be significantly associated with an increased risk of ACSC hospitalization. The literature suggests that the burden of behavioral risk factors and chronic diseases, as well as incidence rates of hospitalization, are disproportionately high among the Canadian Indigenous population compared to the non-Indigenous population.[157–161] In addition, the health status of the Indigenous population differs across Indigenous identities (i.e., First Nations living on- and off-reserve, Métis, and Inuit living in Inuit Nunangat), as well as across place of residence.[162–164] Research conducted by Statistics Canada showed a consistently higher hospitalization rate for Indigenous people living on- and off-reserve, compared to the non-Indigenous population.[165] The study included all hospital records from nine provinces (excluding Québec) and the three territories. Among the most responsible cause of hospital admission, chronic diseases of the respiratory system were reported as one of the most consistent diagnoses. Investigation among Canadian urban Métis adults also showed the magnitude of the rate of ACSC hospitalization to be twice as high for the Indigenous population compared to the non-Indigenous population (393 versus 184 per 100,000 population); even when adjusting for demographic, geographic, and socioeconomic characteristics, Métis still had higher odds of ACSC hospitalization (OR= 1.46; 95% CI: 1.32-1.62).[166]

This is consistent with international research, where Indigenous Australians were also reported to have a disproportionately high risk of chronic conditions such as cardiovascular disease and diabetes, and an elevated risk of hospitalizations related to chronic health conditions.[71,167–170] Trivedi et al. report that Indigenous Australians experience three- to four-fold higher rates of ACSC hospitalization, compared with those of non-Indigenous origin.[171]

Ethnic disparities in the risk of experiencing chronic disease and ACSC hospitalization were also found in other countries. In the United States, the inequalities in pattern of ACSC hospitalization are reported consistently not only for Indigenous peoples, but also for non-whites including Black and Hispanic populations.[172–176] Some studies estimate that the disparity in rate of chronic disease hospitalization is approximately three times greater among African Americans than whites, and does not disappear even after controlling for SES and urban and rural place of residence.[123,133,177–181] Outside of the United States, in Latin American countries, race continues to be a key predictor of disparity for ACSC hospitalization. In a Brazilian cohort study conducted between 2006-2011, Gonçalves et al., found non-white ethnicities to have a significantly higher ACSC hospitalization Cox proportional hazard rate (HR=1.77; 95% CI: 1.13-2.77) compared with the white population.[129]

Health behaviors

Certain health behaviors place individuals at higher risk of ACSC hospitalization. People who smoke tobacco, are physically inactive, have higher levels of alcohol drinking, and do not meet health dietary guidelines in terms of fruit and vegetable consumption are reported to have higher risk of ACSC hospitalization.[71,102,127,182–185]

Weight status

Weight status also affects the risk of ACSC hospitalization.[71] According to a Canadian national study on risk factors for ACSC hospitalization, individuals who were underweight had three times higher odds of ACSC hospitalization events, compared to normal weight people (5.2% versus 1.5%).[8] On the other hand, being overweight had a protective effect against the odds of ACSC hospitalization. However, according to the same study, the association appears to be gender dependent. Specifically, weight status is reported to be a more important factor for women compared to men.

Medication adherence

Poor medication adherence is also linked to preventable use of hospital services.[127,130,186–188] For example, in a national sample of American patients with diabetes from 2005 to 2008, findings suggest that adherence to diabetes medications could lead to 13 percent lower odds of future hospitalization, whereas lack of compliance increases the odds of hospital admission by 15 percent.[189]

Propensity to seek care

The threshold to seek care for certain symptoms varies, which has implications for ACSC hospitalization.[127,190,191] A high propensity to seek care can result in early detection and control of diseases at primary healthcare centers, whereas delay in seeking help might result in a preventable hospitalization. The tendency to seek care can be affected by a patient's individual-level characteristic such as age, sex/gender, SES, and ethnicity. However, evidence is mixed. Some studies have shown that women tend to consult a general practitioner more often than men.[192,193] In a survey from the United Kingdom, Black people, those from lower socio-economic groups, and women showed the lowest likelihood to seek immediate health care compared to White respondents, those from a higher socio-economic level, and men.[194] Research carried out within the United States found a higher likelihood to seek care among older, retired men compared to the younger population. However, the results showed a non-significant association between propensity to seek care and low education or low income.[195] Geographic barriers can also influence people's tendency to delay the usage of primary healthcare,[61] and patients residing in rural or remote areas were found to be at increased risk of having preventable hospitalizations.[91]

Health status

There is consistent evidence that the likelihood of a hospital admission for an ACSC is associated with the presence and severity of health issues.[71,127,196] For instance, in an American study, after adjusting for age and gender in a nationally representative random sample, Wolff et al. found an elevated risk of ACSC hospitalization for every additional co-morbid chronic condition.[197] Presence of one chronic condition increased the likelihood of hospital admission 7.5 times compared to those without a chronic condition. However, for individuals with four or more chronic conditions, the risk of hospitalization was increased 99 times. A Canadian population-based study reported that individuals with poor or fair self-reported health had ten times higher odds of being hospitalized, compared to those who reported excellent health.[8]

Mental disorders including intellectual disability and psychiatric disorders are also reported to impact the odds of ACSC hospitalization.[182] In a population-based study conducted between 1999 and 2003 in Manitoba, individuals with an intellectual disability had significantly higher adjusted rate ratio of ACSC hospitalizations compared to the general population (RR= 6.1; 95% CI: 5.6-6.7).[66] More specifically, people with an intellectual disability had a 54 times greater risk of hospitalization for epilepsy, compared to those without intellectual disabilities. Additionally, evidence from a study conducted in England suggests that the adjusted incidence rate ratio (IRR) of emergency admission for ACSC was more than three times higher for individuals with intellectual disabilities, as compared to patients without intellectual disabilities (IRR= 3.60; 95% CI: 3.25–3.99).[198]

Results from a population-based cohort study from the 2010 Danish National Health Survey suggests a dose-response relationship, as individuals within the highest perceived stress quintile have 2.13 times higher adjusted risk of ACSC hospitalization compared to individuals with the lowest stress level.[196]

2.3.4 Community-level determinants

Regional burden of chronic diseases, and in particular ACSC hospitalization events, are affected not only by individual characteristics but also by the characteristics of the communities within which people reside and receive primary care services.[157,200] Referred to as “contextual effects”,[202,203] these community-level factors can be categorized into five groups: 1) healthy environment (i.e., community-level prevalence of healthy behaviors, self-reported health, weight status, and chronic conditions); 2) natural environment (i.e., air pollution, climate/weather); 3) built environment (i.e., walkability, green space); 4) social environment (i.e., social deprivation); and 5) geographic characteristics (i.e., rural/urban location).

Healthy environment

It is assumed that an individual’s own healthy habits can improve their health outcome. It is also expected that residing in communities where a high proportion of individuals are engaging in healthy behaviors, such as being physically active and having a healthy weight status, may decrease the odds of ACSC hospitalization for their residents.[71] The percentage of the community who report their self-rated health, including chronic conditions, as being poor may explain the across-community variation in ACSC hospitalization.[14] This “healthy environment” effect may stem from the local social and physical characteristics that encourage individuals to participate in healthy behaviors.[14,19,83,204]

Natural environment

The concept of “natural environment” mostly encompasses air quality and weather/climate related factors. There are studies that argue that high level of airborne and gaseous pollutants (e.g., carbon monoxide, nitrogen dioxide, and ozone concentrations),[127,205–208] and excessive temperature,[209] may lead to increased odds of ACSC hospitalization, mostly for patients with congestive heart failure, diabetes, and cardiovascular disease.[207]

Built environment

Attributes of the built environment can put community residents at higher risk of chronic disease and also elevate risk of preventable hospitalization events.[210] Built environment characteristics may impact the choices and behaviors of residents.[211] There is evidence that supports the association between cardiovascular disease and its major risk factors (e.g., hypertension, obesity, and physical activity) and physical built environment measures such as level of street connectivity and walkability, residential density, available green space or vegetation, as well as the level of neighborhood noise, traffic, and nighttime light.[208,212–215] Also, residents with health conditions, such as diabetes, can indirectly benefit from green spaces, which in turn affects their level of physical activity.[216] Neighborhood greenness is suggested to decrease the stress level of individuals by promoting physical activity and social cohesion, which in turn positively affects health outcomes, including chronic diseases (e.g., hypertension and cardiovascular disease).[217]

Social environment

It has been proposed that the communities' socioeconomic context exerts an independent effect on the health of residents, above and beyond an individual's own SES.[218–222] As stated by Durkheim, these "collective characteristics" go beyond the sum of the people that compose it.[223] Defined as the percentage of the population with low income, low education, and/or unemployment, community-level SES has been identified in several studies as an important risk of factor for an increased odds of ACSC hospitalization.[11,36]

Among all the social determinants of health, the inverse association between markers of community-level SES and risk of chronic disease and ACSC hospitalization are the strongest, and the robust effects persist across studies in widely differing healthcare systems and contrasting settings around the world: (e.g., Taiwan,[152] the United States,[11,19,132,196,224–227] Australia,[14] Italy,[97] Germany,[71] Sweden,[228] and Scotland[229]).

Despite the universally funded Canadian healthcare system, community-level SES can differentially affect access to primary healthcare, and elevated rates of ACSC hospitalization have been identified among low-SES communities.[8,9,24, 90,98,148,225,226] A report on the population in Ontario with diabetes between 1992 and 1999 suggests that residents of the lowest income areas were 44% more likely to have emergency admission or hospitalization events for diabetes mellitus compared to those in the highest income quintile, and the effect persisted after adjusting for age, sex, urbanicity, and healthcare system characteristics.[155] In contrast, there was no SES gradient for non-ACSC hospitalizations.

Linked data from the 2000-2001 Canadian Community Health Survey (CCHS) and the Hospital Morbidity Database (HMDB; 2000-2001 to 2004-2005) were used in a pan-Canadian study on ACSC hospitalizations (excluding Québec).[8] The results of non-adjusted models suggested that residents of households in which at least one member holds a postsecondary graduate degree, had two to four times lower odds of ACSC hospitalization events, compared to patients within households where the highest level of education was less than secondary school graduation. The same magnitude of effect was reported for the differential impact of household income markers in non-adjusted estimates. Individuals in the highest income group had two to four times lower odds of ACSC hospitalization incidence compared to the lower-middle- and lowest-income household groups. However, results from gender-specific multivariate regression models showed a differential pattern for income effects. After adjusting for other risk factors, the association between low income and ACSC hospitalization events persisted for only men, with the lowest income quintiles having three times greater odds of ACSC hospitalization, compared with those in the highest quintile. In general, there is a growing body of literature that has discussed gender-based social inequalities in health. The traditional notion is that women have a weaker socioeconomic gradient for health issues than men,[231–234] but findings for health outcomes and SES inequalities by gender are inconclusive.[144,156,233,235]

Using 2003-2006 data, a report by the CIHI indicated a marked difference in the rate of ACSC hospitalizations across 15 Canadian Census Metropolitan Areas (CMAs) with high and low SES.[60] The ACSC hospitalization rates had a significant gradient among three community-level SES categories and rates declined from 458 to 196 per 100,000 moving from the lowest to highest SES community quartiles. These comparative rates were updated later in another CIHI report.[9] According to data from 2006-2007 (FY), the age-adjusted rates of ACSC hospitalization within the lowest income group was 521 per 100,000, while for the same disease condition, affluent communities had nearly half the rate of ACSC hospitalization at 234 per 100,000 population.

There are some contradicting studies that suggest that communities with lower SES do not always have higher rates of ACSC hospitalization. Fishman et al. reported that a higher proportion of individuals with bachelor degrees who lived in Chicago, USA, had higher odds of ACSC hospitalization than people with lower level of education.[204] Also, studies from countries with different healthcare funding systems have shown varying magnitude of effect in terms of the association between SES and rates of ACSC hospitalization.[236] A study by Billings et al. showed that economically disadvantaged communities within urban cities in Ontario, Canada had ACSC hospitalization admission rates that were 1.4 times greater than wealthier areas.[80] This gradient in hospitalization rates was more pronounced in the United States, where a six-fold difference in rates was observed.[80]

There is also some evidence to suggest an interactional effect between SES markers of chronic disease and place of residence. A Canadian population-level study revealed that low income communities in different provinces do not share the same level of risk for ACSC hospitalization.[237] According to this study, people who live in low-income areas from healthier provinces, such as British Columbia (from the perspective of both behaviors and health outcomes), have a greater magnitude of risk for major chronic diseases (e.g., hypertension, diabetes, and heart disease), compared with less healthier provinces such as Québec. This difference can be attributed to heterogeneity in policy interventions across Canadian provinces.

Including both individual and community-level SES markers should be assessed critically, as they can have distinct effects. Although a person with low individual-level SES may have an increased risk of ACSC hospitalization, for the same individual, living in a high-SES community may lower the likelihood of ACSC hospitalization. Therefore, using one measure of SES may hide the vital patterns in this relationship that can be inferred only when both types of SES are included. Disentangling individual and community-level SES measures will also impact the nature of preventative decisions made by policy makers to control rates of ACSC hospitalization. Detecting a significant association between individual-level SES and the likelihood of ACSC hospitalization can help target low-SES individual or families in order to mitigate the unavoidable hospitalization. On the other hand, strong associations between the risk of ACSC hospitalization and community-level SES can result in taking action on the distribution of medical and primary health care resources within disadvantaged communities.

Geographic characteristics: urbanicity

There is global evidence that distance from home to hospital, topographical barriers to access to hospital, and geographic remoteness, known as urbanicity, are associated with the rate of ACSC hospitalization.[6,12,19,107,149,204,238,239]

A study by Lin et al. in Canada has shown that for some areas, overall hospitalization rates declined as the distance from a hospital increased, which means living close to a hospital may encourage more utilization of hospital services.[61]Also, people who anticipate higher frequent healthcare requirements may choose to reside closer to hospitals.[240] In terms of urbanicity, rural-urban disparities in general health, and ACSC hospitalization events in specific, are well documented in Canada.[24,113,241,242] According to the literature, rural Canadians experience a greater burden of poor or fair health status, and are more likely to be living with disabilities.[243,244] According to a 2012 CIHI report, individuals who live in rural areas have a higher rate of ACSC compared to urban residents.[110] Also, the association between the rate of ACSC hospitalization with living in a rural region has been supported by number of studies.[9,48]

The rate of ACSC hospitalization in Canada has been reported to be higher in rural areas (510 per 100,000 populations) compared to urban regions (318 per 100,000 populations).[9] This pattern has also been observed for specific subpopulations living in both community contexts. For instance, people with intellectual disabilities who live in rural areas have 1.3 times higher odds of ACSC hospitalization events than those living in urban areas (OR=1.3; 95% CI: 1.0-1.8).[154] Factors beyond healthcare system characteristics can be a predictive of ACSC hospitalization, and research suggests that in rural areas, specific demographic, cultural characteristics, lifestyle, and socioeconomic factors may lead to an independent impact on the risk of ACSC hospitalization.[238,245]

Many rural Canadian communities have larger proportions of children and seniors ($\geq$ 65 years old) who tend to use healthcare facilities to a greater extent, specifically for ACSC health issues.[246,247] Overall, Canadian rural residents have been reported to exhibit less healthy behaviors (e.g., smoking, low levels of physical activity, and less healthy dietary practices).[248] Rural residents also tend to have different health beliefs, such as self-reliance or preference for receiving informal support networks, which might reduce their propensity to prevent or control a serious health situation.[113,243,249–251]

2.4 Knowledge gaps

There are still knowledge gaps that hinder our understanding of the patterns, magnitude, and determinants of geographic variation in ACSC hospitalization rates across Canada, particularly across communities in which primary healthcare services are delivered.

Lack of pan-Canadian studies on the risk/odds of ACSC hospitalization

Canadian studies on geographic variation in rates of ACSC hospitalization have been mostly limited to specific jurisdictions – including provinces, health regions, and cities[10,24,37,60,61,65,102,103] – or they have been carried out for specific sub-populations (e.g., individuals with intellectual disabilities or specific ethnic populations such as urban Métis).[66,166] Therefore, there is a need to conduct studies using a nationally representative sample.

The need to go beyond ecological studies

Most of the Canadian studies focusing on determinants of ACSC hospitalization are of ecological nature.[8] They provide important knowledge about the population-level rate of ACSC hospitalization and population-level risk factors. However, ecological studies are not able to provide any information about the individual's risk of ACSC hospitalization and the corresponding risk factors at an individual level. Therefore, no individual-level conclusions can be drawn without committing "ecological fallacy".[252]

The need for multi-level analysis

There is some evidence suggesting ACSC hospitalization and its determinants must be addressed separately at each level of geography.[65,71,152,204] More specifically, individuals may differ in their risk of ACSC hospitalization due to:

1) Differences in their individual characteristics, and/or

2) Being exposed to different characteristics of the communities in which they reside and/or the local healthcare system that they rely on for receiving primary healthcare services, and/or

3) The healthcare policies that shape the overall characteristics and management of the healthcare facilities in their heath region.

All of these factors should be accounted for simultaneously when assessing the risk of ACSC hospitalization. A multi-level framework is an analytical tool that allows for the assessment of all groups of factors in a single analytical framework, accounting for the possible dependencies among risk factors for ACSC hospitalization events that occur within the same geographic unit.[253]

2.5 Importance

Results from the current research will set the stage for future pan-Canadian studies to take into account the simultaneous effects of a comprehensive set of potential risk factors at the individual-, community-, and health region-levels. Also, generating estimates for the magnitude of geographic variation in the odds of ACSC hospitalization across Canadian communities will make it possible for future studies to evaluate the temporal nature of these health inequalities and their relationship with access and quality of local healthcare systems. This may have a potential impact for developing policies that target inequalities in the risk of ACSC hospitalization.

2.6 Objectives and hypotheses

2.6.1 Objective 1: Geographic variation in the likelihood of ACSC hospitalization

The first objective is to assess the extent to which place of residence in which we receive primary healthcare services (communities), and geographic units within which healthcare policies are implemented (health regions) affects an individual's likelihood of ACSC hospitalization. Residential communities and health regions are considered two major sources of ecological effects, which exert specific cultural, economic, and policy impacts on the odds of ACSC hospitalizations for people who share these geographic entities. In the current study, I chose residential communities that were nested within health regions. The proportion of the overall variance in the likelihood of experiencing ACSC hospitalization that can be assigned to each of these potential sources of variation (i.e., communities or health regions) will be quantified. For example, if two individuals are randomly selected from different geographic areas, how much of the variation in their likelihood of ACSC hospitalization can be attributed to individual-level factors, the communities in which they reside, and/or the health regions in which they live? It is hypothesized that:

H-1A The individual's likelihood of hospital admission for ACSC is not the same across Canada. Some geographic areas (i.e., communities and health regions) will have higher risk of hospital admission for ACSC compared to other areas. This implies that where people live matters significantly for how likely they are to end up in hospital as the result of ACSC. In other words:

a) Two randomly selected individuals residing within the same community will have a more similar likelihood of ACSC hospitalization compared to the likelihood of other individuals living in same health region, but different communities.

b) Two randomly selected individuals residing within different communities, but the same health region will have similar odds of hospitalization for ACSC compared to individuals living in other health regions.

2.6.2 Objective 2: Effect of individual-level characteristics on ACSC hospitalization

The second objective is to assess the association between the odds of ACSC hospitalization events and specific individual-level characteristics. Individual-level characteristics will also be assessed to determine if they can explain part of the geographic variation in an individual's odds of ACSC hospitalization across communities and health regions. It is hypothesized that:

H-2A: Socio-demographic factors such as age, sex, marital status, ethnic background (visible minority), and individual-level SES are significant determinants of the odds of ACSC hospitalization.

H-2B: Individual-level characteristics will account for some, but not all, of the geographic variation in the odds of ACSC across communities and health regions.

2.6.3 Objective 3: Effects of community-level factors on ACSC hospitalization

The third objective is to assess the magnitude of association between the odds of ACSC hospitalization events and specific community-level characteristics. In other words, the inclusion of some community-level characteristics will be assessed to determine if they can explain part of the geographic variation in an individual's odds of ACSC hospitalization. It is hypothesized that:

H-3A: Community-level characteristics, such as median household income, will have a significant association with the odds of ACSC hospitalization for individuals.

H-3B: Community-level characteristics will account for some, but not all, geographic variation in the odds of ACSC hospitalization across communities and health regions.

By exploring these three main objectives and related research questions, the current study aims to address major gaps in the existing Canadian research on geographic variation in ACSC hospitalization:

1) *The need to go beyond ecological studies:* The current study draws inferences at the individual-level by using individual-level data for both the outcome variable (odds of ACSC hospitalization) and the associated risk factors.

2) *The need for multi-level analysis:* The current study accounts for the geographic variation in odds of ACSC hospitalization within the context of a multi-level analysis framework. Specifically, individuals and their characteristics, communities (i.e., geographic areas where individuals reside and receive their healthcare services), and health regions (i.e., geographic entities which implement healthcare policies) are treated as separate entities as level 1, level 2, and level 3 of the data hierarchy, respectively. The outcome, the odds of an ACSC

hospitalization event, is measured at the lowest level of this hierarchy (level 1) and is assumed to be affected by determinants observed at all three levels.

3) *The lack of pan-Canadian studies:* To address the need for producing generalizable estimates about Canadian population at the national and local level, this study will use the pan-Canadian data from the 2006 Census of Canada linked to the 2006-2009 CIHI administrative health data: the Discharge Abstract Database (DAD) files.[254] By using the linked census-DAD data, the current study will establish a pan-Canadian baseline assessment for the nature and magnitude of geographic variation across all communities, health regions, and provinces (except Québec) for the odds of ACSC hospitalization.

Chapter 3

3 Methods

3.1 Study design and setting

I conducted a pan-Canadian cross-sectional study, using census (2006) from Statistics Canada linked to the pooled healthcare administrative information from the CIHI starting May 16, 2006 to March 31, 2009. The study population generates a representative sample of Canadians (except Québec). At the time of the current research only the 2006 census data was available as a linked census-DAD database. I used more than one fiscal year (2006-2009) DAD files in order to increase the included number of ACSC hospitalization events. However, to avoid the bias effect from the potentially time-varying risk factors, I did not include more hospitalization information beyond 2009.

3.2 Data sources

3.2.1 Linkage of separate datasets

To achieve the objectives of the current study, three main sources of information were required:

1) A representative sample of the Canadian population which includes comprehensive data on individual-level and community–level socio-demographic and socioeconomic characteristics;

2) Geo-coded information to link each individual to their residential community and health region within which they might have been hospitalized;

3) Comprehensive information on hospitalization records for the census participants.

Different data custodians provided the required information. Canada-wide sample information on socio-demographic, socioeconomic, and most of geo-coded data were provided by Statistics Canada census files. Also hospitalization records were provided by CIHI as DAD files. In order to conduct a multi-level analysis on the odds of ACSC hospitalization, these separate sources of information need to be linked.

Addressing the linkage requirement, Statistics Canada has established the Longitudinal Health and Administrative Data Initiative (LHAD), which is a project aimed at linking individual records from censuses and population health surveys with administrative health databases (including the DAD, the Canadian Cancer Registry, and vital statistics databases).[255] Compared to the costly primary data collection of pan-Canadian population-based cohorts, the Statistics Canada data linkage is a cost-effective method, devoid of limitations related to recruitment and respondent burden that are prevalent issues in studies using primary data collection. The longitudinal nature of the CIHI's archived health databases, where individual records are linkable through common identifiers, enabled Statistics Canada to conduct prospective linkages of census cohorts for innovative health surveillance projects, including the study of geographic variation in ACSC hospitalization. The individual components of the linked data used in the current study are explained in the following section.

3.2.1.1 Census 2006: Study population

Statistics Canada conducts a census of population every five years. Data from the national census provides a unique opportunity to access both individual and community-level information on nearly the entire Canadian population. Basic census questionnaires, or the short-form census, include eight demographic questions (such as birth date, gender, marital status, and language). The long-form census includes an additional 53 questions that collect individual-level information on income, employment, dwelling characteristics education, ethnicity, Aboriginal status, and mobility.[256] In total, 20% of individuals from the non-institutional Canadian population were asked to complete the long-form census. Respondents who completed the 2006 long-form questionnaire constructed the study population for the current study. The census was conducted on May 16, 2006 and 4,652,700 people residing in large metropolitan regions, as well as small remote settlements, received the long-form.[257] As the 2006 census is representative of approximately 95-97% of the provincial populations, and 93-94% of the territorial populations, it is considered a reliable capture of the Canadian population in terms of their socio-demographic characteristics, excluding the institutionalized population (e.g., residents of long-term care facilities).

3.2.1.2 Geo-coded information

In addition to detailed socio-demographic and socioeconomic profiles of Canadians, census files also contain detailed residential information on all respondents and their geographic identifications (e.g., Dissemination Area [DA], Census Subdivisions [CSD], Forward Sortation Areas [FSA] which are defined in detail in the following section).

Also, in order to fulfill data requirement of the current study, geo-coded information for Canadian health regions (except Québec) was required. I obtained this information from the Boundaries and Correspondence with Census Geography files, then linked and merged them to the census data using CSDs as the common identifiers.

3.2.1.3 Discharge Abstract Database (DAD): Hospital records

The DAD collects administrative data on hospitalization events, including information on ACSC-related hospital discharges.[258] Approximately three million hospital discharges are recorded and archived in the DAD files annually. Each hospitalization record in the DAD contains information on the main diagnoses and up to 25 secondary diagnoses, time of admission, and treatment information (i.e., up to 20 intervention codes). The diagnostic and intervention codes are based on International Classification of Disease, 10th Revision Canadian Modification codes (ICD10-CA).[259] Therefore, in the current study, the DAD files are the main source of information to track clinical information on all individuals who responded to the 2006 census long-form. For the purpose of this study, the DAD files for three fiscal years (2006-2007; 2007-2008; and 2008-2009) were pooled together (i.e., from May 16, 2006 to March 31, 2009).

3.3 Study sample

This study is a pan-Canadian study using a nationally representative, cross-sectional sample of individual's information, linked to health administrative databases. The study sample was comprised of 2006 long-form census respondents under the age of 75 (excluding Québec residents) whose information was linked prospectively to the three years subsequent data of the DAD files (May 16, 2006 to March 31, 2009). Hospitalizations and death occurring after the age of 75 are not typically considered preventable.[260] Therefore, those people over the age of 75 were excluded from the study. The census-DAD linkage had been already conducted by Statistics Canada and was based on common identifiers from both files (i.e., date of birth, sex, and postal code) and was accomplished using the hierarchical deterministic exact method.[261] According to a validation study by Statistics Canada, the linked data file, with weighted coverage rates exceeding 80%, is representative of the population of all provinces and territories, excluding Québec.[254]

3.3.1 Variable definitions

3.3.1.1 The outcome: ACSC hospitalization

Participants in the 2006 census were followed prospectively over a three-year follow-up interval (May 16, 2006 to March 31, 2009) in the DAD records. The outcome was operationalized as a binary variable defined as whether an individual had at least one ACSC hospitalization event for any of the seven types of ACSC, as defined by the CIHI.[58] These conditions included COPD, asthma, diabetes, grand mal status and other epileptic convulsions, heart failure and pulmonary edema, hypertension, and angina (excluding cases with cardiac procedures). The outcome variable, ACSC hospitalization, was ascertained from the matched first three digits of each most responsible ICD10-CA diagnosis in DAD files (see Appendix A).

To model the outcome, the current study analyzed the odds of ACSC hospitalization. Therefore, to address the issue of temporality for odds calculation, only ACSC hospitalization events that occurred after the census day, May 16, 2006, were used for the analysis and the occurrence of hospitalization events was investigated over the following three years (starting from the census day).

Inclusion and exclusion criteria

Following CIHI’s inclusions criteria for ACSC hospitalization analysis, patients above 74 were excluded from the study sample.[18]

It was not the aim of this study to analyze hospital readmissions and the modeling structure was not sensitive to the order of the hospitalization events in the case of duplicated events. However, to insure the proper age-exclusion criteria was met, the exclusion procedure was applied for each individual DAD file over the three-years of follow up (2006-2007; 2007-2008; and 2008-2009).

Additionally, newborns, stillbirths, and cadaveric donors, as well as those discharged as deceased, were excluded as ACSC hospitalization events based on the definition from the CIHI.[8,18,262]

In total, out of 4,652,700 people whose long format 2006 census were linked to DAD files, 7.5% of individuals did not meet the inclusion criteria.

3.3.2 Geography boundaries that encompass ACSC hospitalization events

One of the main objectives of the current study was to evaluate the contributions from ecological dimensions of "communities" that lead to observed geographic heterogeneity in the odds of ACSC hospitalization. However, there is no commonly accepted definition of a community. Theoretically, community is defined as a group of people living within a common geographic location who share common social connections, perspectives, settings, or circumstances.[230,263–268] However in practice, researchers have not yet come to a consensus on the standard measure of community within which primary healthcare services are delivered, hospitalization events take place, and characteristics impose effects on residents.[266] Therefore, one of the solutions to address this issue is to adopt multiple definitions to use in sensitivity analyses. In the context of the current study, choosing a very small geographic unit to define community would limit the number of respondents in the sample from each community. On the other hand, selecting too large of geographic units may mask potential heterogeneity within these units and would lead to loss of pertinent information.

To minimize the abovementioned problems, the current study has considered *Census Subdivision (CSDs*) and *Forward Sortation Area* (FSAs) as the target residential community definitions. CSDs were employed as the primary community-level to study the odds of ACSC hospitalizations, while FSAs were used to run sensitivity analysis and to study the impact of changing geographic boundaries in the assessment of results.

a) Census Subdivision (CSD): CSDs are generally municipalities (as determined by provincial/territorial legislation such as city, town, village, etc.) or equivalent municipalities (such as Indian reserves, Indian settlements and unorganized territories), which are classified into 55 types.[269] Each CSD consists of a number of Dissemination Areas (DA), which are the smallest standard census geographic units.[270] At the same time, all CSDs are hierarchically nested within provinces.

b) Forward Sortation Area (FSA): FSAs are geographic units defined by the Canada Post Corporation and are designed to help sort mail for efficient delivery. FSAs encompass geographic areas that share the same first three postal code characters. The first character of the FSA code is a letter that identifies the province or territory. The second character identifies urban/rural, and the third character, when combined with the first two characters, identifies a more precise geographic area. FSAs vary in size from a large sparsely populated rural region to the entire of a medium-sized city or a section of a major metropolitan area.[271]

c) Health regions: Health regions are geographic boundaries defined by provincial ministries of health and are the broadest units of geography within this study.

3.3.2.1 Hierarchy of geographic boundaries and nesting process

In order to model ACSC hospitalization events in a hierarchical nested context, the lower level geography units (such as individuals, CSD, or FSAs) must be nested within higher-level units (i.e., health regions). In the current study, health regions are the broadest geography units that by definition, completely respect provincial boundaries.

In most provinces, health region boundaries are aligned with boundaries of the smallest census geographic units, such as DAs or CSDs.[272] Thus, CSDs can be considered nested within health regions in most part of Canada. However, there are exceptions for number of cases where a single census geography unit can be located in more than one health region. That is, there are cases in which CSDs can straddle health regions.[273] To resolve the problem of misalignment between boundaries of CSDs and health regions, population counts were cross-tabulated for each CSD and health region pair and, in cases where a single CSD was located in more than one heath region, all individuals from the less populated CSD were reassigned to the more populated CSD-health region unit pairs.

There is no clear hierarchical relationship between CSD and FSAs except the fact that similar to CSDs, FSAs are also completely nested geographic units within provinces. However, FSA have highly irregular and fragmented boundary lines, with two spatially separated areas often sharing same FSA code.[274]

There were 5,418 CSD and 1,625 FSAs in Canada at the time of the 2006 census.[275] Therefore, in general CSDs could be considered as finer geographic scales compared with FSAs for most of the regions. However, for some metropolitan areas such as Toronto, the city is defined by a CSD identification code while comprised with several FSAs.[274]

All FSAs are naturally nested within provincial boundaries, but not all FSAs are nested in health region geographic boundaries.[276] Therefore, similar strategies as CSD and health region pairs were used to ensure that each FSA is nested only within a single health region. In the end, each CSD and FSA was assigned to a single health region.

The nesting process did not exclude any observation from the study. However, to ensure the study had sufficient statistical power, geographic units with less than 30 observations were excluded from the study.

3.3.3 Individual-level characteristics

For the sake of the current research, I assumed that individual_ and community_ level characteristics are fixed (time invariant) information over 3 years of the follow-up (2006-2009). Two sets of individual-level predictors were included in the statistical model: demographic characteristics and socio-economic characteristics. Demographic characteristics included the following: sex, age, visible minority status, marital status, and immigration status. Sex was defined as a binary variable, and age was categorized into four groups: 1) <20 years; 2) 20 to 39 years; 3) 40 to 59 years; and 4) 60 to 74 years. Visible minority status was dichotomized as white and non-white. Marital status constructed as binomial: 1) legally married; 2) not legally married. Immigration status was assessed based on the place of birth and was operationalized as a categorical variable with two levels: 1) non-permanent residents as well as immigrants; 2) non-immigrants (Canadian citizens by birth).

For the socioeconomic variables, two different constructs of individual-level SES were included: education and individual-level total income.[277] Education was categorized into three groups: 1) less than high school; 2) high school and some college education; and 3) bachelor or higher university degrees. Person-level income was categorized based on low (< $30,000), middle ($30,000-$60,000), and high-level income (>$60,000), defined according to the low-income cut off for 2005.[278]

3.3.4 Community-level characteristics

Area-level information was assigned according to the location of the census participant’s residency area. At the community level (i.e., CSD and FSA), median household income was used as a neighbourhood-level indicator of SES.[154,279–282] Also the binary variables of urban-rural type of CSD or FSA was included in the model.

The community-level income information was a separate source of information provided by Statistics Canada. Therefore, they were matched and merged to the census files using CSDs or FSAs as common identifiers.[288,289] Each CSD or FSA income variable was categorized as a binary variable: 1) low income communities (< $30,000), and 2) non-low income (>$30,000).

3.3.5 Missing data

None of study variables had missing information.

3.4 Statistical analysis

3.4.1 Descriptive statistics

The characteristics of the study cohort were summarized using frequencies and proportions, both for the total sample and by the value of the outcome variable (i.e., ACSC hospitalization).

3.4.2 Multi-level analysis

The 2006 census respondents are clustered within communities (level 2), operationalized as CSDs, which were themselves clustered within health regions (level 3). Due to the nested structure of the data and the binary nature of the outcome variable, a hierarchical 3-level logistic regression model was used to estimate the odds of ACSC hospitalization in terms of individual, community-level (CSD), and health region attributes.[285] Standard statistical techniques were applied to quantify the magnitude and significance of geographic variation in odds of ACSC hospitalization, as well as to investigate whether an individual's odds of ACSC hospitalization was dependent on the area of residence (e.g., intraclass correlation [ICC], median odds ratio [MOR], the 80% interval odds ratio [IOR-80], and the sorting out index). All analyses were performed in SAS 9.4 (SAS Institute Inc., Cary, NC).[286]

A number of multi-level models with random intercept were constructed using the GLIMMIX procedure in SAS 9.4, which allowed the odds of ACSC hospitalization to vary simultaneously across cluster units (CSDs and health regions). Two separate options were considered for the community-level (level 2) cluster variable: CSD or FSA. Thus, two versions of each multi-level model pertaining to CSDs was implemented. To address the objectives of the current study, sequentially developed statistical models were constructed as follows:

a) Model 1: Fully unconditional (null) model

b) Model 2: Model 1 + individual-level predictors

c) Model 3: Model 2 + community-level predictors

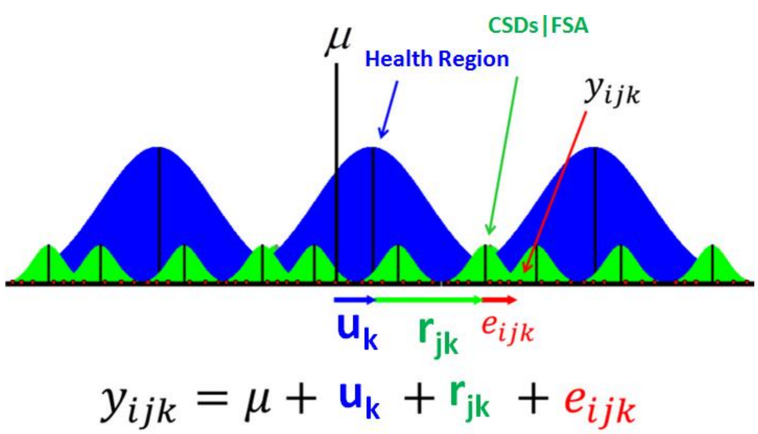
d) Model 3a: Model 3 – individual-level income

3.4.2.1 Analyses for objective 1: Fully unconditional model (Model 1)

To assess hypotheses H-1A and H-1B (see the objectives section), an unconditional (unadjusted or null) 3-level model was constructed which only included random intercepts for across-community, as well as across-health region variations (Model 1). Therefore, no predictor variables were specified at any level of analysis.

The null model aimed to estimate and decompose the total variance of unadjusted log odds of ACSC hospitalization into three postulated sources of variation: 1) individual (level 1), community (level 2), and health region (level 3). Therefore, it would allow detecting any general contextual effect at community and health region levels.[287] Figure 3.1 schematically illustrates the specification of the model which takes into account the dependency between observations from the same cluster-level (i.e., community or health region).

Mathematical expression and details for all constructed models in the current study is presented in Appendix B.



3-1 Schematic relationship of three-level hierarchical modeling

3.4.2.1.1 Measures of area-level variance and clustering: intra-class coefficient (ICC)

To address the first objective of this study, various statistics were constructed from Model 1. At first intra-class coefficient [ICC], which is the degree of correlation between observations within each cluster was explored.[288–291]

As is described in Appendix B, for the binary outcome of odds of ACSC hospitalization, the ICC is calculated as follows

$$\text{ICC}(\rho) = \frac{V_A}{(V_A+3.29)} \quad (3.1)$$

In which V_{A} represents the residual variance at community (CSD) or health region-level and individual-level variance equals to $\frac{\pi^2}{3}$ (that is, 3.29). Therefore, clustering measures for Model 1 are calculated as follows:

1) $\rho(\text{intra-health region}) = cor\ (y_{ijk}\ ,\ y_{i'j'k}) = \tau_H^2/(\tau_C^2+\tau_H^2+3.29)$ (3.2)

This statistic estimates the proportion of variability in the outcome that stems from health region effects: expresses the correlation in the odds of ACSC hospitalization between two individuals taken randomly from the same health region.

2) $\rho(\text{intra-health region, intra-community}) = cor\ (y_{ijk}\ ,\ y_{i'jk}) = (\tau_H^2 + \tau_C^2)/(\tau_C^2+\tau_H^2+3.29)$ (3.3)

This statistic expresses the correlation in the odds of ACSC hospitalization between two individuals taken randomly from same community within the same health region.

3.4.2.2 Individual-level adjusted model (Model 2)

To test the hypothesis H-2A and H-2B, Model 2 was constructed from the null model (Model 1) which assessed the role of predictors at the individual-level (details explained in Appendix B.)

The model assumes a fixed effect coefficient which implies that pattern of association between the logit of ACSC hospitalization event and covariates do not depend on the cluster units such as community

(CSD) or health regions. In other words, it assumes no effect modification by clustering units. Model 2 enables the assessment of the adjusted outcome variance at the community- and health region-level.

3.4.2.2.1 Measures of cluster-level heterogeneities

a) The Median Odds Ratio (MOR)

To have a more intuitive interpretation for community- and health region-level variances, MOR was employed.[292] Proposed for the first time by Larsen et al., it is a measure of residual heterogeneity between clusters.[293] For the current study, MOR conceptualizes the median value of the distribution of randomly selected pairs of odds ratio of ACSC hospitalization for individuals with similar covariates but from different clusters: the high-risk clusters of ACSC hospitalization and the clusters at low-risk. In other words, it identifies the extent to which the individual's risk of being hospitalized for ACSC is determined by residential community, or health region. Therefore, MOR can be used for quantifying contextual phenomena. MOR can directly be compared with the impact of an individual-level covariate (e.g., sex) to see which ones are having a greater impact on the odds of outcome.

It is calculated as follows:

$$MOR = \exp\left[\sqrt{2 \times V_a}\,\right] \times 0.6745 \qquad (3.4)$$

where $V\ a$ is the community- or health region-level variance parameter estimate of each model and 0.6745 is the 75th percentile of the cumulative distribution function of the normal distribution with mean 0 and variance1.While a MOR value of 1 indicates an absence of community- or health region-level difference, a value > 1 denotes stronger cluster-level effects.

Two MOR statistics were defined in the current study:

a) Measure of heterogeneity in the odds of ACSC hospitalization for two individuals across two different high-risk and a low-risk health region:

$$MOR_C \approx \exp\left(0.95 \times \sqrt{\tau_C^2}\right) \qquad (3.5)$$

b) Measure of heterogeneity in the odds of ACSC hospitalization for two individuals across high-risk and low-risk communities (CSD):

$$MOR_H \approx \exp\left(0.95 \times \sqrt{\tau_H^2 + \tau_C^2}\right) \quad (3.6)$$

where τ_C^2 and τ_H^2 are community-level (CSD) and health region-level variances of the random effects respectively.

b) Proportional Change in Variance (PCV)

Proportional Change in Variance (PCV) is a parameter estimation that was used to capture the amount of variation in the odds of ACSC hospitalization (Model 1), which was explained by the included variables in each subsequent model (Model 2, 3) and is calculated as follows: [287]

$$PCV = \left(\frac{(V_a - V_b)}{V_a}\right) \times 100 \quad (3.7)$$

where $V\ a$ is the community- or health region-level variance parameter estimate (e.g., of the empty model) while $V\ b$ denotes the same parameter estimate for a multi-level model including extra predictive covariates.

3.4.2.3 Community-level adjusted model (Model 3)

Model 3 expands on Model 2 and estimates the fixed effect of community-level determinates (e.g., community-level income and urbanicity) while adjusting for random intercepts between communities (level2) and health regions (level3). This model is designed to test hypothesis H-3A and H-3B of the study objectives (see Appendix B for details).

3.4.2.3.1 Measures of cluster-level heterogeneities

a) The 80% Interval Odds Ratio [IOR-80%]

In contrary to individual-level variables, cluster-level effects (in this case, community [CSD] or health region-level effects) only take one value in each cluster. Therefore, to quantify cluster-level effects, it is important to compare patients from different clusters of identical random effect values.[287] However, taking the comparison between two individuals, the probability of ACSC hospitalization differs only with regards to the cluster-level covariate. Once all possible pair of odds of ACSC hospitalization pertained to individual's cluster-level effects are calculated, the median of such a distribution and the interval around the median that comprises 80% of the OR values is referred to as the IOR-80%. The IOR-80% incorporates both the fixed cluster-level risk factor effect and the unexplained between-cluster heterogeneity in an interval calculated as follows:

$$IOR_{lower} = \exp\left[\beta + \sqrt{2 \times V_A} \times (-1.2816)\right] \approx \exp(\beta - 1.81\sqrt{V_A}) \quad (3.8)$$

$$IOR_{upper} = \exp\left[\beta + \sqrt{2 \times V_A} \times (1.2816)\right] \approx \exp(\beta + 1.81\sqrt{V_A}) \quad (3.9)$$

The coefficient β is the regression coefficient for the cluster-level variable (e.g., community-level income), V_A is the cluster-level (i.e., community or health region) variance, and values –1.2816 and +1.2816 are the 10th and 90th percentiles of the normal distribution with mean 0 and variance1. The interval IOR-80% is narrow in the case of small residual variation between clusters, and wide if the variation between these clusters is large. If the interval span over the value of 1, it is an indication that the effect of the cluster-level risk factor is not strong compared with the remaining residual cluster-level heterogeneity.

b) The Proportion of Opposed Odds Ratios (POOR index)

As proposed by Merlo, another informative alternative to IOR-80% index is the “sorting out index” or the Proportion of Opposed Odds Ratios (POOR) index.[294]

Basically, similar to the IOR-80% procedure, the POOR procedure is defined for a specific cluster-level covariate within the model. It considers all odds ratios comparing a random cluster exposed to the cluster-level covariate and a random cluster not exposed to that. The proportion of all opposite direction effects to the overall odds ratios is calculated from the constructed exposed-non-exposed pairs of observation.

The POOR index can take any value from 0 to 50%. While the POOR of 0% indicates that all pair-wise odds ratio comparisons are in the same direction as the overall cluster-specific odds ratio, a POOR of 50% implies that half of the pair-wise comparisons are in the opposite direction of the overall odds ratio. Therefore, larger values for the POOR signal a higher heterogeneous association between the outcome and the cluster-level covariate.

The POOR is calculated as follows:

$$POOR = \Phi(-\left|\frac{\alpha}{\sqrt{2\hat{\tau}^2}}\right|) \quad (3.10)$$

α represents the regression coefficient estimated for the specific cluster-level covariate, while $\hat{\tau}^2$ denotes the variance of the distribution of general cluster random effects.

3.4.3 Correction for possible multicollinearity in Model 3 (Model 3a)

Three important but potentially related SES variables were included within Model 3: a) individual-level education, b) individual-level income, and c) CSD-level median household income. A correlation analysis was employed to assess the degree of correlation between these three variables and to determine which should be excluded or maintained within the model. After removal of the candidate variable, the full model was constructed to evaluate the effects of the covariate removal on the statistical analysis from the previous model (Model 3a).

3.4.4 Logistic regression model (Model 3b)

To be able to compare results from multilevel models with the results from commonly used non-multilevel models, logistic regression analysis was also conducted including the entire list of covariates (i.e., individual + CSD-level) that were controlled for in Model 3. Odds ratios as well as 95% confidence intervals (95% CI) of all fixed-effects were assessed along with their p-values.

4 Chapter 4

4.1 Results

In total, 4,652,700 people who responded to the 2006 census were linked to hospital administrations discharge database (DAD files) by Statistics Canada. Of those, 93% of individuals meet the inclusion criteria. Therefore, the final sample consisted of 4305400 individuals under 74 years old, nested within 3080 CSDs and 80 health regions across all provinces of Canada (except Québec). During the three years of follow up, I have identified 29130 people with at least one ACSC hospitalization event, which comprised less than one percent of study participants.

All presented frequency distributions are rounded to the base of five and all coefficients are obtained based on weighted samples in accordance with Statistics Canada disclosure rules.

4.2 Descriptive analysis

Descriptive statistics of study population for whom residential areas, CSDs, were nested in health regions are presented in Table 4.1. I have also included similar descriptive statistics computed for the nested FSA-health region database (see Appendix C in Table C.1).

Majority of the study sample was within 40 to 59 years age bracket, with male and females having almost equal representation. Among the study sample, 55% were not married; 45% had high school education with no university degree attainment; 65% earned an individual income in the lowest bracket (< $30,000); 75% were non-immigrant Canadians; and 75% were not visibly minorities. Community-level variables included the CSD-level median household income and proportion of individuals living in urban or rural areas. According to the typical CSD-level characteristics, 80% of the sample lived in urban communities and 80% lived in areas with CSD-level median household income of below $30,000 (low income communities).

Table 4-1 Descriptive characteristics of the CSD-health region study population

Variables	Total population (%)	ACSC hospitalization event (%)	
		Yes	No
Sex			
Women	50	45	50
Men	50	55	50
Age			
< 20 years	25	15	25
20 to 39 years	30	10	30
40 to 59 years	35	35	15
60 to 74 years	15	45	15
Marital status			
Legally married	45	50	45
Legally not married	55	50	55
Educational attainment			
Less than high school	40	50	40
High school & no bachelor	45	40	45
Bachelor and higher	15	5	15
Immigration status			
Immigrants	25	15	25
Non-immigrant	75	85	75
Ethnicity			

Non-visible minority	75	85	75
Visible minority	25	15	25
Individual-level Income			
< $30,000	65	70	65
$30,000- $60,000	30	25	30
>=$60,000	5	0	5
Community-level variables			
Level of urbanization			
Urban	80	70	80
Rural	20	30	20
Community-Level median income			
< $30,000	80	85	80
> $30,000	20	15	20

4.3 Characteristics of patients with an ACSC hospitalization in unadjusted analysis

Table 4.1 displays frequency distributions of study variables among patients who had an ACSC hospitalization. During the follow up, the prevalence of ACSC hospitalization events among the sample was less than one percent. Respondents to 2006 census who had at least one ACSC hospitalization were 55% male; aged between 60 to 74 years (45%); did not attain a high school degree (50%); were non-visibly minority (white) (85%); with same prevalence of married and not married status (50%); were non-immigrants (85%); lived mostly in urban regions (70%); had an individual-level income of less than $30,000 per year (70%); and lived in CSDs with a median household income of below $30,000 (85%).

4.4 Multilevel analysis results

Tables 4.2 to 4.5 present the results of the multilevel models related to the odds of ACSC hospitalization. Results were used to address the three research objectives.

4.4.1 Objective 1: Justification for multilevel analysis application (Null Model estimates)

Preliminary analyses to assess the relevance of a three-level model was conducted at first step. The null model accounted for the non-independence of individuals living in the same area. Results could help testing the hypothesis *H_1a and H_1b* of general partitioning of variance among three different levels of analysis: individuals, CSDs, and health regions. To do so, we assessed a) the unadjusted variability in odds of ACSC hospitalization across CSDs within the same health region, and b) across health regions.

Table 4.2 presents the residual variances of the outcome across CSD and health regions ($\sigma^2_{CSD} = 0.56, \sigma^2_{HR} = 0.07$). The findings show evidence of clustering effects (un-modeled contextual effects) were observed in the log odds of ACSC hospitalization within CSDs and health regions. The ICC suggests that the general CSD-level contextual effects account for over 16% of the variability in the residual log odds of ACSC hospitalization. In comparison, approximately 1.7% of the remaining variability in the residual log odds was accounted for by general health region characteristics, leaving up to 82% of the remaining variability to be related to individual-level variance. Hence, the results provided strong evidence of regional effects and a justification to apply a three-level regression analysis for the remaining analyses.

Similarly, MOR was calculated for the null model as a measure of area-level heterogeneity in the odds of ACSC hospitalization across geographic regions. At the CSD-level, MOR was calculated as 2.12, while the same measure for health region general effects was calculated as 1.3. Both MOR values were higher than 1 which indicates the presence of substantial CSD and modest health region heterogeneity in the odds of ACSC hospitalization ($MOR_{CSD} = 2.12 > MOR_{HR} = 1.3$).

Table 4-2 Estimated variance components, ICC, MOR, and PCV of constructed multilevel model for CSD-Health region database

	Model 1*	Model 2**	Model 3***	Model 3a****
Covariance Parameter Estimates (Random intercept effects)				
Variance (SE)				
Level 3				
HR intercept	0.07 (0.015)	0.042 (0.010)	0.044 (0.010)	0.043 (0.01)
Level 2				
CSD intercept	0.56 (0.021)	0.52 (0.020)	0.52 (0.020)	0.53 (0.020)
Level 1				
Individual effects	3.29	3.29	3.29	3.29
ICC				
HR effect	1.70	1.10	1.13	1.12
CSD effect	16.02	14.58	14.62	14.72
MOR				
MOR_{HR}	1.3	1.22	1.22	1.22
MOR_{CSD}	2.12	2.04	2.04	2.05
PCV(%)				
HR	REF	36.00	-4.00	0.10
CSD	REF	10.50	-0.31	0.23
Total PCV effect†				
HR	34.00			34.20
CSD	10.22			9.50
* Null model; ** Model adjusted with compositional risk factors; *** Model adjusted for both compositional and contextual risk factors; **** Model adjusted for both compositional and contextual risk factors, excluding individual-level income; †Model 3 compared to Null model				

4.4.2 Objective 2: Compositional effects (Model 2 estimates)

In Model 2, the conditional odds ratio of ACSC hospitalization was adjusted for specific individual-level characteristics. The model aimed to test *H-2A and H-2B* of the second objective. As shown in Table 4.3, all included individual-level risk factors were significantly associated with the odds of the outcome ($p < 0.0001$). Compared with females, males were 1.44 time more likely to be hospitalized for ACSC (95 % CI: 1.42-1.45). Compared to the youngest age group (< 20 years), there was an almost fourteen-fold increased odds of having ACSC hospitalization events for individuals over the age of 60 (95 % CI: 14.0-14.6). Legally married individuals had lower odds of having ACSC hospitalization compared to not legally married counterparts (OR= 0.74,95 % CI: 0.73-0.75). Compared to individuals with no high school degree, university educated people were less likely to encounter ACSC hospitalization events (OR= 0.41, 95 % CI: 0.4-0.42). Immigrants had lower odds of having ACSC hospitalization compared to those born in Canadians (OR= 0.65, 95 % CI: 0.64-0.66). Visible minorities were 1.08 (95 % CI: 1.06-1.1) more likely to experience ACSC hospitalization compared to their counterparts, and compared with individuals with income below or equal to $30,000, those in higher income brackets had lower odds of ACSC hospitalization events (linear relation was detected: $OR_{\$30,000-\ \$60,000} = 0.59$, $OR_{>=\$60,000} = 0.43$).

As presented in Table 4.3, the inclusion of specific compositional effects explained the proportion of the originally observed variability across CSD [PCV_{CSD}= 10.5 %], relative to the null model, whereas it was able to explain the variability in the outcome between health regions by greater amount [PCV_{HR}=34%].

After adjusting for individual-level characteristics, level 2 variance across CSDs remained statistically significant and accounted for 14.58% of the variability in the outcome variable (ICC_{CSD} = 14.58%, see Table 4.2). Simultaneously, the level 3 variance across health regions accounted for only 1.1% of the variability in odds of ACSC hospitalization (ICC_{HR} =1.10%, see Table 4.2).

Having the null model as reference, the MOR for CSDs and health regions was reduced to 2.04 and 1.22, respectively (see Table 4.2). However, considerable heterogeneity still existed between CSD and health region measures, with MOR values remaining above 1. Also, adjusting for some compositional effects did not change the ranking of the relevance among CSD and HR effects based on MOR values ($MOR_{CSD} > MOR_{HR}$).

Table 4-3 Estimated regression coefficients (fixed effects) for the multilevel and logistic regression models

	Model 2*	Model 3**	Model 3a***	Model 3b****
Individual-level fixed effects: Odds Ratio (95% Confidence Limits)				
Sex				
Men	1.44 (1.42-1.45)	1.44 (1.42-1.45)	1.29 (1.27-1.30)	1.44 (1.42-1.45)
Women	Ref	Ref	Ref	Ref
Age Categories				
< 20 years	Ref	Ref	Ref	Ref
20 to 39 years	1.16 (1.13-1.20)	1.16 (1.13-1.20)	1.05 (1.03-1.08)	1.22 (1.20-1.25)
40 to 59 years	4.8 (4.7-4.9)	4.8 (4.7-4.9)	3.9 (3.8-4.0)	5.1 (5.0-5.2)
60 to 74 years	14.3 (14.0-14.6)	14.3 (14.0-14.6)	12.6 (12.4-12.9)	15.3 (15.0-15.7)
Marital status				
Legally married	0.74 (0.73-0.75)	0.74 (0.73-0.75)	0.72 (0.71-0.73)	0.75 (0.74-0.76)
Legally not married	Ref	Ref	Ref	Ref
Educational attainment				
Less than high school	Ref	Ref	Ref	Ref
High school only	0.64 (0.63-0.65)	0.64 (0.63-0.65)	0.59 (0.58-0.60)	0.61 (0.61-0.62)
Bachelor and higher	0.41 (0.40-0.42)	0.41 (0.40-0.42)	0.33 (0.32-0.34)	0.37 (0.36-0.38)
Immigration status				
Immigrant	0.65 (0.64-0.66)	0.65 (0.64-0.66)	0.70 (0.66-0.69)	0.54 (0.53-0.55)
Non-immigrant	Ref	Ref	Ref	Ref
Ethnicity				

Non-visibly minority	Ref	Ref	Ref	Ref
Visibly minority	1.08 (1.06-1.10)	1.08 (1.06-1.10)	1.14 (1.12-1.16)	1.07 (1.05-1.08)
Individual-level Income				
< $30,000	Ref	Ref		Ref
$30,000- $60,000	0.59 (0.58-0.60)	0.59 (0.58-0.60)		0.58 (0.57-0.59)
>=$60,000	0.40 (0.41-0.45)	0.43 (0.41-0.45)		0.41 (0.40-0.43)
Community-level fixed effects				
Urbanicity				
Urban		Ref	Ref	Ref
Rural		0.90 (0.87-0.92)	0.90 (0.87-0.92)	1.16
POOR(%)		46.0	46.0	
IOR(L,U)		(0.23-3.50)	(0.23-3.50)	
CSD-level median income				
< $30,000	Ref	Ref	Ref	Ref
$30,000- $60,000		0.83 (0.74-0.93)	0.77 (0.70-0.93)	0.85 (0.83-0.86)
POOR(%)		43.0	40.4	
IOR(L,U)		(0.21-3.23)	(0.20-3.01)	
* Model adjusted with compositional risk factors; ** Model adjusted for both compositional and contextual risk factors; *** Model adjusted for both compositional and contextual risk factors excluding individual-level income; **** Logistic regression model adjusted for all compositional and contextual variables				

4.4.3 Objective 3: Specific CSD-level contextual effects (Model 3)

To accomplish the last objective of the study, I constructed Model 3 from the previous one (Model 2). Model 3 included CSD-level median income as well as the urbanicity of the residential areas. The model estimated the extent to which inclusion of these variables contributes to reducing the variation in odds of ACSC hospitalization.

4.4.3.1 General contextual effects: ICC, MOR

In general, adjusting for the selected compositional and contextual effects in Model 3 increased the relevance of geographic effects compared to the previous model.

The inclusion of specific CSD-level variables, however, did not have a noticeable impact on the variance of the outcome at the CSD-level. However, it increased the variance at the health region-level by 4% ($\sigma^2_{CSD} = 0.52$, $\sigma^2_{HR} = 0.044$, see Table 4.2). Also, the ICC measure at the CSD-level was not changed notably in comparison to the previous model (Model 2), while it increased by 4% for health regions (see Table 4.2). Residual heterogeneities (MOR) in outcome between CSD and health regions increased by less than one percent (see Table 4.2). With reference to the previous model (Model 2), the included variables explained 4% of variability between health regions (PCV_{HR} = -4%), whereas for the CSDs the reduction in variability was less than one percent (see Table 4.3). Overall, the fully adjusted model (Model 3) reduced the between-health region variability by 34%, compared with the null model. This means that 66% of between-health region variability is yet to be explained. However, the same model could explain the between CSD variabilities by just 10.2%, which leaving 90% of between CSD variability unexplained (see Table 4.2).

4.4.3.2 Specific contextual effects: IOR and POOR.

Accounting for CSD-level characteristics in Model 3 supports the findings of Model 2, as it did not change the significance or magnitude of individual-level characteristics. In addition, it suggested a significant association between both CSD-level median income and urbanicity with the odds of ACSC hospitalization.

In Model 3, over and above individuals' characteristics, living in a high-income community (average income > \$30,000) was significantly associated with odds of ACSC hospitalization. Individuals who live in high-income CSDs had on average lower odds of an ACSC hospitalization (OR= 0.83; see Table 4.3). However, based on the 80%-IOR, comparing individuals with identical characteristics from high and low-level income CSDs, the odds of an ACSC hospitalization was between 0.23 and 3.3 in 80% of such comparisons. It is a wide interval that also includes 1. This implies that effect of this community-level variable is not large in comparison with the unexplained between-CSD variations. Moreover, the percentage of ORs of opposite direction was considerable (POOR = 40.4%).

According to Model 3, living in an urban area was on average, significantly associated with an increased odds of ACSC hospitalization (OR= 0.9, 95% CI: 0.87-0.92). However, the effect had 80%-IOR estimates with a wide interval that also included 1 (0.23, 3.5). Moreover, the high percentage of ORs of opposite direction indicated heterogeneity of the effect of urbanicity (POOR = 46.1%).

4.4.4 Model 3a: Exclusion of individual-level income variable from the analysis

Table 4.4 illustrates results of correlation analysis for all variables included in the study. A moderate correlation was detected between education and individual-level income (Corr: 0.4; $p < 0.0001$; see Table 4.4). To avoid the issue of collinearity between variables, individual-level income was removed from Model 3 and results were investigated to find any possible changes in the estimates generated in Model 3. Table 4.3 summarises the estimates and corresponding changes. According to these results, except for the effect of urbanicity and marital status, the exclusion of individual-level income had a significant confounding effect on the results with more than 5% changes in the magnitude of the effects (Table 4.3). In terms of effect size, removal of individual-level income increased the impact of immigration and visible minority effects by 6% and 4%, respectively. However, the effect size of other variables was decreased, with the largest amount of reduced effects occured for the effect of education, particularly among people with the highest level of education (19%) and for individuals aged 40 to 59 years (17.5%).

Compared to Model 3, exclusion of individual-level income had consequences on CSD and health region general contexual effects. Model 3a could explain a slightly greater proportion of variation between health regions (0.1%) and up to 0.2% for between CSD-level variation compared to Model 3. Finally, MOR measures indicate that removing individual-level income increased between CSD heterogenity, but the amount of change was less than one percent.

Table 4-4 Correlation between included risk factors

	Age	Sex	MS	IS	VM	IE	II	U	CMI
Age	1.00	-0.02	0.53	0.2	-0.14	0.4	0.4	0.01	-0.02
Sex		1.00	-0.004	-0.01	-0.01	-0.04	0.2	-0.01	0.003
MS			1	0.2	-0.1	0.33	0.33	-0.001	0.02
IS				1	0.4	0.2	0.03	0.21	-0.03
VM					1	-0.1	-0.2	-0.004	-0.1
IE						1	0.4	0.2	0.1
II							1	0.1	0.1
U								1	0.1
CMI									1

Definitions: MS: Marital Status; IS: Immigration Status; VM: Visible Minority; IE: Individual_Level Education; II: Individual_Level Income; U: Urbanicity; CMI: CSD_Level Median Income

4.5 Model 3b: Comparison of multilevel analysis with logistic regression

For the purpose of comparison, the likelihood of ACSC hospitalization was estimated using a logistic regression model which included all individual and community-level variables that were used in the multilevel analysis. For most of the covariates, the average effect estimates were very similar or equal to the reported values in the multilevel analysis. However, the findings for two variables were substantially different: the odds associated with ACSC hospitalization for immigration, as well as education (BA and higher) decreased by over 16% and 10% respectively in logistic regression compared to the multilevel modeling ($OR_{Immigration} = 0.54$, $OR_{Education(BA\ and\ Higher)} = 0.37$ see Table 4.3). Also the logistic regression model suggests an opposite direction for urbanicity (OR=1.16). Aside from the coefficient differences, logistic regression yielded underestimated values for corresponding standard deviations as compared with multilevel models (standard errors reduced by 15 folds for CSD_Level income, and 4 folds for urbanicity and for most of the effect decreased by close to two times).

4.6 Effect of geographic boundaries

To assess the robustness of findings to the choice of geographic boundaries, a second dataset was produced in which CSDs were replaced by FSAs as community-level units. A separate set of multilevel analyses were performed and results from the full model are presented in Table C.2 (see Appendix C). Comparing the full model for both the CSD and FSA databases (Model 3), no substantial differnces were observed for compositional or specific contextual effects (including urbanicity as well as FSA-level median income). However, once comparing the general random effects of FSAs against CSDs, substantial differences were detected (see Table C.3, Appendix C). While health region effects exhibited differences across two databases (${\sigma^2}_{HR}^{CSD} = 0.044$, ${\sigma^2}_{HR}^{FSA} = 0.07$), variability in the odds of ACSC hospitalization was substantially smaller across FSAs compared to CSDs ($\sigma_{CSD}^2 = 0.6, \sigma_{FSA}^2 = 0.12$). Degree of clustering was noticably lower within FSAs as compared with CSDs (ICC_{CSD}=14.62; ICC_{FSA}=5.5). Moreover, a higher proportion of variability across FSAs were explained by controlling for included compositional and contexual effects than the variability across CSDs (PCV_{CSD}:10% PCV_{FSA}=49.4%). Likewise, degree of heterogeneity of effects was considerably higher across high and low-risk CSDs compared to high and low-risk FSAs (MOR_{CSD} =2.04, MOR_{FSA} =1.5).

Chapter 5

5 Discussion

This study used novel linkages of census data with hospitalization administrative data (DAD files). To the best of my knowledge, this is the first Canadian study to simultaneously report on three-levels of variation (individual, CSD, and health region) on an individual's odds of ACSC hospitalization.

The primary aim of this study was to investigate and quantify the variation in odds of ACSC hospitalization that is attributable to the CSDs where people reside and health regions within which they receive primary and/or acute healthcare services across Canada (excluding Québec).

In this chapter, I provide an overview of findings in Section 5.1 to 5.6, and strengths and limitations are addressed in Section 5.7. Finally, conclusions drawn from the study are summarized in Section 5.8.

5.1 Geographic variation in the odds of ACSC hospitalization

Canadian studies, mostly using an ecological design, have established that geographic variation exist in the rate of ACSC hospitalization.[9,58] However, there was a need to study the breakdown of such geographic variations into the accountable compositional or contextual effects of these geographic variations.

In the current study, results from three subsequent multilevel models suggest that, after controlling for potential compositional (i.e. age, sex, visible minority, marital status, immigration status, individual-level income, and educational attainment) and contextual fixed effects (CSD-level median income and urbanicity), significant systematic variation remained in the odds of ACSC hospitalization between CSDs, as well as health regions.

In the current study, general contextual effects of place were hypothesized to stem from two sources:1) CSDs as municipal boundaries of residences with social influences on the health outcomes of patients, and 2) from health regions, which provide primary or acute healthcare services for the population.

Therefore, the model results were assessed from two different perspectives: 1) whether there is similarity or clustering in the residual outcome of people sharing the same area of living (CSDs) exists, or of people sharing the same health regions for receiving primary or acute care services; 2) quantifying the heterogeneity in the outcome of two identical people living within high- or low-risk geographic units (CSDs or health region) to one another (MOR_{CSD}, MOR_{HR}). To address these questions, variances at both levels were assessed. According to my study results, the adjusted variance in the outcome was greater at CSDs compared to health regions ($\sigma_{CSD}^2 = 0.52$, $\sigma_{HR}^2 = 0.044$). CSDs as smaller geographic units, showed higher degree of clustering than health regions (ICC_{CSD}=14.62, ICC_{HR}=1.13). That means, people who share the same CSDs will have more similarity in their odds of ACSC hospitalization compared to those who share the same health regions ($ICC_{CSD} > ICC_{HR}$).

Also, for people with the exact same individual-level and community-level characteristics (modeled or un-modeled), changing their place of residence (CSD) from higher outcome risk to the lower risk CSDs, would result in stronger protective effect compared with changing a high risk to a low-risk health region ($MOR_{CSD} = 2.04 > MOR_{HR} = 1.22$). That means living in some geographic areas (i.e., communities and health regions) for the same individual will lead to a higher odds of hospital admission for ACSC compared to other communities.

The findings suggest that, the variation in the magnitude of the odds of the outcome between CSDs and health regions was not entirely attributable to included compositional and contextual covariates. In fact, these variables only explained a modest proportion of systematic variability between CSDs (PCV_{CSD}= 10.22 %) and comparatively account for a larger proportion of variations across health regions (PCV_{HR}= 34%). The remaining measured variation (close to 98%) in the outcome was most likely due to unmeasured factors, which were not accounted for in the current. More importantly, these hidden risk factors of ACSC hospitalization, mostly at CSD level, affect disadvantaged, high-risk individuals more than affluent patients. On the other hand, changing health regions from a high-risk to low-risk one, did not appear to have considerable protective influence for high-risk patients except for urban residents, disadvantaged communities (below $ 30,000 CD-level income), individuals younger than 20 years age, and visible minority individuals (see discussion at 5.3.4).

These findings confirm my hypothesis that an individual's odds of hospital admission for ACSC is not the same across Canada. This implies that where people live matters significantly for how likely they are to end up in hospital as the result of ACSC.

Prior Canadian studies have investigated the odds of ACSC hospitalizations across,[8–10,17,24,60,61,63,64,160] or within health regions[36,63–66,102,103] However, despite including neighbourhood factors (e.g., urbanicity), studies did not quantify the general contextual effects of health regions as geographic entities. Even for studies that report significant variation in ACSC hospitalization events, it is not clear whether these variations are due to compositional or contextual effects of neighborhoods (e.g., health regions).

Few Canadian studies have accounted for the effect of place and geography through a broader lens (e.g., two-level mixed modeling framework).[295,296] Omariba et al.,[295] found modest but significant contextual effects from census tracts (CTs), on the risk of hospitalization for patients with CVD who lived in Ontario between 2006 and 2008. Also, Vanasse et al.,[296] used multilevel analysis to evaluate the association between neighborhood (DAs) variations in odds of CVD hospitalization for patients with diabetes living in Montreal in 2007.

To the best of my knowledge, the current study is the first to quantify geographic differences in the odds of ACSC hospitalization, beyond urban-rural effects, for a nationally representative sample of Canadians using two different nested geographic units with different social and political influences. Although multilevel studies mostly tend to account for geographically shared characteristics as nuisance effects, the current study put a stronger emphasis on the importance of such commonly shared risk factors for ACSC patients.

5.2 Effect of individual-level characteristics on ACSC hospitalization

The current study suggests that regardless of geographic location (i.e., where people live, or the health region in which they receive primary or acute care services), Canadians were at higher odds of ACSC hospitalization when they were over 60 years of age, male, visible minority, non-immigrant, not legally married, had low educational attainment (no high school degree), and had a low household income (< $30,000).

These findings are consistent with previous Canadian literature in terms of the significance and direction of the association between the included compositional factors and the odds of ACSC hospitalization.[8,9,24,103,110,155,166,297]

Also, as recent Canadian publications have emphasized, there is an inverse association between the odds of ACSC hospitalization for communities with a higher density of immigrants.[14,18] Upon measuring immigrant status at the individual level, the results of current study also showed that immigrants on average had significantly lower odds of ACSC hospitalization compared to their Canadian counterparts. Immigrant status in the current study was defined as a combined variable that captured two groups: 1) landed permanent immigrants prior to May 16, 2006 as well as non-permanent residents at the time of the census day. Non-immigrants were considered Canadian citizens by birth. It should be noted that in my study, I cannot comment about the duration of residence in Canada. However, there are reports that the healthy effect of immigrant effect declines with longer duration of residence.[298]

Based on the findings, the included compositional effects were more successful in explaining between health region variance as opposed to between CSD variances.

The results were tested with and without the presence of individual-level income, which was assumed to have high collinearity with educational attainment. Despite the confounding impact on the effect sizes, the exclusion of individual-level income did not change the significance or direction of any covariate.

5.3 Fixed effects of community-level factors on ACSC hospitalization

5.3.1 CSD-level income

The odds of hospitalization for ACSC patients has been reported to be sensitive to community-level SES (i.e., income, education, employment, etc.) attributes. Aligned with other Canadian studies,[9,103,230] the current study found community-level income (i.e., CSD-level median income) to be a significant driver of an individual's odds of ACSC hospitalization across Canada.

Living in an area with a low-CSD-level median income (< $30,000) on average increased the odds of ACSC hospitalization events for individuals with other identical characteristics (modeled or un-modeled). This variable remained significant and positively associated with odds of ACSC hospitalization, both with and without the presence of individual-level income within the model.

However, I also found that, despite the significance of this risk factor, it did not explain much of the variance in ACSC hospitalization across CSDs.

5.3.2 Urbanicity

Of geographic effects, urbanicity is one of the most studied variables.[8,110,297] Findings from the current study suggest that, adjusting for all included risk factors at both individual and CSD-levels, people who were living in a rural area in 2006 showed lower odds of having ACSC hospitalization events as compared to their urban counterparts living within the same CSD and health region. I found the direction of the effect to be the same in all attempted fully adjusted multilevel models (Model 3 and 3a). Despite the similarities between the currents study's fixed effects and previous studies, the average conditional urbanicity effect contradicted some of Canadian studies [24,230] as it suggests significant lower odds of ACSC hospitalization for an average rural individual (a female, below 20, with no educational attainment, not married, with income below $30,000, of no visible minority, born Canadian, living in an disadvantage CSD community) compared to an urban counterpart. Several aspects of this discrepancy are discussed in the following:

Most of studies have used logistic regression to estimate odds of ACSC hospitalization.[24,230] On the statistical ground, logistic regression operates based on population estimates or marginal effects, while the multilevel analysis estimates log odds ratios conditional on the cluster or random effects (i.e. CSDs, FSAs, and Health regions). Once I ignored the clustering or small-scale effects, running the logistic regression analysis (Model 3b); I found the average rural residents to have significantly higher odd of ACSC hospitalizations compared to urban residents. This conclusion agrees well with most of Canadian studies.

For an individual living within a community cluster, four possible interpretations can be drawn from multilevel analysis results: 1) the individual living in rural area was healthier, 2) the individual was not healthier, but had better access to primary healthcare and better disease management if low odds of ACSC hospitalization is an indicator of efficient primary healthcare services, 3) counterpart individual with same characteristics living in urban area was hospitalized more frequently for the ACSC issue compared to the rural resident living within the same CSD, FSA and health region, or 4) the sample is not a true representation of the ACSC hospitalization events in rural areas. To better differentiate these possibilities, different aspects should be taken into account

Urbanicity is a controversial topic in relation to the health of Canadians based on their burden of disease (specifically chronic diseases), their access to primary and acute care services, and in particular their rate of hospitalization for ACSC.[113,242] The literature consistently reports that rural areas in Canada have disparate access to primary healthcare and people are utilizing emergency departments as a replacement for a lack of effective access to primary healthcare centers.[111,243,247,248,300,301] There are Canadian studies that report the rate [9,110] or risk of ACSC hospitalization to be higher for rural residents[24,230] whereas some studies with pan-Canadian design have found no significant difference between urban and rural areas.[8]

Of prior studies that have reported higher risk or rate for rural patients, mostly they have been focused on certain geographic areas (such as one or limited number of city or provinces)[230,299] or certain ACSC diseases (e.g hypertension)[24] while the current study have considered the aggregated set of ACSC diseases across all Canada (except Québec).

Another recent pan-Canadian study reported that living in urban areas had a protective effect against risk of ACSC hospitalization, which was defined as a binary indicator of having any of seven ACSC.[298] However, once they conducted separate analysis for each ACSC, urbanicity did not appear to be significant for all of conditions (e.g., epilepsy, COPD, and asthma). This study had a comparable population to the current study because they also used the 2006 Canadian census and followed ACSC hospitalization events over the three-year period of 2006-2009. However, our studies differed in that, 1) they did not include younger ages (below 18 years old), and 2) they did not perform multilevel analysis.

It should be taken into account that, this was the first time the effect of urbanicity was analyzed within a multilevel framework at two geographic levels (i.e., CSD and health region). Therefore, the results of this study need to be validated or compared with a structurally similar study within Canadian context.

To have a meaningful explanation for the effect of urbanicity, statistical aspects beyond fixed effects of ACSC hospitalization are required to be considered (e.g. heterogeneity of effects). Also, I argue that, there is interplay between several multidirectional factors such as: the role of distance and hospital characteristics, the consequences of global definition for “rural” areas, and demographic profile characteristics of rural residents across Canada which are discussed in more detail.

5.4 Heterogeneity in odds of ACSC hospitalization across rural-urban areas

5.4.1 Joint interpretation of contextual effects within multilevel context

Despite the significant average effect of urbanicity and CSD-level income on the odds of ACSC hospitalization, I found high heterogeneity across the urban-rural continuum and low-high CSD-level income groups. In other words, considerable opposite effects were observed, compared to the overall odds ratio for both variables. This finding aligns with prior research that suggests not all rural areas across Canada experience the same level of adverse health outcome in comparison to urban areas.[302] This suggests that the marginal odds ratios of ACSC hospitalization could hide the strong heterogeneity of urbanicity within a commonly used logistic regression model and emphasizes the importance of using multilevel analysis. Inclusion of urbanicity and CSD-level income did not mitigate the variability in the variance of ACSC hospitalization between CSDs or health regions. In other words, there should be other more influential contextual or compositional effects that can account for the area-level influence on the odds of ACSC hospitalization for Canadians.

Findings from current study also showed that the inclusion of CSD-level covariates did not change the significance or size of the adjusted compositional effects. It may imply that contextual effects within the modeling structure did not confound the effect of these variables. However, there was no assessment of interaction or cross-level effects between compositional and contextual effects. Therefore, it cannot be determined whether place of residence may interact or modify the effects of individual-level characteristics in regards to the odds of ACSC hospitalization.

5.4.2 Comparison of fixed specific effect with general contextual effects within multilevel framework

The calculated MOR and its reciprocal value from the Model 3 created an interval of [0.5, 2.04]. Considering the scale of the MOR index, it allows for direct comparison of general contextual effect with fixed-effect values. The results indicated that most of the fixed-effect characteristics had an odds ratio that lay inside of the interval [0.49, 2.04] (see Table C.4, Appendix C).

For individuals who lived in an urban area, or those who were male, born Canadian, of visible minority, under the age of 20, with no university degree, not married, with income level of less than $30,000, or those who lived in CSDs with median income of less than $30,000, changing their living area (CSD) from a lower risk to a higher risk area, had a more adverse effect on the odds of ACSC hospitalization compared to their counterparts. In other words, compared with low-risk individuals, for disadvantaged people who had higher odds of ACSC hospitalization in each adjusted group (e.g., age, sex, etc.), changing the place of residence (CSD) appeared to be a strong determinant that could compete with most of their adjusted risk effects in the current study (i.e. MOR_{CSD} was greater than most of fixed-effect odds ratios).

On the other hand, the general effects of health regions were just comparable with the effect of urbanicity, visible minority, age effect (younger than 40 years), as well as effects of CSD-level income. That implies, relocating from a low-risk to high-risk health region area, had comparable and slightly greater adverse impact on the individual's odds of ACSC hospitalization, if they were younger than 40 years old, of visible minority and living within low CSD-level income, or in urban areas compared to their counterparts ($MOR_{HR} > OR_{\text{Age below 40, Visible Minority, CSD\_Level Income, Urbanicity}}$ see Table C.4 , Appendix C).

The consequence of the discussion above for urbanicity effect can be rephrases as follows: the current study suggests rural individuals have higher protection against the odds of ACSC hospitalization compared to urban residences. However, once the same rural individuals change their CSD, FSA, or health region community from low-risk to high risk, they can lose their protective urbanicity effect against other unknown, more influential contextual effects.

5.4.3 Distance barriers and hospital influence on geographic variation in odds of ACSC hospitalization

The characteristics of hospitals that admitted patients as well as the distance between hospital and place of residency could not be identified in this study. These variables are of great importance for meaningful interpretation of ACSC hospitalization outcomes as they can provide a higher level of information, complementary to primary healthcare influences. The necessity of having hospital characteristics and distance information become even more vital when considering rural residents.

Chronic disease hospital admissions involve the interplay of several competing factors. First, on the patient's side, people might have different decisions on using hospital services based on their distance to the center. Studies that have investigated the relationship between distances to the nearest hospital have reported mixed conclusions. Some suggest a ‘distance decay’ effect which implies a negative association between distance and rate of hospital utilization.[61,113,241,242,303] Some Canadian studies report opposite effects. For instance, it is well documented that, a greater proportion of rural residents utilize local emergency departments as multipurpose facilities within rural areas.[113] However, there is also high geographic variability in the Canadian rural emergency services in terms of their quality of healthcare services.[304]

Additionally, admission to hospital is a process that directly depends on the local structure, as well as the decision of an acute care centre.[305] The urbanicity of residence of a patient with an ACSC may have an influence on the clinician decision (e.g., travel time for patient or their proximity to a hospital).[226,305–307] On the other hand, ACSC hospital admissions are by nature “supply-sensitive conditions” as stated by Wennberg and colleagues.[308] That means different hospitals have different thresholds for ACSC admissions according to their bed-supply availability or the severity of disease at the time. The severity of conditions was not measured in the current study. Also in some Canadian cases there was heterogeneity in hospital decision for admission or surgery operations that did not necessarily followed a distinctive urban-rural pattern and was rather discretionary decision based on health condition or procedures (e.g. hip surgery vs. cardiac).[302]

5.4.4 Global definition of rural regions

Similar to majority of Canadian studies, the current study, defined urbanicity as a binary variable to capture general urban-rural differences. However, as results suggest, I argue that rural regions in Canada are heterogeneous communities, which cannot always be distinctively separated from urban counterparts in terms of health outcomes. Overwhelmingly, studies use “rural” as equivalent to “remote” and “inferior” regions when it comes to healthcare accessibility. However, there are evidences to contradict that notion.[302] To bring regions with varying population structure, and varying degree of proximity to urban areas under the same title, “rural” may impose difficulty in interpreting health outcomes especially for ACSC hospitalization events.[238] Therefore, to have a more realistic interpretation I suggest future studies to specify types of rural communities based on their population density, as well as their communicating pattern to the nearest urban area.

5.4.5 Rural demographic profile and selection bias

Canadian rural residents tend to have different sociodemographic profile compared to urban areas. For instance, they are considered to have high “dependency ratios” which implies a higher prevalence of very young (0-19 years of age) and seniors (older than 60 years of age) compared to urban areas.[309] Older age proved to be a very strong predictor of ACSC hospitalization. In the current study, I excluded seniors over 74 from the study. That can bias the urbanicity effect toward lower odds of hospitalization for rural Canadians.

There are risk modifiers such as ethnicity or cultural measures, which can affect rural Canadian’s odds of ACSC hospitalization.[310] However, in the current study, cross-level interaction between urbanicity and ethnicity or cultural measures, was not explored. Also I did not control for some subgroup characteristics such as disabled individuals living within rural areas. As a Canadian study have shown there are urban-rural gradients between ACSC hospitalization of these group of people.[154]

5.5 The importance of the choice of geographic boundaries

In the current study, I employed different choices of geography units to estimate odds of ACSC hospitalization. These boundaries are assumed to have either cultural-contextual effects or policy making-contextual influences, which are compared in the following:

5.5.1 Residential community boundary effects

I chose CSD and FSAs with the assumption that they embody or host factors that have health outcome consequences and these hidden (measured or hidden) characteristics are shared between people living within same geographic boundaries. So they are not arbitrary but to a large degree reflect common social, cultural, economic as well as physical environments.

There were 5,418 CSD and 1,625 FSAs in Canada at the time of 2006 census.[275] Upon creating nested geographic boundaries they were reduced to 3080 CSD and 1175 FSAs.

On average, CSDs appeared as smaller units of analysis in some Canadian areas compared to FSAs. Following that, the results of current study were able to show that aggregation of information across broader or less regulated geographic units (FSA) will remove the variation and disparities in odds of ACSC hospitalization. Therefore, compared to CSDs, the odds of ACSC hospitalization across FSAs showed less variability (see Table C.4). Likewise, the degree of correlation and shared risk factors among observations was also reduced for FSAs as compared to CSDs. However, the adjusted compositional and contextual factors showed robust effects regardless of the area unit of analysis. In conclusion, shared risk factors within FSAs were less heterogeneous and therefore, these units of analysis appeared as less influential on the odds of ACSC hospitalization compared to CSDs. On the other hand, CSDs were able to capture a greater portion of contextual effects that influence the odds of ACSC hospitalization as opposed to broader area-level units of analysis such as FSAs.

This highlights the necessity of studying the odds of ACSC hospitalization at smaller geographic units in order to quantify general contextual effects in relation to the odds of ACSC hospitalization.

5.6 The role of health regions from multilevel analysis

In many studies, ACSC hospitalization is considered an indicator of the accessibility and efficiency of the primary healthcare system.[11,19–22,87] Also, prior studies suggest that Canadians are receiving a different level of access to primary healthcare services based on their geographic location.[86,88–90,110]

The current study does not argue for using potentially preventable hospitalizations as an indicator for the performance of primary care delivery in Canada. I did not directly include any accessibility measure of healthcare services nor investigate other healthcare equity dimensions. However, I was able to capture the proportion of heterogeneity in odds of ACSC hospitalization that is attributable to health regions as administrative units governing most of local accessibility, efficiency, and quality of the healthcare system. Results of current study can shed light on the effect of health regions on odds of ACSC hospitalization based on two different perspectives: Considered as sole geographic entities, health regions had larger regional boundaries in comparison to smaller geographic units such as CSDs or FSAs. In such a context, the results confirmed that ACSC hospitalization variability across health regions was not substantial but rather had more uniform influence across the country compared to the residential community effects. Also, health region effects on the odds of ACSC hospitalization were more amenable to the adjustment of included individual-level or compositional characteristics. In other words, compositional effects were able to explain higher proportional variability at health regions compared to CSDs.

Therefore, sole assessment of odds of ACSC hospitalization across such large-scale geographic regions could mask much of the variation and important information that exist at smaller geographic scales (e.g. CSDs).

On the other hand, health regions are not just simply geographic units, but rather administrative boundaries, which are responsible for the service efficiency and the quality of primary and acute health services. Through that lens, one can draw important and slightly contradicting conclusions as follows:

1) Significant disparities in odds of ACSC hospitalization stem from these administrative boundaries, which persisted even after adjustment for some compositional and contextual effects. That might reflect the fact that health care policies set by health regions are not the same across Canada. Considering some level of locality in policy making in provinces, such a result does not come as surprise.

2) The small heterogeneity in odds of ACSC hospitalization events across health regions (MOR_{HR}) might reflect some aspects of the universality of Canadian healthcare system. However, it may also signal that regardless of high heterogeneity of ACSC hospitalizations events across communities, health regions as administrative units have uniform and locally-insensitive performances. This emphasizes the need for policy makers to facilitate specific and context-oriented healthcare services for communities. Specifically, the results demonstrated that disadvantaged individuals would be more prone to the general contextual influences from health regions and communities.

Therefore, based on current results, policy makers can develop risk scores for individuals as well as geographic regions. Following that, they can target high-risk cases for the development of locally relevant intervention plans that can properly address the disparities in odds of ACSC hospitalization.

Also results from current study can help healthcare planners to develop predictive models that can identify new risk groups and communities.

5.7 Strengths & limitations

5.7.1 Strengths

Most Canadian studies on ACSC hospitalization have been constrained by using small samples of specific jurisdictions such as provinces, health regions, and cities. Also, many prior studies focused on specific sub-populations, such as specific ethnic groups. In contrast, the current study was pan-Canadian (except Québec) and consisted of a nationally representative sample of Canadians. Therefore, the generalizability of the study was increased compared to most of the small-scale Canadian studies on the odds of ACSC hospitalization.

This study utilized novel linkages of census and the health administrative data for hospitalization. This provided robust information on individual-level socio-economic and demographic characteristics, their residential areas and details of use of acute care services for ACSC.

In contrast to ecological studies, the current study included detailed individual-level information (e.g., SES data) linked to hospital admissions data to estimated odds of ACSC hospitalization. Moreover, area-level variables, including ecological SES measures were also included in the analysis. The unique feature of the current study is that individual-level, as well as area-level risk factors were investigated simultaneously using a multilevel modeling approach.

Few Canadian studies have used multilevel models to study the odds of ACSC hospitalization within small geographic areas. This study was novel in that it compared differences in odds of ACSC hospitalization, which was driven by contextual versus compositional effects. Also, to the best of my knowledge, this is the first Canadian study to report on quantified geographic variations in odds of ACSC hospitalization attributable to health region and community-level effects within a multilevel framework.

5.7.2 Limitations

The study also has several limitations. First, the observational nature of the current study makes that open to confounding and no causal conclusion can be draw from the results. While this study benefits from population-based information on linked census-DAD data, the results still do not represent the associated odds that belongs to some groups, such as institutionalized populations. Also, because of the suppressed information (e.g. for low-population rural areas), it is anticipated that the rural population is underestimated in this study. These limitations can affect the generalizability of the findings.

Aside from the seven individual-level variables included in the current study, there is a need to include a more comprehensive list of relevant factors that may influence ACSC hospitalization events such as:

demographic variables (e.g., duration of residence for immigrants); sociodemographic variables (e.g., employment status); health status (e.g., level of psychological distress, number of comorbidities, information about disease severity), lifestyle factors (e.g. unhealthy behaviors, access to nutritious food, adherence to medication, care-seeking behaviors, cultural traits). Also variables such as immigration status need to be defined more comprehensively in order to capture household structure and its corresponding effects.

Variables that were adjusted in the current study were measured in 2006. I assumed variables were unchanged during the three years of follow-up. However, that is a strong assumption as they may have changed in the intervening months and years before hospitalization events.

A multicollinearity was detected among individual and community-level attributes of SES risk factor. For future studies more advance analysis is recommended to adjust for SES attributes.

The characteristics of hospital facilities (e.g. rural versus urban) that admitted individuals for ACSC hospitalization could not be determined. Also, patient readmission during the three years of follow up was not considered, nor was the severity of disease at the time of admission. Including these factors could strengthen conclusions regarding the differences between rural-urban CSDs in terms of risk of ACSC hospitalization.

The study aimed to estimate the odds of an individual having a potentially preventable hospitalization for any of ACSC disease attributes. Therefore, no separate, condition-specific analysis for each of the seven types of ACSC was performed. It is recommended that future studies consider carrying out separate analysis to gain a better understanding of potentially different needs and risk associated with each of ACSC profiles.

CSDs were chosen to approximate communities in the models. This option allowed a measure to have a large enough sample size, as well as be conveniently nested within health regions. However, these geographic units are not small enough to capture details of living areas as well as heterogeneity in the odds of ACSC hospitalization. There is a need for future studies to examine smaller geographic boundaries such as effects of family and household in order to have a more realistic estimate of risk factors and event characteristics.

Finally, a spatial model is a more advantageous to multilevel analysis as it could take into account spatial autocorrelations of events and their risk factors. These models should be employed in future studies as they account for the effect of space, as well as place, when studying the risk of ACSC hospitalizations.

5.8 Conclusion

Taking a multilevel approach, this study advances our understanding of geographic variation in the odds of ACSC hospitalization for Canadians. Considerable variation in risk of ACSC hospitalization was detected across CSDs and to lesser degree across health regions. The disparities did not disappear even after controlling for the effects of individual and community-level characteristics. This finding indicates there are still important unknown risk factors related to individual characteristics or their area of residence that increased the odds of ACSC hospitalization. On the other hand, health regions appeared as more homogeneous sources of effect with modest variability in risk of ACSC hospitalization compared to the effect of CSDs. A higher variability across CSDs suggested that place of residence was of greater importance for an individual's odds of ACSC hospitalization compared to the effects of health regions.

The study findings were in agreement with much of the literature on the effects of age, sex, education, marriage, ethnicity, and income (i.e., individual- and community-level). In specific, results from the current research confirms and quantifies the adverse effects of socioeconomic inequalities across subpopulations of Canadians as well as communities. Also, results from this study, did not support the commonly accepted notion that urban areas in Canada have lower risk of ACSC hospitalization compared to rural residents. Therefore, results from my research may help policy makers to develop more focused, evidence-based decisions about determinants of ACSC hospitalization and consequently removing potential healthcare inequality and inequities across the country.

5.8.1 Future research

Further investigation is necessary to explore the mechanism by which characteristics of communities and health regions affect the likelihood of hospitalization for Canadian patients with ACSC. Also, the results from the current study strongly suggests that healthcare policy needs to accommodate local needs of patients with ACSC whose odds of ACSC hospitalization is strongly influenced by smaller geographic boundaries.

The current study identified high-risk sub-populations as well as high risk communities. Build upon these risk factors, future studies can assist policy makers in several ways:

1) By more comprehensive assessment of the role of important risk factors such as: distance to and density of physician within each community, distance to nearest hospital, severity of disease at the time of admission, number of comorbidities, healthy behavior, immigration history, occupational information, number of contacts with the primary healthcare before hospital admission, characteristics of communities;
2) By transforming the results from the predictive models to risk score for at risk subpopulations or communities.

Therefore, healthcare policy makers can develop targeted and local-based prevention plans to efficiently reduce inequality as well as inequities across Canadian communities.

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Appendix A:

Defining Ambulatory care sensitive related hospitalizations based on most responsible ICD10-CA (Source: Canadian Institute for Health Information, January 2008)[8]

Numerator: Inclusion criteria: Any most responsible diagnosis code of:

● Grand mal status and other epileptic convulsions ICD-9/9CM: 345 ICD-10-CA: G40, G41

● Chronic obstructive pulmonary diseases (COPD) Any most responsible diagnosis (MRDx) code of: ICD-9/9CM: 491, 492, 494, 496 ICD-10-CA: J41, J42, J43, J44, J47 MRDx of Acute lower respiratory infection, only when a secondary diagnosis of J44 ("Secondary diagnosis" refers to a diagnosis other than most responsible) in ICD-10-CA or 496 in ICD-9/9CM is also present: ICD-9/9CM: 480 – 486, 466, 487.0 ICD-10-CA: J10.0, J11.0, J12-J16, J18, J20, J21, J22

● Asthma ICD-9/9CM: 493 ICD-10-CA: J45

● Diabetes ICD-9: 250.0, 250.1, 250.2, 250.7 ICD-9-CM: 250.0, 250.1, 250.2, 250.8 ICD-10-CA: E10.0^^, E10.1^^, E10.63, E10.9^^ E11.0^^, E11.1^^, E11.63, E11.9^^ E13.0^^, E13.1^^, E13.63, E13.9^^ E14.0^^, E14.1^^, E14.63, E14.9^^

● Heart failure and pulmonary edema (Excluding cases with cardiac procedures) ICD-9/9CM: 428, 518.4 ICD-10-CA: I50, J81

● Hypertension (Excluding cases with cardiac procedures) ICD-9/9CM: 401.0, 401.9, 402.0, 402.1, 402.9 ICD-10-CA: I10.0, I10.1, I11

● Angina (Excluding cases with cardiac procedures) ICD-9: 411, 413 ICD-9-CM: 411.1, 411.8, 413 ICD-10-CA: I20, I23.82, I24.0, I24.8, I24.9

● List of cardiac procedure codes for exclusion (code may be recorded in any position. Procedures coded as cancelled, previous and "abandoned after onset" are excluded): CCI: 47^^, 480^-483^, 4891, 4899, 492^-495^, 497^, 498^

ICD-9-CM: 336, 35^^, 36^^, 373^, 375^, 377^, 378^, 3794-3798 CCI: 1HA58, 1HA80, 1HA87, 1HB53, 1HB54, 1HB55, 1HB87, 1HD53, 1HD54, 1HD55, 1HH59, 1HH71, 1HJ76, 1HJ82, 1HM57, 1HM78, 1HM80, 1HN71, 1HN80, 1HN87, 1HP76, 1HP78, 1HP80, 1HP82, 1HP83, 1HP87, 1HR71, 1HR80, 1HR84, 1HR87, 1HS80, 1HS90, 1HT80, 1HT89, 1HT90, 1HU80, 1HU90, 1HV80, 1HV90, 1HW78, 1HW79, 1HX71, 1HX78, 1HX79, 1HX80, 1HX83, 1HX86, 1HX87, 1HY85, 1HZ53 rubric (except 1HZ53LAKP), 1HZ54, 1HZ55 rubric (except 1HZ55LAKP), 1.HZ.56, 1.HZ.57, 1HZ59, 1HZ80,

1HZ85, 1HZ87, 1IF83, 1IJ50, 1IJ54GQAZ, 1IJ55, 1IJ57, 1IJ76, 1IJ80, 1IK57, 1IK80, 1IK87, 1IN84, 1LA84, 1LC84, 1LD84, 1YY54LANJ

Exclusion criteria:

1. Death before discharge
2. Individuals 75 years of age and older

Comments:

A new “combination” code for acute lower respiratory infections in patients with Chronic Obstructive Pulmonary Disease (J44) was introduced with ICD-10-CA and has no equivalents in ICD-9/ICD-9-CM. Cases coded with a primary diagnosis of an acute lower respiratory infection and a secondary diagnosis of J44 in ICD-10-CA or 496 in ICD-9/9CM will be included in the COPD case count. This was undertaken to ensure that COPD cases with acute lower respiratory infections are captured in ICD-9/CM jurisdictions in the same fashion, as they would be in ICD-10-CA jurisdictions, and to compensate for evident erroneous non-application of the combination code in ICD-10-CA jurisdictions. It was not possible to exclude Dressler’s syndrome in jurisdictions coding in ICD-9 as a unique code for this condition does not exist in the ICD-9 classifi cation. As of 2002/03, Québec is the only jurisdiction in Canada using the ICD-9 classifi cation system, therefore Québec rates may be slightly higher than elsewhere due to the inclusion of this condition (Dressler’s syndrome is coded as 411.0 in ICD-9-CM and I24.1 in ICD-10-CA). A unique code for Diabetes with hypoglycaemia (ICD-10-CA: E10.63, E11.63, E13.63, E14.63) does not exist in the ICD-9/ ICD-9CM classifi cation systems. This condition was coded using ICD-9 code of 250.7 and ICD-9CM code of 250.8, which also included diabetes with other specifi c manifestations. However, this has minimal eff ect on the comparability of rates between ICD-9 and ICD-10 coding jurisdictions

Appendix B:

Multilevel model construction

B.1 Null model

The final null model (Model 1), was an aggregated model assessing simultaneously all sources of variance explored in Models 1a, 1b, and 1c, as presented in this section.

In these models, the outcome variable is considered a binary variable: likelihood of ACSC hospitalization occurrence ($\boldsymbol{\pi_{ijk}}$), where $\boldsymbol{\pi_{ijk}}$ is the probability that the i^{th} individual in the j^{th} level 2 cluster (CSD or FSA) and the k^{th} level 3 cluster (health region) has an ACSC hospitalization event: $\pi_{ijk} = P(Y_{ijk} = 1)$; Y_{ijk}~ Bernoulli (π_{ijk}). The indices i, j, and k denote individuals, communities, and health regions where there are:

$i = 1, 2,....,n_{jk}$ individual within community j and in health region k;

$j = 1, 2,..., j_k$ community within health region k; and

$k = 1, 2,..., k$ health regions.

Model 1a - Individual-level model

This single-level (level 1) null model estimates the log-odds of having ACSC hospitalization event for each individual as a function of the community (CSD/FSA) mean plus a random error:

$$\eta_{ijk} = ln\left(\frac{\pi_{0jk}}{1-\pi_{0jk}}\right) + e_{ijk} = \eta_{0jk} + e_{ijk},\ \ e_{ijk} \sim N(0, \sigma^2) \qquad \text{(B.1)}$$

where η_{ijk} is the log odds (logit) of ACSC hospitalization event for the i^{th} individual in the j^{th} community (CSD/FSA) nested within the k^{th} health region. The term η_{0jk} is the mean log odds (logit) of ACSC hospitalization events in the j^{th} community (CSD/FSA) within the k^{th} health region, and e_{ijk} is a random "individual effect", capturing the deviation of actual individual's log-odds of ACSC hospitalization event from their corresponding community-level (CSD/FSA) mean. The variance of e_{ijk} equals $\frac{\pi^2}{3}$ on the logit scale which is a fixed number showing the error variance of binary models.[288,290,311]

Model 1b - Community-level model

Community-level effects are modeled at the level 2.

$$\eta_{0jk} = \beta_{00k} + r_{jk},\ r_{jk} \sim N(0, \tau_C^2) \qquad \text{(B.2)}$$

We view each community-level (CSD/FSA) mean, η_{0jk}, as an outcome varying randomly around some health region mean(β_{00k}) where β_{00k} is the mean log-odds within the kth health region. The term r_{jk} is a random community-level (CSD/FSA) effect, defined as the deviation of the mean of jkth community (CSD/FSA) from the health region mean. Within each of health regions, the variability of the outcome among communities (CSD/FSA) is assumed to be the same.

Model 1c - Health region-level model

The level 3 model represents the variability among health regions. The health region means,β_{00k} are assumed to vary randomly around a grand mean (μ):

$$\beta_{00k} = \mu + u_k,\ u_k \sim N(0, \tau_H^2), \qquad \text{(B.3)}$$

u_k is a random "health region effect", that is, the deviation of the mean of kth health region from the grand mean. The term τ_H^2 specifies the variance of health region random effects.

Model 1 - Aggregated three-level unconditional model

The final model (Model 1d) encompasses all levels of information (Models (1a, 1b, 1c)) and can be written in one equation as follows:

$$\eta_{ijk} = ln\left(\frac{\pi_{ijk}}{1-\pi_{ijk}}\right) + e_{ijk} = \mu + r_{jk} + u_k + e_{ijk} \qquad \text{(B.4)}$$

This model provides a baseline for comparing the estimated magnitude of variation in the likelihood of ACSC hospitalization events across communities (CSD/FSA) and health regions in Canada (except Québec).

B.2 The choice of ICC formula for Binary outcome

In the case of continues outcome and within a multi-level analysis context, ICC appropriately describes the proportion of total variance in the outcome that is attributable to the cluster effects. In other words, it quantifies the degree of similarity between two randomly chosen individuals within a same cluster (i.e., community/health region). The ICC ranges from 0 to 1. The higher value of ICC indicates greater degree of correlation between outcomes within the same cluster. The coefficient is usually expressed as $\frac{V_A}{(V_A+\sigma^2)}$, where V_A denotes the variance of the distribution for the varying effects, and σ^2 represents the variance of residuals. However, for a binary outcome such as odds of ACSC hospitalization, cluster-level (i.e., community/health region) residual variances (V_A) are on the logit scale, while the individual-level residual variance (σ^2) is on the probability scale. This leads to lack of comparability between two residual variances. As a remedy for such an inconsistency the literature suggests to consider ICC within a linear threshold model method or latent variable model.[312] This method is built upon conversion of an individual-level variance from the probability scale into the logit scale so that individual, community (CSD/FSA), and healthcare variances are expressed on the same scale.[313] The underlying assumption is that the risk of having an ACSC hospitalization incidence is a continuous latent variable expressed by the binary outcome and only individuals who cross a certain incidence risk threshold will end up in hospital with an ACSC diagnosis. Therefore, the unobserved individual variable follows a logistic distribution with individual-level variance equal to $\frac{\pi^2}{3}$ (that is, 3.29).

B.3 Model construction details for Individual-Level Adjusted Model (Model 2)

The outcome in Model 2 is models as follows:

$$\text{logit}(p_{ij}) = ln\left(\frac{\pi_{ijk}}{1-\pi_{ijk}}\right) = X_{ijk}^T\beta + r_{jk} + u_k + e_{ijk} = \mu + \beta_1\, sex_i + \beta_2\, age_i + \beta_3\, race_i + \beta_4\, mar_i + $$

$$+\beta_5\, edu_i + \beta_6\, inc_i + r_{jk} + u_k + e_{ijk} \ ,$$

$$u_k \sim N(0,\tau_H^2), r_{jk} \sim N(0,\tau_C^2), e_{ijk} \sim N(0,\sigma^2) \qquad \text{(B.5)}$$

The term (X_{ijk}^T), is a vector of individual-level variables including: sex (sex_i), age (age_i), race/ethnicity ($race_i$), marital status (mar_i), urbanicity ($urban_i$), education (edu_i), and income (inc_i)which were estimated with fixed effect- coefficient vectors β.

B.4. Model construction details for community-Level Adjusted Model (Model 3)

The following equation explains the model which adjusts for community-level income (inc_j) and urbanicity:

$$\text{logit}(p_{ij}) = ln\left(\frac{\pi_{ijk}}{1-\pi_{ijk}}\right) = \mu + \beta_1\, sex_i + \beta_2\, age_i + \beta_3\, eth_i + \beta_4\, mar_i + \beta_5\, urban_i + \beta_6\, edu_i + \beta_7\, inc_i + \beta_8\, inc_{jk} + r_{jk} + u_k + e_{ijk} \ ,$$

$$u_k \sim N(0, \tau_H^2), r_{jk} \sim N(0, \tau_C^2), e_{ijk} \sim N(0, \sigma^2) \qquad \text{(B.6)}$$

Appendix C.

Table C.1 Comparison of fixed specific effects with general contextual effects for CSD database

	Model 3	MOR_{CSD}/MOR_{HR} *	Model 3a	MOR_{CSD}/MOR_{HR} **
Odds Ratio ***				
Individual-level fixed effects				
Sex				
Men	1.44	**2.04**/1.22	1.3	**2.05**/1.22
Women				
Age Categories				
< 20 years				
20 to 39 years	1.2	**2.04/1.22******	1.1	**2.05/1.22**
40 to 59 years	5	2.04/1.22	4.00	2.05/1.22
60 to 74 years	14.3	2.04/1.22	13.00	2.05/1.22
Marital status				
Legally married***	1.35	**2.04**/1.22	1.4	**2.05**/1.22
Legally not married				
Educational attainment				
Less than high school				
High school only***	1.6	**2.04**/1.22	1.7	**2.05**/1.22
Bachelor and higher	2.4	**2.04/**1.22	3	2.05/1.22
Immigration status				
Immigrants	1.54	**2.04**/1.22	1.4	**2.05**/1.22
Non-immigrant				
Ethnicity				

Non-visibly minor				
Visibly minor	1.1	**2.04/1.22**	1.14	**2.05/1.22**
Individual-level Income				
< $30,000				
$30,000- $60,000***	1.7	**2.04**/1.22		2.05/1.22
>=$60,000***	2.3	2.04/1.22		2.05/1.22
Community-level fixed effects				
Urbanicity				
Urban				
Rural	1.11	**2.04/1.22**	1.11	**2.05/1.22**
CSD-level median income				
< $30,000				
$30,000- $60,000	1.2	**2.04/1.22**	1.3	**2.05**/1.22

* MOR value related to Model 3

** MOR values related to Model 3a

*** Any odds ratio is converted into its reciprocal value to be comparable with MOR measures

***** Bold MOR values are equal or higher than corresponding risk factors

Table C.2 Descriptive characteristics of the FSA-study population

Variables	Total population (%)	ACSC hospitalization Event (%)	
		Yes	No
Sex			
Women	50	45	50
Men	50	55	50
Age			
< 20 years	25	15	25
20 to 39 years	30	10	30
40 to 59 years	15	35	15
60 to 74 years	15	45	15
Marital status			
Legally married	45	50	45
Legally not married	55	50	55
Educational attainment			
Less than high school	40	50	40
High school & no bachelor	45	40	45
Bachelor and higher	15	5	15
Immigration status			
Immigrants	25	15	25
Non-immigrant	75	85	75
Ethnicity			
Non-visibly minor	75	85	75
Visibly minor	25	15	25

Individual-level Income			
< $30,000	65	70	65
$30,000- $60,000	30	25	30
>=$60,000	5	0	5
Community-level variables			
Level of urbanization			
Urban	80	70	80
Rural	20	30	20
Community-Level median income			
< $30,000	80	85	80
> $30,000	20	15	20

Table C.3 Comparing the estimated multilevel regression coefficients for CSD versus FSA models

	Model 3_CSD	Model 3_FSA
Odds Ratio (95% Confidence Limits)		
Individual-level fixed effects		
Sex		
Men	1.44 (1.42-1.45)	1.43 (1.41-1.45)
Women	Ref	Ref
Age Categories		
< 20 years	Ref	Ref
20 to 39 years	1.16 (1.13-1.20)	1.14 (1.11-1.17)
40 to 59 years	5.0 (4.6-4.9)	4.7 (4.6-4.8)
60 to 74 years	14.30 (14.00-14.60)	14.00 (13.70-14.30)
Marital status		
Legally married	0.74 (0.73-0.75)	0.75 (0.74-0.76)
Legally not-married	Ref	Ref
Educational attainment		
Less than high school	Ref	Ref
High school no bachelor	0.64 (0.63-0.65)	0.644 (0.64-0.65)
Bachelor and higher	0.41 (0.40-0.42)	0.42 (0.41-0.43)
Immigration status		
Immigrants	0.65 (0.64-0.66)	0.64 (0.63-0.65)
Non-immigrant	Ref	Ref
Ethnicity		
Non-Visibly Minor	Ref	Ref

Visibly Minor	1.08 (1.06-1.1)	1.12 (1.1-1.14)
Individual-level Income		
< $30,000	Ref	Ref
$30,000- $60,000	0.59 (0.58-0.6)	0.60 (0.59-0.61)
>=$60,000	0.43 (0.41-0.45)	0.45 (0.43-0.47)
Community-level fixed effects		
Urbanicity		
Urban	Ref	Ref
Rural	0.90 (0.87-0.92)	0.88 (0.86-0.89)
POOR(%)	46.05	
IOR(L,U)	(0.23-3.50)	
CSD_level median income		
< $30,000	Ref	Ref
$30,000- $60,000	0.80 (0.70-0.90)	0.78 (0.74-0.80)
POOR(%)	43.04	
IOR(L,U)	(0.21-3.23)	

Table C.4 Comparing random effects from multilevel analysis for CSD versus FSA databases

	Model 3_CSD	Model3_FSA
Covariance Parameter Estimates (Random intercept effects)		
Variance (SE)		
Level 3		
HR intercept	0.044(0.010)	0.07 (0.014)
Level 2		
CSD/FSA intercept	0.52 (0.020)	0.12 (0.006)
Level 1 (individual effects)	3.29	3.29
ICC		
HR effect	1.13	2.00
CSD/FSA effect	14.62	5.50
MOR		
MOR_{HR}	1.22	1.30
$MOR_{CSD/FSA}$	2.04	1.50
Total PCV% effect		
HR	33.03	59.00
CSD/FSA	10.2	49.4
* Full model (All compositional and contextual effects included except for individual-level income)		

Curriculum Vitae

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