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Determining the Association between Continuity of Primary Care and Acute Care Use among Adult Patients with Chronic Kidney Disease in Alberta

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Determining the Association between Continuity of Primary Care and Acute Care Use among Adult Patients with Chronic Kidney Disease in Alberta

by

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ABSTRACT

Background: Acute care use is high among individuals with chronic kidney disease (CKD). It is unclear how relational continuity of primary care influences downstream acute care use.

Aim: To determine if poor relational continuity of primary care is associated with higher rates of all-cause and potentially preventable acute care use among adults with CKD. This project had two objectives:

1) To describe the relational continuity of primary care received among adults with CKD in Alberta over a 2-year period and,

2) To determine if poor relational continuity of care is associated with higher rates of all-cause and CKD-related ACSC hospitalization and ED visits among adults with CKD.

Design and Setting: A population-based retrospective cohort study of adults with stages 3 and 4 CKD and at least three visits to a primary care provider between April 1, 2011 to March 31, 2014 in Alberta, Canada.

Method: Relational continuity was calculated using the Usual Provider Continuity index and descriptive statistics were used to summarize patient and acute care encounter characteristics. Adjusted rates (per 1,000 person-years) and incidence rate ratios for all-cause and CKD-related ambulatory care-sensitive condition (ACSC) hospitalizations and emergency department (ED) visits were estimated using negative binomial regression modelling.

Results: Among 86,475 individuals with CKD, 51.3%, 30.0%, and 18.7% of patients had high, moderate, and poor continuity of primary care, respectively. There were 77,988 all-cause hospitalizations, 204,615 all-cause ED visits, 6,489 (8.3% of all hospitalizations) CKD-related ACSC hospitalizations, and 8,461 (4.1% of all ED visits) CKD-related ACSC ED visits during a

median follow-up of 2.3 years. Rates of all-cause hospitalization and ED use increased with poorer continuity of primary care in a stepwise fashion across CKD stages. Poor continuity of primary care was also associated with higher rates of CKD-related ACSC hospitalization and ED visits, particularly among individuals with stage 3 CKD.

Conclusion: Poor continuity of care is associated with increased acute care use and targeted strategies are needed to strengthen patient-provider relationships within primary care among those with CKD.

PREFACE

This thesis is original, unpublished, independent work by the author, C. C. Chong. The components of the thesis project reported in Chapter 2 is covered by Ethics Certificate number REB16-1575_MOD11, issued by the University of Calgary Conjoint Health Research Ethics Board for the project "Determining the Association between Continuity of Primary Care and Acute Care Use among Adult Patients with Chronic Kidney Disease in Alberta" on October 21, 2020.

The following manuscript is based on work from this thesis and has been submitted for publication. Christy Chong was involved in the conceptualization and design of the study. She was responsible for drafting the manuscript, conducting the analysis and interpreting the data with guidance from her thesis committee (Drs. Paul Ronksley, Meghan Elliott, David Campbell, and Fariba Aghajafari). All authors contributed important intellectual content and provided a critical review of the paper.

This study is based in part by data provided by Alberta Health and Alberta Health Services. The interpretation and conclusions are those of the researchers and do not represent the views of the Government of Alberta. Neither the Government of Alberta nor Alberta Health express any opinion in relation to this study.

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DEDICATION

~ To my parents for their love and support

~ To past, current, and future loved ones with kidney disease – I see you and I hear you

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LIST OF SYMBOLS, ABBREVIATIONS, AND NOMENCLATURE

Symbol	Definition
ACSC	Ambulatory Care-Sensitive Condition
ACR	Albumin Creatinine Ratio
AKDN	Alberta Kidney Disease Network
CI	Confidence Interval
CKD	Chronic Kidney Disease
CKD-EPI	Chronic Kidney Disease Epidemiology Collaboration
CHF	Congestive Heart Failure
COPD	Chronic Obstructive Pulmonary Disease
DAD	Discharge Abstracts Database
eGFR	Estimated Glomerular Filtration Rate
ED	Emergency Department
IRR	Incident Rate Ratio
IQR	Interquartile Range
ICD	International Statistical Classification of Diseases
KDIGO	Kidney Disease Improving Global Outcomes
KHSCN	Kidney Health Section of the Medicine Strategic Clinical Network

NACRS	National Ambulatory Care Reporting System
RECORD	Reporting of studies Conducted using Observational Routinely-collected Data
SD	Standard Deviation
STROBE	Strengthening the Reporting of Observational Studies in Epidemiology
PVD	Peripheral Vascular Disease
PCR	Protein Creatinine Ratio
UPC	Usual Provider of Care

CHAPTER ONE: INTRODUCTION

1.1 Chronic Kidney Disease

Chronic kidney disease (CKD) is the reduction in kidney function over time. It can manifest as a reduction in the filtration capacity of the kidneys (measured as an estimated Glomerular Filtration Rate (eGFR) of less than 60mL/min/1.73m^2) and/or as increased urinary excretion of proteins (Albumin Creatinine Ratio (ACR) greater than or equal to 3mg/mmol) for three or more months (1). Based on clinical guidelines (2), CKD is grouped into severity categories using eGFR and ACR levels where increasing levels indicate greater reductions in kidney function (**Appendix A**). Unless markers of kidney damage are present (i.e., presence of albuminuria, urine sediments, etc.), stages 1 and 2 indicate the absence of CKD (2). Therefore, CKD ranges from stage 3a, where there is mild impairment in kidney function, to stage5, where a patient is considered to have kidney failure and require dialysis treatment.

In Canada, CKD (stages 3a, 3b, 4, and 5) affects approximately 3% of individuals who are 18 years or older (3). The prevalence of CKD increases with age, with a higher prevalence of severe stages of CKD among individuals aged 65 years and older (4). There are a variety of risk factors for CKD such as the presence of diabetes, hypertension, cardiovascular disease, and/or obesity (5). Being male, having a lower socioeconomic status, and smoking are additional factors that increase the risk of having CKD (6).

1.1.1 CKD and Acute Care Use

CKD is a highly complex chronic condition that often involves the management of several comorbidities (e.g., diabetes, hypertension, and other cardiovascular diseases) (7) and complications (e.g., hyperkalemia, fluid buildup, gout, anemia, and metabolic

acidosis) (8). As a result, the survival and quality of life of patients with CKD are worse than other major chronic condition populations such as cancer (9). Acute care use, particularly of hospital and emergency department (ED) services are three- to eight- times greater among patients with CKD than the general population (10, 11). The economic burden of CKD is also high, with approximately $32 billion spent annually on the care of this patient population in Canada (12). Given the medical complexity of CKD and the progressive, irreversible decline in kidney function over time, these patients require appropriate, effective, and accessible care to reduce their reliance on acute care services (10, 13, 14). A commonly used metric to assess healthcare quality is the identification of potentially preventable acute care encounters for ambulatory care-sensitive conditions (ACSCs). ACSCs are defined as "*medical conditions for which timely and effective outpatient care can help to reduce the risk of hospitalization by either preventing the onset of an illness, controlling an acute episodic illness, or management of a chronic disease*" (15). There are key ACSCs specific to patients with CKD which include: volume overload, hyperkalemia, malignant hypertension, and heart failure (16). Previous work has found that approximately 10% of acute care encounters among patients with CKD were for CKD-related ACSCs that were potentially preventable (14, 17). As Kidney Disease Improving Global Outcomes (KDIGO) Guidelines suggest that referral to a nephrologist is recommended for patients with an eGFR < 30 mL/min/1.73m^2 (2), many patients with CKD, primarily those in the less advanced stages of CKD (stage 3a, 3b, and 4), are managed in primary care settings (18). Therefore, effective primary care management of patients with CKD is of particular importance to reduce the risk of

adverse consequences of kidney disease progression and potentially preventable acute care encounters.

1.2 Continuity of Care

Continuity of patient care is essential for the effective delivery of health care (19). It is defined as *"the process by which the patient and the physician are cooperatively involved in ongoing health care management towards the goal of high quality, cost-effective medical care"* (20). There are two core concepts of continuity of care (21). Firstly, it is focused on the care that patients receive from their health care providers (21). Patient care can include a provider's knowledge about their patients, the management of patient needs, or the relationship between a patient and their health care providers (21). Secondly, continuity of care is concerned with the delivery of care over time from one or more health care providers within one or more healthcare settings (19). This can include care that is delivered over a short period of time (e.g. during a hospitalization) or over a longer time period (e.g. care within a long-term care facility) (21).

The value and benefit of continuity of care has been recognized by primary care physicians in Alberta (22). For example, the Alberta Medical Association published clinical practice guidelines that aimed to increase continuity in primary healthcare settings (22). The guidelines recommend that primary care providers: 1. foster patient-provider relationships; 2. promote and advocate for continuity to all patients in the healthcare system; 3. identify and manage patients who may benefit the most from continuity; 4. book patients to visit their own primary care physician at least 80% of the time; 5. improve access to appointments; 6. measure baseline continuity and track the

progress; 7. optimize the patient care team to improve and support continuity; and 8. optimize all potential improvements in all contexts (22).

1.2.1 Types of Continuity of Care

There are three types of continuity of care: informational, managemental, and relational continuity.

Informational Continuity of Care

Informational continuity is *"the use of information on past events and personal circumstances to make current care appropriate for each individual"* (21). This includes having a range of knowledge on a patient's clinical history, personal beliefs, and values. Information about a patient can be available electronically, by paper, or by memory (19). An essential component to this type of continuity of care is the coordinated transfer of knowledge between different health care providers (19). Since patients who have multiple chronic conditions are often managed by a multidisciplinary healthcare team, communication between team members is essential to ensure that patient needs are met and consistent (19). The accumulation of knowledge about a patient is another essential component of informational continuity as it can lead to more effective and individualized care (19).

Managemental Continuity of Care

Managemental continuity involves *"a consistent and coherent approach to the management of a health condition that is responsive to a patient's changing needs"* (21).

This includes sharing management plans with the patient's healthcare team in an organized and timely manner to ensure that management goals are met and that changes can be made when appropriate. Identifying and documenting patient goals and preferences also ensures that patient care is consistent across different providers – consistency in care is crucial for the management of patients with multiple chronic conditions (19). Additionally, flexibility in managing patients in terms of adapting to dynamic needs, contexts, and values is another important aspect of managemental continuity of care (19).

Relational Continuity of Care

Relational continuity is the *"ongoing therapeutic relationship between a patient and one or more providers that spans various healthcare events and results in accumulated knowledge of the patient and care that is consistent with the patient's needs"* (21). This dimension of continuity generally improves when patients have a continuous relationship with a provider that they consistently see over time (19). A strong relationship with a usual provider can help build a mutual sense of trust, understanding, and responsibility over time. Moreover, studies have shown that receiving care from a specific provider over time has been associated with improvements in disease self-management, medication adherence, and the ability to recognize health problems (23). As a result, primary care providers, in particular, are able to step in during unforeseen medical emergencies and provide comprehensive care in an outpatient setting (24).

1.3 Chronic Disease Management

According to the National Centre for Chronic Disease Prevention and Healthy Promotion, chronic disease is defined as, "*conditions that last one year or more and require ongoing medical attention or limit activities of daily living or both*" (25). Common chronic diseases include CKD, cardiovascular disease, cancer, chronic obstructive pulmonary disease (COPD), type 2 diabetes, and Alzheimer's disease. Many public health strategies in Canada have been taken to manage chronic disease and they include the implementation of self-management educational programs, healthy public policies, information systems, etc. A key factor in managing chronic disease is the continuity of care between patients and health care providers. This was highlighted in a report released by Alberta Health Services which stated that, "*managing chronic conditions and diseases involves an integrated and coordinated system of supports, including families and communities, that empowers individuals to maintain and improve their health, their quality of life*" (26).

1.4 Importance of Relational Continuity of Primary Care in Patients with Chronic Disease

Although there are three types of continuity of care, informational and managemental continuity are fundamentally dependent on the level of relational continuity between a provider and patient (22). Within primary care, relational continuity is the most valued form of continuity among primary care providers (27) and individuals with chronic conditions (28). Since patients with chronic conditions require ongoing medical care from primary care providers to ensure that their health can be managed on a

day-to-day basis, this population may greatly benefit from having high relational continuity of care. For example, establishing a strong sense of affiliation between a patient and their primary care providers would lead to increased visits to the same provider overtime. This continuous process would further improve and stabilize the relationship a patient has with their provider and subsequently, lead to the accumulation of knowledge about the patient (informational continuity) and personalized management of their needs (managemental continuity).

1.4.1 Outcomes Associated with Relational Continuity of Care

Many associations have been found between the level of relational continuity of care and various outcomes among patients with chronic conditions. Among patients with asthma, high relational continuity of care was associated with decreased rates of ED visits, hospitalizations, and total days spent in a hospital (29). Similar associations were found among patients with human immunodeficiency virus (30), depression, bipolar affective disorder (31), and diabetes (32). The healthcare cost and risks of hospitalization and ED visits also decreased as relational continuity of care increased among patients with diabetes, hypertension, asthma, and COPD (33). Lastly, high relational continuity of care led to improved patient-reported satisfaction among those with chronic conditions (34).

1.5 Relational Continuity of Care in CKD

Despite the advances in knowledge on the impact of relational continuity of care among patients with other chronic conditions, the CKD patient population has not been

well studied. Of the limited studies on relational continuity and CKD, many are focused on individuals with late stages of CKD and/or kidney failure. For example, a study of incident patients who initiated dialysis examined the association between relational continuity of primary care and risk of death and hospitalization (35). They found no significant association between high primary care continuity and lower risk of mortality (35). Further, high continuity was not significantly associated with lower risk of all-cause hospitalization (35). In a qualitative study that explored stages 4 and 5 CKD patient perceptions of continuity of care within United Kingdom hospital-based specialist services (24), they found that relational continuity was the most valued form of continuity of care. Interestingly, patients perceived relational continuity of care differently depending on if they were receiving community or specialist care (24). For instance, many patients expected a more personal relationship with their primary care provider as opposed to their specialist (24). Another theme that was identified was the importance of the speed of access to health care providers (24). For example, during times of medical emergency or change, being able to see a familiar primary care provider was a priority for patients because they valued and trusted their provider's expertise and decision-making capability (24). All in all, the findings from these studies are less generalizable to patients in earlier stages of CKD (stages 3 and 4).

Only two studies explored continuity of care in individuals with less advanced stages of CKD. One study was a retrospective cohort study from Korea which found that poorer relational continuity of care was associated with a higher incidence of kidney failure (36). In another study among adults with diabetes and stages 3 and 4 CKD, poor relational continuity was associated with poor clinical outcomes, patient dissatisfaction,

and an increased rate of ED visits (37). Although this is the only study that reported on the association between relational continuity of care and acute care use in the CKD population, this study was focused on patients with complex diabetes and CKD.

A large proportion of individuals with CKD in Canada have stage 3 CKD. This stage of CKD is manageable with few symptoms; thus, referral to a nephrologist is generally not required/recommended. As a result, approximately 80% of patients with stage 3 CKD in Alberta are followed within primary care settings (4, 18, 38). In a study that explored patient-reported barriers to healthcare, poor relational continuity of care was the most commonly reported barrier among those with stage 3 CKD (39). Since an early diagnosis and effective management from a primary care provider are key factors that can improve CKD outcomes, future research should explore how relational continuity of primary care impacts patients with earlier CKD stages. The findings from past studies that highlight the importance of seeing a familiar provider during medical emergencies (24) and the association between poor continuity with increased rates of ED visits (24, 37) further emphasizes the need to determine how relational continuity of care is associated with acute care use in this specific group of individuals.

1.6 Research Aim

This project aims to determine if poor relational continuity of primary care is associated with higher rates of acute care use (hospital and ED) among adults with stages 3 or 4 CKD compared to those with moderate and high continuity. This is an essential step to understand how continuity of primary care is related to acute care use in this high-risk population. With this in mind, our study objectives are to:

1) Describe the relational continuity of primary care received among adults with CKD in Alberta over a 2-year period and

2) Determine if poor relational continuity of care is associated with higher rates of all-cause and CKD-related ACSC hospitalization and ED visits among adults with CKD.

CHAPTER TWO: DETERMINING THE ASSOCIATION BETWEEN CONTINUITY OF PRIMARY CARE AND ACUTE CARE USE AMONG ADULTS WITH CHRONIC KIDNEY DISEASE IN ALBERTA

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2.1 Abstract

Background: Acute care use is high among individuals with chronic kidney disease (CKD). It is unclear how relational continuity of primary care influences downstream acute care use.

Aim: To determine if poor relational continuity of primary care is associated with higher rates of all-cause and potentially preventable acute care use among adults with CKD.

Design and Setting: A population-based retrospective cohort study of adults with stages 3 and 4 CKD and at least three visits to a primary care provider between April 1, 2011 to March 31, 2014 in Alberta, Canada.

Method: Relational continuity was calculated using the Usual Provider Continuity index and descriptive statistics were used to summarize patient and acute care encounter characteristics. Adjusted rates (per 1,000 person-years) and incidence rate ratios for all-cause and CKD-related ambulatory care-sensitive condition (ACSC) hospitalizations and emergency department (ED) visits were estimated using negative binomial regression.

Results: Among 86,475 individuals with CKD, 51.3%, 30.0%, and 18.7% of patients had high, moderate, and poor continuity of primary care, respectively. There were 77,988 all-cause hospitalizations, 204,615 all-cause ED visits, 6,489 (8.3% of all hospitalizations) CKD-related ACSC hospitalizations, and 8,461 (4.1% of all ED visits) CKD-related ACSC ED visits during a median follow-up of 2.3 years. Rates of all-cause hospitalization and ED use increased with poorer continuity of primary care in a stepwise fashion across CKD stages. Poor continuity of primary care was also associated with higher rates of CKD-related ACSC hospitalization and ED visits, particularly among individuals with stage 3 CKD.

Conclusion: Poor continuity of care is associated with increased acute care use and targeted strategies are needed to strengthen patient-provider relationships within primary care among those with CKD.

Keywords: Ambulatory Care; Chronic Renal Insufficiency; Continuity of Patient Care; Hospitalization; Physician-Patient Relations; Primary Health Care

2.2 Introduction

In Canada, the estimated prevalence of chronic kidney disease (CKD) is approximately 3% (0.73 million) of individuals who are 18 years or older (3). CKD is a complex chronic condition that often involves the management of several comorbidities (7), such as hypertension, diabetes and cardiovascular disease. Common complications of CKD include hyperkalemia, anemia, and metabolic acidosis (8). The Kidney Disease Improving Global Outcomes (KDIGO) Guidelines recommend referral to a nephrologist for patients who have an estimated glomerular filtration rate (eGFR) < 30 mL/min/1.73m^2 (2). As a result, many patients with less advanced CKD are managed exclusively in primary care settings (18). Effective primary care management of patients with CKD is of particular importance to reduce the risk of adverse consequences of kidney disease progression and associated morbidity from cardiovascular disease.

Continuity of care is essential for the effective delivery of patient-centred healthcare (19) and there are three interconnected types: informational, managemental, and relational continuity. Informational continuity is the coordination and integration of a patient's medical history and values, managemental continuity is providing timely care that responds to a patient's dynamic needs, and relational continuity is the ongoing therapeutic relationship between a patient and their health care providers (21). Within primary care, relational continuity is principally more important for patients with chronic conditions who require ongoing medical care in an outpatient setting (27, 28). Various patient-reported outcomes have been associated with high relational continuity, including improved satisfaction, health-related quality of life, medication adherence, and trust (34, 40-43). Reduced rates of multimorbidity have also been associated with increased

relational continuity (44). Lastly, strong affiliations between patients and providers have led to decreased emergency department (ED) visits, hospitalizations, and healthcare costs among patients with asthma (29), heart failure (45), depression (31), and diabetes (32).

One of the top research priorities for patients with CKD is the need to optimize strategies to enhance the management of CKD, improve patient outcomes, and reduce potentially preventable acute care use (46, 47). A commonly used metric to assess outpatient healthcare quality is the identification of potentially preventable acute care encounters for ambulatory care-sensitive conditions (ACSCs). There are key ACSCs specific to patients with CKD where timely and effective primary care may reduce the risk of acute care use, which include: volume overload, hyperkalemia, malignant hypertension, and heart failure (16). Prior work has shown that acute care use is high among those with CKD (10) and that approximately 10% of CKD-related encounters are potentially preventable (14, 17). However, it is unclear how relational continuity of care within the primary care setting is associated with all-cause and potentially preventable acute care among patients with CKD.

Given the value and benefit of high continuity of primary care, it is essential to understand its impact in this high-risk population. We aimed to determine if poor relational continuity of primary care is associated with higher rates of acute care use among adults with CKD compared to those with higher continuity. The study objectives were to 1) describe the relational continuity of primary care received among adults with CKD in Alberta, and 2) determine if poor relational continuity of care is associated with higher rates of all-cause and CKD-related ACSC hospitalization and ED visits among adults with CKD.

2.3 Methods

Data source, Setting, and Study Population

We used an established computerized repository of provincial administrative and laboratory data from across Alberta called the Alberta Kidney Disease Network (AKDN) to define CKD status using serum creatinine measurements (**Appendix B**) (48). A unique patient identifier (provincial healthcare number) was used to link patients with CKD to various administrative data sources (Alberta Health Population Registry, Alberta Renal Program Database, Ambulatory Care Classification Reporting System, Discharge Abstract Database, and Provider Claims) to capture detailed socio-demographic data, clinical information, and encounters with acute and primary care services (48). We created a cohort of adults (aged 18 years and older) with two or more outpatient serum creatinine measurements between April 1, 2011 to March 31, 2014 in Alberta, Canada. Using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation (49), CKD diagnosis was defined by a series of two or more serum creatinine measurements that equated to an eGFR < 60 ml/min/1.73m^2 taken at a minimum of 90 days and a maximum of 18 months apart, with no recovering kidney function. The index date for CKD diagnosis was defined by the first eGFR measurement < 60 ml/min/1.73m^2. CKD stage was defined by eGFR category using KDIGO guidelines (2). This included: stage 3a (eGFR 45 – 59 ml/min/1.73m^2), stage 3b (eGFR 30 – 44 ml/min/1.73m^2), and stage 4 (eGFR 15 – 29 ml/min/1.73m^2). Those who were dialysis dependent, received a kidney transplant, or had kidney failure (i.e., eGFR < 15 mL/min/1.73m^2) prior to the index date were excluded, as these individuals are generally managed by nephrologists

rather than primary care providers. Individuals with CKD who had at least three outpatient visits to a single primary care provider during a two-year period before the index date were included in our final cohort. They were followed until death, outmigration, dialysis start, or the end of the study (March 31, 2014).

Measurement of Exposure Variable – Relational Continuity of Primary Care

Relational continuity of primary care was defined as the proportion of outpatient visits to a primary care provider (i.e., family physician) among those with at least three outpatient visits, during a two-year period prior to index date. Outpatient primary care visits and visits to a usual provider (defined as the primary care physician that a patient visited the most during a two-year period prior to index date) were identified from the Alberta Health Provider Claims database. The level of continuity of primary care was calculated using the Usual Provider Continuity (UPC) index and categorized as poor (< 50%), moderate (50 – 74%), or high (75 – 100%) (50) (**Appendix C**). We assumed that the continuity level defined in a two-year period prior to index date was constant from the index date to the time of censoring/end of the study. Other measures of relational continuity of primary care were considered (e.g., continuity of care index, modified modified continuity index, and sequential continuity index). However, the UPC index was chosen based on our ability to measure this within our administrative data, standardized approach to categorization, and ease of interpretation.

Measurement of Outcome Variables – Identification of All-Cause and Potentially Preventable Acute Care Use

We evaluated acute care use among individuals with CKD using four outcome measures: 1) all-cause hospitalizations, 2) all-cause ED visits, 3) CKD-related potentially preventable hospitalizations, and 4) CKD-related potentially preventable ED visits. All patients were followed from the day they entered the study (CKD diagnosis date) until death, outmigration, dialysis start, or the end of the study. The number of hospitalizations and ED visits during this period were recorded from the Discharge Abstracts Database (DAD) and National Ambulatory Care Reporting System (NACRS), respectively (51, 52) – these data sources contain coded information for 100% of acute care encounters in Alberta. These data were used to determine the rate of hospitalization and/or ED visits for each patient (number of events per 1,000 person-days).

Potentially preventable acute care use was defined as hospitalizations and ED visits for CKD-related ACSCs (i.e., volume overload, hyperkalemia, malignant hypertension, and heart failure) (16). These were captured using the most responsible diagnosis code within DAD and NACRS based on International Statistical Classification of Diseases and Health Related Problems, Tenth (ICD-10) diagnostic coding (**Appendix D**).

Measurement of Modifying and/or Confounding Variables

We identified demographic and clinical variables from Alberta Health administrative data for the cohort. These included age, sex, household location (urban vs. rural), and neighbourhood-level median household income quintile. Albuminuria was defined by the hierarchical combination of albumin-to-creatinine ratio (ACR), protein-to-creatinine ratio (PCR), or urine dipstick measurement; on the basis of availability. This

was categorized as normal (A1), moderate (A2), or severe (A3) based on pre-specified cut-points within the AKDN provincial lab repository (**Appendix E**) (53). Given that multimorbidity is common among patients with CKD (54), the presence of 30 chronic comorbidities were identified using validated ICD-9 and ICD-10 coding algorithms in the two years prior to entering the study (55). The proportion of patients with at least one visit to a specialist in the two years prior to index date were also measured.

Statistical Analysis

We summarized patient demographic and clinical characteristics using descriptive statistics (means and standard deviations (SD), proportions, medians and interquartile ranges (IQR), and 95% confidence interval (CI)) for the overall cohort and stratified by level of continuity of primary care. We also calculated the number of hospital and ED encounters and additional characteristics related to hospitalizations (median and cumulative length of stay) for the overall cohort and stratified by level of continuity. Unadjusted rates of hospitalizations and ED visits per 1,000 person-years were initially calculated using Poisson regression models. Assumption testing was conducted and we found evidence of over-dispersion in the data. We also observed an excess of zeros within the distribution of hosptializations and ED visits. While a zero-inflated negative binomial regression model was considered, it was not used given difficulties in interpretation. Thus, negative binomial regression models were used to estimate incident rate ratios (IRRs) for hospitalizations and ED visits. We found that CKD stage modified the relationship between continuity of care and acute care use ($p < 0.05$) and thus reported IRRs stratified by CKD stage. To assess model fit, we used the Akaike information

criterion, Bayesian information criterion, and McFadden's pseudo-R squared. Within all statistical modeling, confounding variables were included using a forward stepwise regression process. We set the high continuity group as the reference and reported unadjusted and adjusted CKD stage-stratified IRRs for all-cause hospitalizations and ED visits. These IRRs were adjusted for age, sex, household location, median household income quintile, CKD-related comorbidities, and albuminuria severity. The analysis was repeated to determine the association between continuity of primary care and rates of CKD-related ACSC hospitalizations and ED visits. Stata 16 was used for all analyses (Stata Corp., College Station, TX) (56). The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) (57) and Reporting of studies Conducted using Observational Routinely-collected Data (RECORD) (58) guidelines were used (**Appendix F**). This project was approved by the University of Calgary Conjoint Health Research Ethics Board.

2.4 Results

Baseline Characteristics

There were 1,234,672 registered adults (aged 18 years and older) with at least two outpatient serum creatinine measurements between April 1, 2011 to March 31, 2014 in Alberta (**Figure 1**). We excluded individuals with no CKD diagnosis and those that had recovering kidney function and identified 94,596 individuals diagnosed with CKD. Individuals who were dialysis dependent, received a kidney transplant, or had kidney failure were excluded. Finally, those with less than three outpatients visits with a single primary care provider during the two years prior to CKD diagnosis were also excluded,

resulting in a final cohort of 86,475 individuals.

The mean age of the overall cohort was 76.0 ± 11.2 years and 56.6% of the individuals were females (**Table 1**). Fifty one percent of individuals had high continuity, 30.0% had moderate continuity and 18.7% had poor continuity. When stratified by CKD stage, the majority (52.5%) of individuals with CKD stage 3a had high continuity, while the proportion with poor continuity increased with later stages of CKD (**Appendix G**). Approximately 22.7% of patients with stage 4 CKD had poor continuity. Individuals with poor continuity were more likely to live in a rural residential location, have severe albuminuria, and have a higher mean number of comorbidities compared to individuals with moderate or high continuity. The proportion of individuals with CKD-related comorbidities (e.g., hypertension, diabetes, chronic heart failure, atrial fibrillation, peripheral vascular disease (PVD)) were highest among the poor continuity group. Approximately 12% of the cohort saw a nephrologist at least once, and the largest proportion of visits to any specialist (e.g., nephrologist, endocrinologist, oncologist, etc.) were among individuals with poor continuity.

All-Cause Acute Care Use

Overall, there were 77,988 all-cause hospitalizations among 34,810 individuals with CKD with a median follow-up time of 2.3 years (IQR: 1.5 – 2.8 years) (**Table 2**). Individuals with poor and moderate continuity of primary care accounted for almost 60% of all-cause hospitalizations. The median cumulative length of stay was shortest among those with high continuity (11 days (IQR: 4 – 33 days)) compared to moderate (13 days (IQR: 5 – 39 days)) and poor continuity groups (15 days (IQR: 6 – 42 days)). The number

of all-cause ED visits was 204,615 among 51,152 individuals with CKD. Similar to all-cause hospitalizations, 62% of ED visits were among individuals with poor and moderate continuity. The poor continuity group had a higher median number of ED visits (2 visits (IQR: 0 – 4 visits)) than those with moderate (1 visit (IQR: 0 – 3 visits)) and high continuity (1 visit (IQR: 0 – 2 visits)).

Among individuals with CKD, the poor continuity group had unadjusted hospitalization and ED visit rates that were approximately double the rates observed among the high continuity group (613.5 (95% CI: 605.6 – 622.7) vs. 344.9 (95% CI: 341.9 – 349.4) hospitalizations per 1,000 person days; 1,757.2 (95% CI: 1,744.3 – 1,773.3) vs. 823.4 (95% CI: 817.6 – 829.2) ED visits per 1,000 person days). Adjusting for relevant confounders, individuals with poor continuity of care were 1.52 (95% CI: 1.47 – 1.57) and 1.78 (95% CI: 1.73 – 1.83) times more likely to experience an all-cause hospitalization and ED visit, respectively, compared to individuals with high continuity of care (**Figure 2**).

Similar trends were observed in a stepwise fashion across CKD stage 3a, 3b and 4, with poor continuity of care being associated with higher rate ratios for all-cause hospitalizations and ED visits compared to the moderate continuity group (**Figure 3**, **Appendix H, Appendix I**).

Potentially Preventable Acute Care Use

Our cohort had 6,489 (8.3% of all hospitalizations) CKD-related ACSC hospitalizations and 8,461 (4.1% of all ED visits) CKD-related ACSC ED visits. Over half of these ACSC hospitalizations and ED visits were among individuals with poor or

moderate continuity. Ninety-six percent and 86.0% of CKD-related ACSC hospitalizations and ED visits were attributable to heart failure, respectively (**Appendix J**).

The unadjusted CKD-related ACSC hospitalization and ED visit rates among those with poor continuity of care were 53.1 hospitalizations (95% CI: 50.6 – 55.6) and 71.0 ED visits (95% CI: 68.2 – 74.0) per 1,000 person-years, respectively. After adjustment, poor continuity of care was associated with significantly higher ACSC hospitalization (IRR: 1.58 (95% CI: 1.44 – 1.74)) and ED rates (IRR: 1.68 (95% CI: 1.54 – 1.82)) compared to those with high continuity. Similar, yet attenuated, trends were observed for individuals with moderate continuity ($IRR_{hospitalization}$: 1.23 (95% CI: 1.13 – 1.34); $IRR_{ED\ visits}$: 1.28 (95% CI: 1.19 – 1.38)) compared to those with high continuity.

When stratified by CKD stage, rate ratios for ACSC acute care use were significantly higher among individuals with poor continuity and earlier stages of CKD (stages 3a and 3b) (**Figure 4, Appendix K, Appendix L**). No significant differences were observed in the rate ratios for ACSC hospitalizations and ED visits across continuity of primary care among individuals with stage 4 CKD.

2.5 Discussion

In this population-based cohort study, we found that approximately one in five individuals with CKD had poor continuity of primary care in Alberta. Rates of all-cause hospitalization and ED use increased with poorer continuity of primary care and followed a stepwise fashion across CKD stage. Poor continuity of primary care was also associated with higher rates of CKD-related ACSC hospitalization and ED visits among patients

with earlier stages of CKD. These findings provide preliminary evidence into the importance of relational continuity of primary care among adults with earlier CKD, as well as the need to identify strategies to improve coordination of primary, acute, and specialist care for this high-risk patient population.

Relational continuity of primary care has been well explored in patient populations with various chronic conditions. Worrall *et al.* reported that 27.2% of patients with diabetes in Newfoundland and Labrador, Canada had poor continuity of primary care (59). Among adults in Taiwan with asthma and chronic obstructive pulmonary disease (COPD), approximately 22.4% had poor continuity of care (60). Further, increases in healthcare costs, all-cause hospitalizations, ED visits, and death as continuity of care decreased have also been reported among individuals with asthma (60), COPD (60), cancer (61), and diabetes (59, 62). These findings suggest that poor relational continuity of primary care is common and is associated with increased all-cause acute care use across multiple populations with various chronic conditions. To our knowledge, we are the first Canadian study to have extended these findings to a cohort of individuals with CKD and have demonstrated that poor relational continuity of primary care is associated with high rates of hospitalizations and ED visits that are potentially preventable. Similar to many chronic conditions, CKD is a complex chronic condition that relies on coordinated care between primary care and specialty care teams to delay irreversible progression of kidney loss and downstream cardiovascular complications (63, 64). Considering that CKD often involves the management of several comorbidities (e.g., diabetes, hypertension, heart failure, PVD) (7), primary care plays an essential role in the early identification and management of less advanced CKD and concordant comorbidities

that contribute to kidney function preservation. Thus, strong relational continuity of primary care has the potential to delay the progression of kidney loss and reduce kidney related complications that contribute to acute care utilization. Understanding how relational continuity in primary care settings can be enhanced in this complex population is essential to inform targeted strategies that will reduce potentially preventable acute care encounters.

Our findings highlight that in earlier stages of CKD prior to routine consultation with a nephrologist, the rates of potentially preventable hospitalizations and ED visits increased as continuity of primary care decreased. Previous work has reported that the risk of CKD-related ACSC hospitalization increased with declining kidney function (14), suggesting that optimizing continuity of care with a primary care provider among those with CKD could reduce hospitalizations and ED visits for potentially preventable reasons. Within primary care practices in Canada that manage individuals with CKD, there are currently gaps in care regarding prescribing guideline-concordant preventive medications (e.g., angiotensin-converting enzyme inhibitors, and angiotensin receptor blockers), and routine monitoring and testing for albuminuria (65, 66). These gaps in care are likely contributing to CKD-related ACSC acute care encounters. To achieve guideline-recommended CKD care, strategies that focus on improving primary care continuity have been proposed and they include booking patients to visit their usual primary care provider at least 80% of the time, improving access to appointments, measuring and tracking continuity over time, and reducing physician turnover (22, 67). Primary care reforms have also been initiated to optimize primary care continuity, access, and quality of care (68). For example, Ontario (Canada) adopted a patient rostering model

for primary care practice through the implementation of Family Health Teams in 2005 (69) and it has led to reductions in ED visits, larger cost savings, and improvements in patient-reported access to primary care services (70, 71). It would be of interest to understand if this model, in addition to other provider payment models involving capitation payments, have the potential to improve continuity of primary care and reduce potentially preventable acute care encounters within the context of Alberta. Our findings also underscore the role of a nephrologist for individuals with stage 4 CKD who are transitioning into nephrology care. Specifically, timely and appropriate referral to a nephrologist, as recommended in the KDIGO guidelines when a patient enters stage 4 CKD (eGFR < 30 mL/min/1.73m^2) (2), may compliment continuity of care at the primary care level and reduce mortality rates (72) across CKD stages. Overall, high continuity of primary care is a process of patient-centered care that should be promoted in the CKD population in all levels of healthcare as it appears to have a protective role against potentially preventable CKD-related acute care encounters.

We found that the most common CKD-related ACSC hospitalizations and ED visits were for heart failure. Individuals with kidney failure and requiring dialysis are usually at greatest risk for developing heart failure (73-75); however, our findings suggest that a large percentage of potentially preventable acute care use for heart failure occurred among those with stages 3 and 4 CKD. Currently, there are numerous strategies for reducing heart failure among non-dialysis dependent patients. They include cardiac-resynchronization therapy, dietary interventions to control fluid overload, and use of pharmacologic medications like beta-blockers, renin-angiotensin-aldosterone antagonists, loop diuretics, and nitrates (76-78). Considering that patients with less advanced stages of

CKD are primarily managed in the primary care setting but begin transitioning into nephrology care during stage 4 CKD, heart failure strategies that apply a multidisciplinary team approach across primary care, cardiology, and nephrology care have been a practical and effective way to manage and prevent acute decompensation among this complex population (78-80). Consistent evidence has shown that this approach has led to reduced hospitalizations, all-cause mortality, and improved quality of life measures among non-CKD patients (81-83). Future research should target underlying comorbidities that are common among patients with CKD, notably heart failure, using primary care strategies to reduce potentially preventable acute care use and the associated costs.

Our study has several limitations that should be considered. Firstly, we were only able to include individuals diagnosed with CKD using laboratory measurements and would not have captured individuals who did not utilize laboratory services. However, this number is expected to be relatively small and unlikely to invalidate the findings from this study as we used population-level laboratory data from the AKDN repository. Additionally, we classified CKD diagnosis using at least two eGFR measurements taken at least 90 days apart which should have minimized potential misclassification bias of individuals with acute kidney injury. This definition is commonly used (84-86) and follows internationally recommended kidney guidelines (i.e., KDIGO) (2). A second limitation in our study is that the UPC index did not consider patient and provider perceptions and experiences of relational continuity of primary care. The individual reasons for seeking acute care services were also not captured which suggests an opportunity for future qualitative research to explore patients' and providers' continuity

of care and acute care utilization experiences. Future studies should also describe the other aspects of continuity of primary care (informational and managemental continuity) among adults with CKD in order to gain a comprehensive understanding of continuity of care for this high-risk patient population. Lastly, we used CKD-related ACSCs to infer potentially preventable hospitalizations and ED visits, which represents a spectrum of preventability that are influenced by a number of social determinants of health that are not captured within our administrative data sources. While we were able to account for important patient-level factors (e.g., residential location, neighbourhood income, etc.) related to increased risk for acute care use within our adjusted analysis, future work should consider including additional elements related to CKD-specific quality of care indicators, such as the management of blood pressure and glycemia.

2.6 Conclusion

In summary, approximately one in five individuals with CKD had poor continuity of primary care and the rate of all-cause and potentially preventable acute care use significantly increased with poor continuity of care. Our study suggests that due to these observed associations, reductions in potentially preventable CKD-related acute care encounters may be realized through healthcare models and policies that strengthen patient-provider relationships at the primary care level among individuals with less advanced stages (stage 3a and 3b) of CKD. Targeted interventions aimed at those with specific comorbidities (e.g., heart failure) or individuals transitioning into nephrology care may potentially lead to decreased reliance on acute care use for common CKD-related ACSCs. This work describes relational continuity, which is only one aspect of

continuity of primary care among the CKD population and further research into informational and managemental continuity of care is needed to improve patient experiences, patient-centred care, and health outcomes.

2.7 Declarations

Ethical Approval and Consent to Participate

Ethics approval for the study was obtained from the conjoint health ethics review board at the University of Calgary. As this study uses secondary data, individual patient consent was not required.

Availability of Data and Materials

This study is based in part by data provided by Alberta Health and Alberta Health Services. The interpretation and conclusions are those of the researchers and do not represent the views of the Government of Alberta. Neither the Government of Alberta nor Alberta Health express any opinion in relation to this study.

CC and PR had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. We are not able to make our data set available to other researchers due to our contractual arrangements with the provincial health ministry (Alberta Health), who is the data custodian.

Competing Interests

The authors declare that there is no conflict of interest.

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CC and PR were involved in the conception and design of the study. CC and PR were responsible for drafting the manuscript and interpreting the data. CC and JW contributed to the study design and conducted the analysis. CC, PR, ME, FA, and DC contributed to the conception and interpretation of study findings. All authors were responsible for revising the manuscript for important intellectual content, approved the final version, and agree to be accountable for all aspects of the work.

2.8 Tables and Figures

Table 1. Patient demographic and clinical characteristics by continuity of primary care.

Patient Characteristics	Level of Relational Continuity of Primary Care			Overall
	Poor	Moderate	High	
Number of individuals (%)	16,143 (18.7)	25,948 (30.0)	44,384 (51.3)	86,475 (100.0)
CKD stage, n (%)				
3a (45-59 ml/min per 1.73m^2)	9,153 (56.7)	15,489 (59.7)	27,274 (61.5)	51,916 (60.0)
3b (30-44 ml/min per 1.73m^2)	5,145 (31.9)	7,960 (30.7)	13,313 (30.0)	26,418 (30.6)
4 (15-29 ml/min per 1.73m^2)	1,845 (11.4)	2,499 (9.6)	3,797 (8.6)	8,141 (9.4)
Age, mean (SD)	76.1 (12.6)	75.7 (11.4)	76.2 (10.5)	76.0 (11.2)
Age category, n (%)				
18-44	360 (2.2)	357 (1.4)	364 (0.8)	1,081 (1.3)
45-64	2,469 (15.3)	3,930 (15.1)	5,880 (13.2)	12,279 (14.2)
65-74	3,611 (22.4)	6,697 (25.8)	11,926 (26.9)	22,234 (25.7)
75-84	5,571 (34.5)	9,492 (36.6)	17,326 (39.0)	32,389 (37.5)
85+	4,132 (25.6)	5,472 (21.1)	8,888 (20.0)	18,492 (21.4)
Females, n (%)	9,571 (59.3)	14,902 (57.4)	24,483 (55.2)	48,956 (56.6)
Location of residence, n (%)				
Urban	13,221 (82.0)	21,978 (84.8)	40,339 (91.0)	75,538 (87.5)
Rural	2,909 (18.0)	3,932 (15.2)	3,988 (9.0)	10,829 (12.5)
Albuminuria, n (%)				
Normal/mild (A1)	7,601 (47.1)	13,458 (51.9)	23,991 (54.1)	45,050 (52.1)
Moderate (A2)	2,021 (12.5)	3,221 (12.4)	5,660 (12.8)	10,902 (12.6)
Severe (A3)	1,440 (8.9)	2,007 (7.7)	2,979 (6.7)	6,426 (7.4)
Unmeasured	5,081 (31.5)	7,262 (28.0)	11,754 (26.5)	24,097 (27.9)
Median household income quintile, n (%)				
1 (lowest)	4,627 (28.7)	6,944 (26.8)	11,130 (25.1)	22,701 (26.3)
2	3,673 (22.8)	5,893 (22.7)	10,036 (22.6)	19,602 (22.7)
3	2,958 (18.3)	5,012 (19.3)	8,735 (19.7)	16,705 (19.3)
4	2,246 (13.9)	3,687 (14.2)	6,576 (14.8)	12,509 (14.5)
5 (highest)	2,062 (12.8)	3,686 (14.2)	6,986 (15.7)	12,734 (14.7)
6 = Unknown	577 (3.6)	726 (2.8)	921 (2.1)	2,224 (2.6)
Comorbidities, n (%)				
Asthma	1,106 (6.9)	1,385 (5.3)	1,699 (3.8)	4,190 (4.9)
Atrial fibrillation	3,472 (21.5)	4,741 (18.3)	7,241 (16.3)	15,455 (17.9)
Cancer	1,723 (10.7)	2,573 (9.9)	3,785 (8.5)	8,081 (9.3)
Congestive heart failure (CHF)	4,635 (28.7)	5,785 (22.3)	8,068 (18.2)	18,488 (21.4)
Chronic obstructive pulmonary disease (COPD)	5,379 (33.3)	7,239 (27.9)	10,000 (22.5)	22,618 (26.2)
Cirrhosis	168 (1.0)	142 (0.6)	186 (0.4)	496 (0.6)
Diabetes mellitus	5,871 (36.4)	8,848 (34.1)	15,497 (34.9)	30,216 (34.9)
Hypertension	14,008 (86.8)	22,293 (85.9)	38,475 (86.7)	74,776 (86.5)
Peripheral vascular disease (PVD)	1,084 (6.7)	1,413 (5.5)	2,052 (4.6)	4,549 (5.3)
# of comorbidities, mean (SD)	3.9 (2.3)	3.3 (2.0)	3.0 (1.8)	3.2 (2.0)
Number of people with at least one visit to a specialist in a 2 year-period before index date, n (%)				
Nephrology	2,350 (14.6)	3,228 (12.4)	4,788 (10.8)	10,366 (12.0)
Endocrinology	187 (1.2)	228 (0.9)	310 (0.7)	725 (0.8)
Oncology	49 (0.3)	39 (0.2)	34 (0.1)	122 (0.1)
Psychiatry	1,756 (10.9)	1,591 (6.1)	1,591 (3.6)	4,938 (5.7)
Cardiology	4,332 (26.8)	6,344 (24.5)	10,001 (22.5)	20,677 (23.9)
Respiratory	1,600 (9.9)	2,198 (8.5)	2,797 (6.3)	6,595 (7.6)
Internal medicine	9,095 (56.3)	13,088 (50.4)	20,713 (46.7)	42,896 (49.6)

Table 2. All-cause and ambulatory care-sensitive condition (ACSC) related hospitalizations and Emergency Department (ED) visit characteristics by continuity of primary care.

	Characteristics	Level of Relational Continuity of Primary Care			Overall N = 86,475
		Poor (n = 16,143)	Moderate (n = 25,948)	High (n = 44,384)	
All-cause hospitalization	Number of individuals	7,938	11,020	15,852	34,810
	Total number of hospitalizations (% of all hospitalizations)	19,835 (25.4)	25,551 (32.8)	32,602 (41.8)	77,988 (100.0)
	Number of hospitalizations, median (IQR)	0 (0 – 2)	0 (0 – 1)	0 (0 – 1)	0 (0 – 1)
	Person-time, years (% of all person-time)	32,328.8 (17.9)	53,698.6 (29.7)	94,520.5 (52.4)	180,547.9 (100.0)
	Length of hospital stays, days, mean (SD)	13.7 (21.1)	12.8 (19.2)	12.7 (20.0)	12.9 (20.0)
	Length of hospital stays, days, median (IQR)	0 (0 – 7)	0 (0 – 5)	0 (0 – 4)	0 (0 – 5)
	Cumulative length of hospital stays, days, median (IQR)	15 (6 – 42)	13 (5 – 39)	11 (4 – 33)	13 (5 – 37)
	Unadjusted hospitalization rate per 1,000 p-y (95% CI)	613.5 (605.6 – 622.7)	475.8 (470.2 – 481.9)	344.9 (341.9 – 349.4)	432.0 (429.5 – 435.6)
ACSC-related hospitalization	Number of individuals	1,095	1,369	1,842	4,306
	Total number of ACSC hospitalizations (%)	1,714 (26.4)	2,045 (31.5)	2,730 (42.1)	6,489 (100.0)
	Number of ACSC hospitalizations, median (IQR)	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)
	Person-time, years (% of all person-time)	32,328.8 (17.9)	53,698.6 (29.7)	94,520.5 (52.4)	180,547.9 (100.0)
	Length of hospital stays, days, mean (SD)	1.6 (6.7)	1.4 (5.7)	1.4 (6.0)	1.4 (6.1)
	Length of hospital stays, days, median (IQR)	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)
	Cumulative length of hospital stays, days, median (IQR)	0 (0 – 7)	0 (0 – 5)	0 (0 – 4)	0 (0 – 5)
	Unadjusted ACSC hospitalization rate per 1,000 p-y (95% CI)	53.1 (50.6 – 55.6)	38.1 (36.5 – 39.8)	28.9 (27.9 – 30.1)	36.0 (35.1 – 36.9)
All-cause ED visit	Number of individuals	11,234	16,237	23,681	51,152
	Total number of ED visits (%)	56,809 (27.8)	70,147 (34.3)	77,659 (38.0)	204,615 (100.0)
	Number of ED visits, median (IQR)	2 (0 – 4)	1 (0 – 3)	1 (0 – 2)	1 (0 – 3)
	Person-time, years (% of all person-time)	32,328.8 (17.9)	53,698.6 (29.7)	94,520.5 (52.4)	180,547.9 (100.0)
	Unadjusted ED visit rate per 1,000 p-y (95% CI)	1,757.2 (1,744.3 – 1,773.3)	1,306.3 (1,297.2 – 1,316.5)	823.4 (817.6 – 829.2)	1,133.3 (1,129.9 – 1,139.8)
ACSC-related ED visit	Number of individuals	1,414	1,731	2,272	5,417
	Total number of ACSC ED visits (%)	2,294 (27.1)	2,726 (32.2)	3,441 (40.7)	8,461 (100.0)
	Number of ACSC ED visits, median (IQR)	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)
	Person-time, years (% of all person-time)	32,328.8 (17.9)	53,698.6 (29.7)	94,520.5 (52.4)	180,547.9 (100.0)
	Unadjusted ACSC ED visit rate per 1,000 p-y (95% CI)	71.0 (68.2 – 74.0)	50.8 (48.9 – 62.7)	36.5 (35.3 – 37.7)	46.9 (45.9 – 47.9)

Table 3. Unadjusted and adjusted incident rate ratios for all-cause and ambulatory care-sensitive condition (ACSC) related hospitalizations and Emergency Department (ED) visit by continuity of primary care.

	Variables	Level of Relational Continuity of Primary Care			Overall
		Poor (n = 16,143)	Moderate (n = 25,948)	High (n = 44,384)	N = 86,475
All-cause hospitalization	Number of individuals	7,938	11,020	15,852	34,810
	Number of all-cause hospitalizations	19,835	25,551	32,602	77,988
	Unadjusted incident rate ratio of all-cause hospitalizations (95% CI)	1.85 (1.79 – 1.91)	1.41 (1.37 – 1.45)	[Reference]	
	Adjusted* incident rate ratio of all-cause hospitalizations (95% CI)	1.52 (1.47 – 1.57)	1.28 (1.25 – 1.32)	[Reference]	
ACSC-related hospitalization	Number of individuals	1,095	1,369	1,842	4,306
	Number of ACSC-related hospitalizations	1,714	2,045	2,730	6,489
	Unadjusted incident rate ratio of ACSC-related hospitalizations (95% CI)	1.96 (1.77 – 2.16)	1.35 (1.24 – 1.48)	[Reference]	
	Adjusted** incident rate ratio of ACSC-related hospitalizations (95% CI)	1.58 (1.44 – 1.74)	1.23 (1.13 – 1.34)	[Reference]	
All-cause ED visit	Number of individuals	11,234	16,237	23,681	51,152
	Number of all-cause ED visits	56,809	70,147	77,659	204,615
	Unadjusted incident rate ratio of all-cause ED visits (95% CI)	2.18 (2.12 – 2.24)	1.60 (1.56 – 1.64)	[Reference]	
	Adjusted* incident rate ratio of all-cause ED visits (95% CI)	1.78 (1.73 – 1.83)	1.42 (1.39 – 1.46)	[Reference]	
ACSC-related ED visit	Number of individuals	1,414	1,731	2,272	5,417
	Number of ACSC-related ED visits	2,294	2,726	3,441	8,461
	Unadjusted incident rate ratio of ACSC-related ED visits (95% CI)	2.10 (1.92 – 2.29)	1.44 (1.33 – 1.55)	[Reference]	
	Adjusted** incident rate ratio of ACSC-related ED visits (95% CI)	1.68 (1.54 – 1.82)	1.28 (1.19 – 1.38)	[Reference]	

* Adjusted by age, sex, household location, median household income quintile, cirrhosis, chronic heart failure, peripheral vascular disease, atrial fibrillation, asthma, chronic obstructive pulmonary disease, cancer, diabetes, hypertension, and albuminuria severity.

** Adjusted by age, sex, household location, median household income quintile, cirrhosis, peripheral vascular disease, atrial fibrillation, asthma, chronic obstructive pulmonary disease, cancer, diabetes, and albuminuria severity.

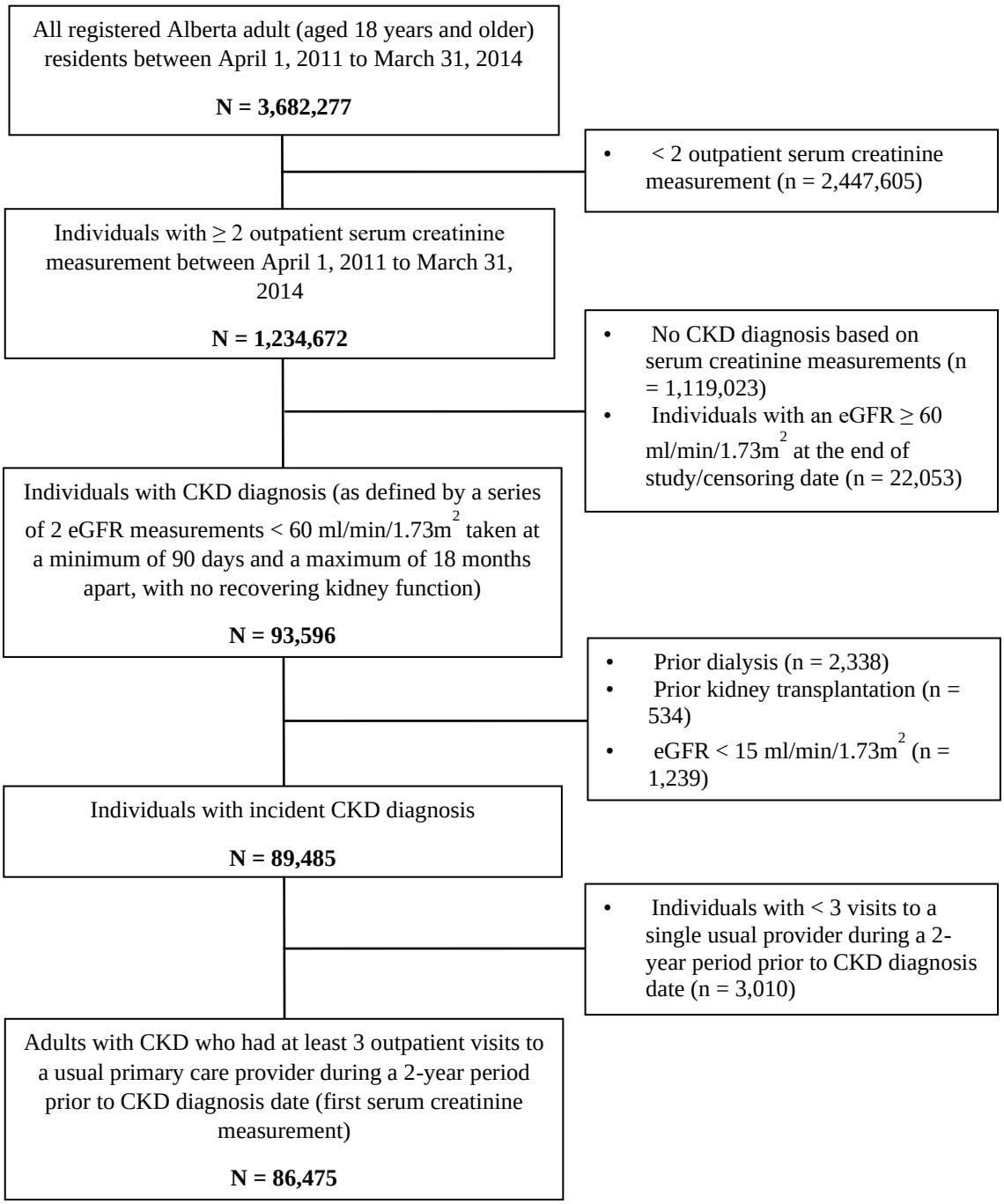


Figure 1. Criteria to determine the final study cohort.

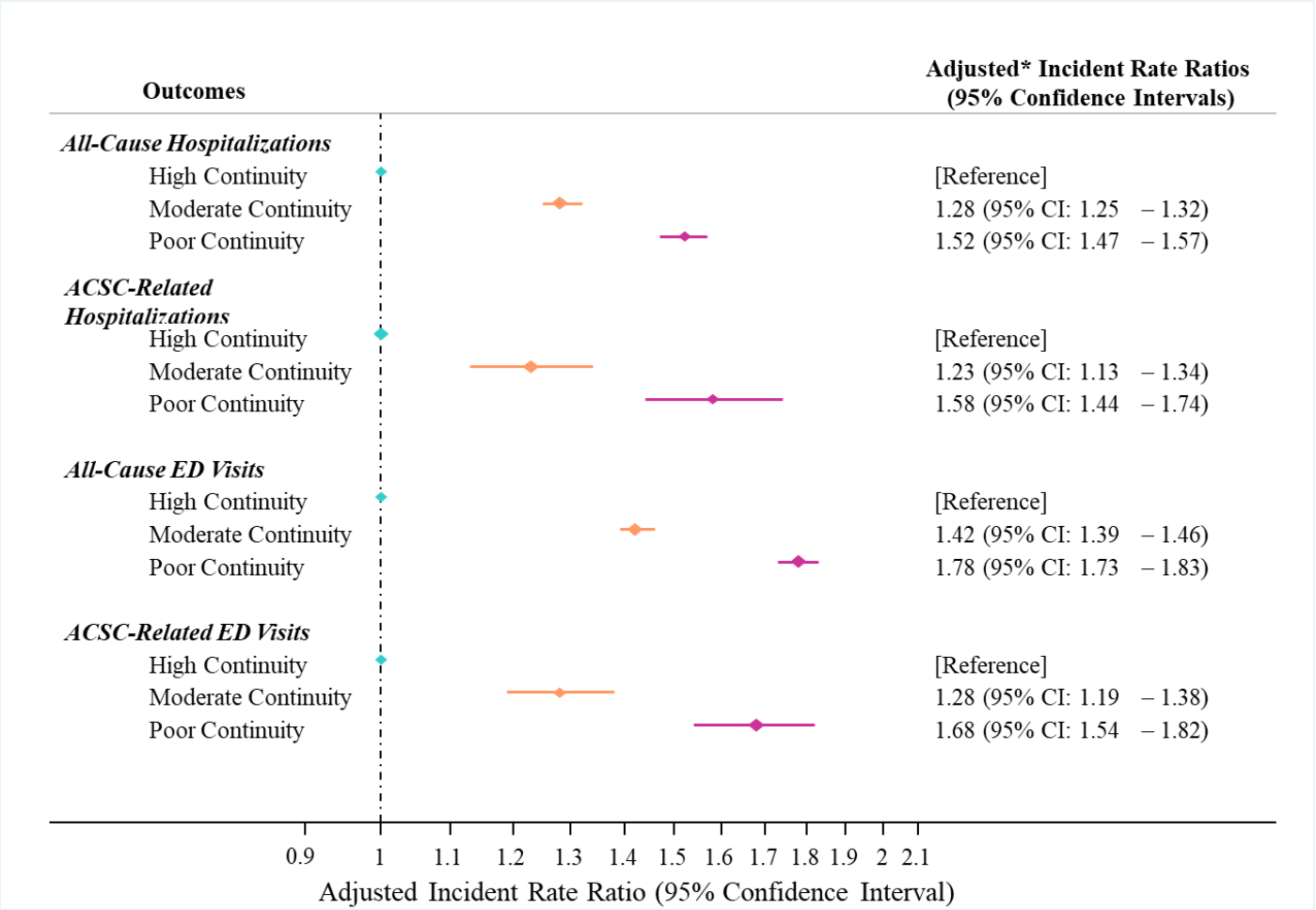
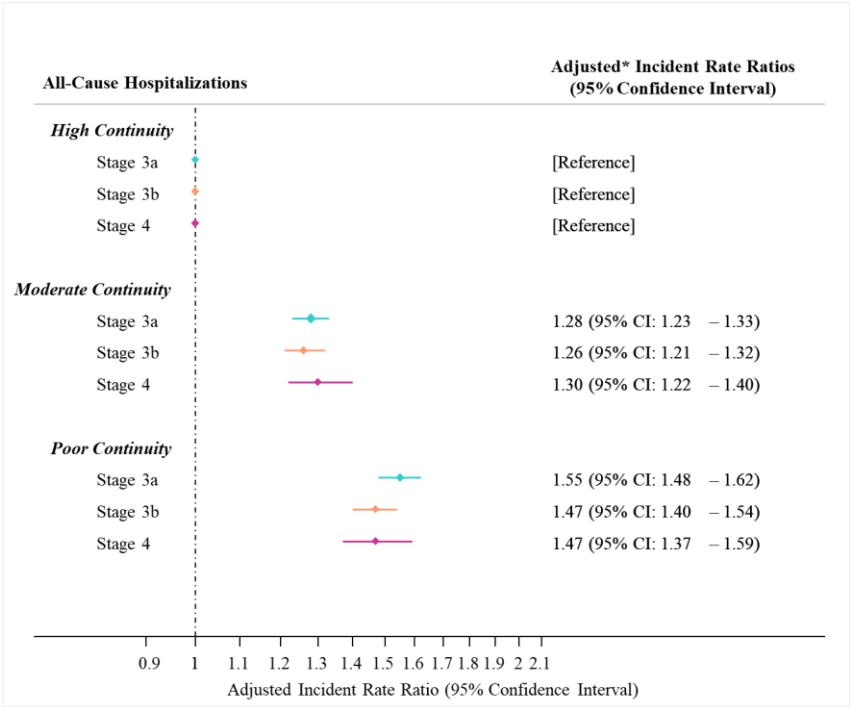


Figure 2. The association between continuity of primary care and incident rate ratios of all-cause and ambulatory care-sensitive conditions (ACSC) hospitalizations and Emergency Department (ED) visits.

* All-cause models adjusted by age, sex, household location, median household income quintile, cirrhosis, chronic heart failure, peripheral vascular disease, atrial fibrillation, asthma, chronic obstructive pulmonary disease, cancer, diabetes, hypertension, and albuminuria severity. ACSC-related models adjusted by age, sex, household location, median household income quintile, cirrhosis, peripheral vascular disease, atrial fibrillation, asthma, chronic obstructive pulmonary disease, cancer, diabetes, and albuminuria severity.



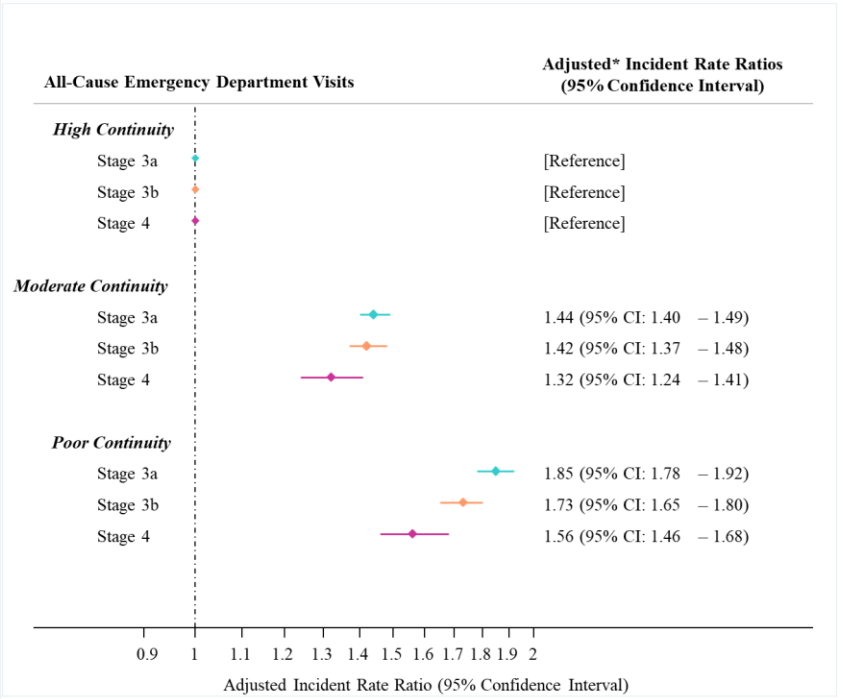


Figure 3. The association between continuity of primary care and incident rate ratios of all-cause hospitalizations and Emergency Department (ED) visits by CKD stage.

* Adjusted by age, sex, household location, median household income quintile, cirrhosis, chronic heart failure, peripheral vascular disease, atrial fibrillation, asthma, chronic obstructive pulmonary disease, cancer, diabetes, hypertension, and albuminuria severity.

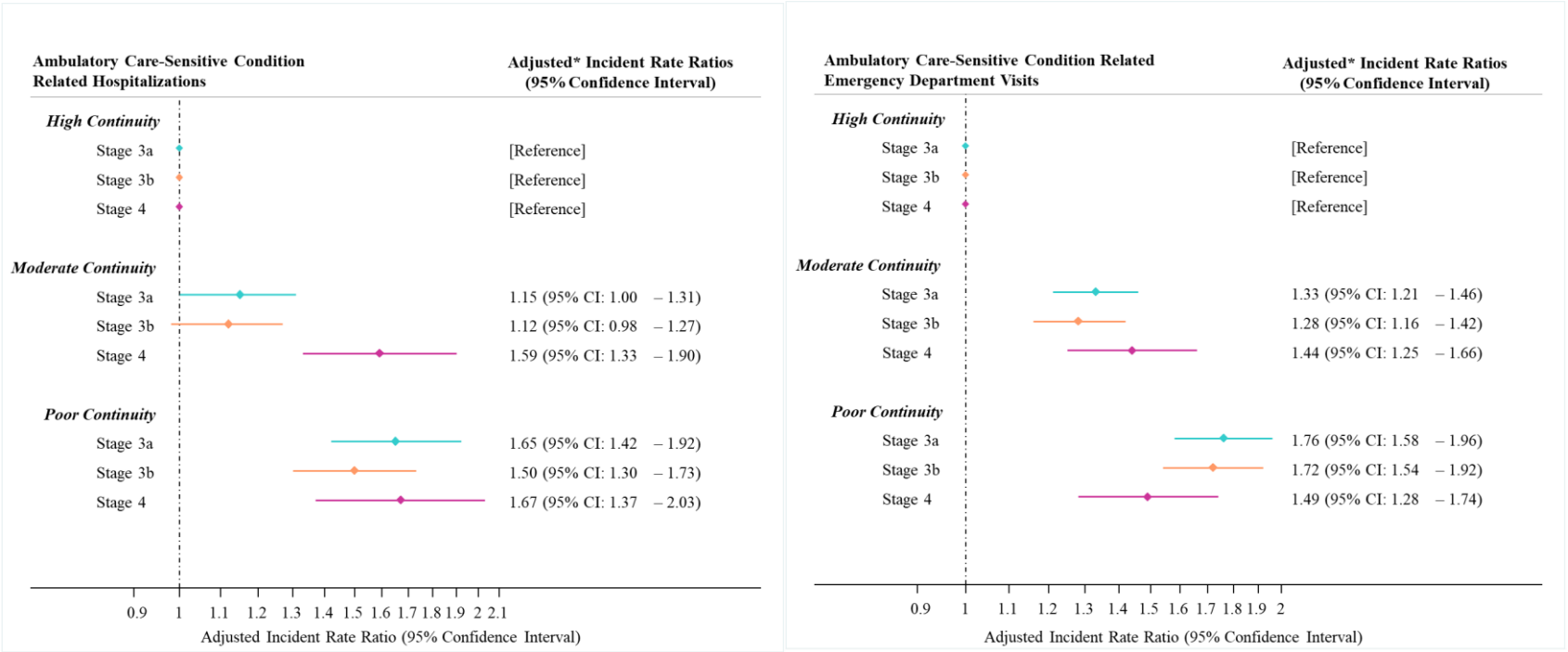


Figure 4. The association between continuity of primary care and incident rate ratios of ambulatory care-sensitive conditions (ACSC) hospitalizations and Emergency Department (ED) visits by CKD stage.

* Adjusted by age, sex, household location, median household income quintile, cirrhosis, peripheral vascular disease, atrial fibrillation, asthma, chronic obstructive pulmonary disease, cancer, diabetes, and albuminuria severity.

CHAPTER THREE: DISCUSSION

3.1 Summary of Research Findings

Among non-CKD populations, high relational continuity of primary care has been associated with improvements in patient management and patient-reported outcomes (34, 40-43). However, there is a paucity of evidence on relational continuity of primary care among individuals with CKD and how it is related to all-cause and potentially preventable acute care use. The objectives of this thesis were to describe the relational continuity of primary care received among adults with CKD in Alberta and determine if poor relational continuity of care was associated with higher rates of all-cause and CKD-related ACSC hospitalization and ED visits.

Using provincial administrative and laboratory data, we found that approximately one in five individuals with CKD had poor continuity of primary care in Alberta. Individuals with poor continuity were more likely to live in a rural residential location, have severe albuminuria, and have a higher number of comorbidities compared to individuals with moderate or high continuity. Where continuity of primary care was poorer, the rates of all-cause hospitalization and ED use were higher, in a stepwise fashion across CKD stage. Additionally, similar trends were observed across earlier stages of CKD (stage 3a and 3b), with poor continuity of care being associated with higher rates of CKD-related ACSC hospitalizations and ED visits.

3.2 Results of this Study within the Context of Existing Literature

Relational continuity of care within primary care settings has been widely recognized as an important health care metric, and studies have shown that high continuity with a single primary care provider is a critical factor in improving patient

satisfaction, medical adherence, and patient-centered care (34, 40-43). Despite the known benefits of strong interpersonal relationships between patients and their primary care providers, poor relational continuity of primary care continues to be common among the general population. Two studies conducted in Quebec and Manitoba estimated that approximately 21 – 36% of individuals have poor continuity of primary care (87, 88) and high continuity of care has been associated with reduced odds of an ACSC hospitalization (89). Similar results have been observed among chronic disease populations. For example, 27% of individuals with diabetes in Newfoundland and Labrador, Canada (59) and 22% of individuals with asthma and COPD in Taiwan had poor continuity of primary care (60). Additionally, among populations with asthma (60), COPD (60), cancer (61), and diabetes (59, 62), poor continuity of care has been associated with increased healthcare costs, all-cause hospitalizations, ED visits, and death. As described in Chapter 1, many of the existing studies in relational continuity of care and CKD have focused on individuals with late stages of CKD (i.e., kidney failure or dialysis dependence) and found that poor continuity was not associated with increased risk of mortality and all-cause hospitalization (35). In our population of individuals with less advanced stages of CKD (particularly stage 3 CKD), we demonstrated that poor relational continuity of primary care was associated with high rates of hospital and ED encounters for all-cause and potentially preventable reasons. These discrepant findings may be a function of who is providing care to these patients as those with stage 3 CKD are often managed by primary care providers alone with little involvement from nephrologists. Our work suggests that high relational continuity of primary care may have the potential to reduce kidney-related complications that contribute to unnecessary

acute care utilization among those with earlier stages of CKD.

3.3 Strengths

There are numerous strengths of this research. Firstly, we utilized data from the AKDN repository of laboratory and administrative data from Alberta, Canada. This dataset retrieves, stores, and maintains laboratory tests for approximately 4.5 million individuals who accessed any laboratory within Alberta (48). This enabled us to identify virtually all individuals with CKD based on the availability of this population-level laboratory data to assess the association between continuity of primary care and rates of all-cause and potentially preventable acute care use.

Secondly, we were able to link laboratory data using unique patient identifiers to other computerized data sources (i.e., DAD, NACRS, Physician Claims, and the Alberta Health Registry File) to collect detailed health outcomes and resource utilization metrics. It also provided information about clinical and select demographic characteristics, which were useful for adjusting for potential effect measure modifying and confounding variables. Specifically, we were able to capture information on age, sex, residential location, neighbourhood income, albuminuria severity, and common chronic medical conditions.

Lastly, previous studies have determined diagnosis of CKD using a single eGFR measurement < 60 mL/min/1.73m^2 (90) which increases the probability of misclassification bias. Specifically, individuals may be misclassified as having CKD if they in fact had an acute kidney injury – a state where kidney function rapidly declines and may subsequently recover as this also relies on eGFR measurements for diagnosis

(91). Considering that this form of kidney damage is commonly diagnosed within hospital settings compared to outpatient primary care settings, the proportion of individuals that would have been potentially misclassified as having acute kidney injury within the community is expected to be small. In our study, we minimized this form of bias to ensure that incident cases of CKD were not overestimated by defining CKD using two eGFR measurements that were taken at least 90 days apart. This definition is commonly used (84-86) and follows internationally recommended kidney guidelines (2).

3.4 Limitations

There are limitations in our study that should be considered when interpreting the results. We developed a cohort of individuals diagnosed with CKD using serum creatinine laboratory measurements and would not have captured individuals who did not utilize laboratory services. It is possible that we may have missed patients who have undiagnosed CKD and that this group may also be most likely to have poor continuity of care. Given that the AKDN contains provincial-wide data from over 4.5 million adults with CKD, this limitation is unlikely to invalidate the findings from this project as the number of missing patients is likely relatively small.

Although we were able to provide evidence that poor continuity of primary care is common among individuals with CKD and that it is associated with high rates of all-cause and potentially preventable acute care use, we used CKD-related ACSCs to infer potentially preventable hospitalizations and ED visits. ACSCs represent a range of preventability that are likely influenced by clinical factors (i.e., symptom severity, medication adherence) as well as several social determinants of health (i.e., level of social

and family support, access to community resources, educational level, employment status, etc.) (92). These factors were not captured within our administrative data sources and may be related to both continuity of care and the rates of all-cause and potentially preventable acute care encounters observed in this study. We were able to account for important social factors (i.e., residential location, neighbourhood income, etc.) that are related to increased risk of acute care use within our adjusted analyses. However, these were aggregate level markers that aimed to represent individual-level socioeconomic status and may result in residual confounding or potential misclassification within our cohort. In order to develop preventative, upstream solutions to reduce unnecessary acute care use in this medically complex population, the patients' and caregivers' lived experiences, social determinants of health, and potential barriers that are related to continuity of primary care must be better understood. This requires the need for surveys and/or medical chart reviews to capture this level of detail, which is often not feasible for population-level studies.

3.5 Future Directions and Policy Implications

Enhancing CKD management within primary care and reducing potentially preventable acute care encounters are research priorities for patients and other CKD stakeholders (46, 47). The findings from this thesis contribute to these areas of research but it is important to recognize that further work is needed to create targeted interventions that improve relational continuity of primary care among this medically complex group.

At a ministry of health level, primary care reform strategies have been introduced in Canada and the United States to optimize primary care continuity, address inequities in

access to primary care, and quality of care more broadly (68). For example, primary care practices in Ontario adopted a patient enrollment model called the 'Family Health Teams'. This model of care involves a mutual formal agreement between a collaborative health team and an enrolled patient where, under this agreement, patients will only seek medical care and treatment (excluding emergencies) from their primary care provider (93). In return, their provider will aim to deliver timely and comprehensive care (93). This appears to be an effective method of increasing health care savings, patient-reported access to primary care services, providers' access to patient medical information, and reducing the use of the ED for non-emergent care (70, 71, 93). Additional evidence is still required to determine if this model, in addition to other payment models involving capitation, financial incentives, and premiums, have the potential to improve continuity of primary care and reduce potentially preventable acute care encounters in Alberta.

Given that continuity of care encompasses not only relational, but also managemental and informational continuity, targeted interventions that address all dimensions of continuity may have the largest impact. The use of a province-wide electronic medical record system, such as Alberta Health Services' recently established Connect Care, would be an effective strategy to directly enhance informational continuity of care. The implementation of Alberta Health Services' Connect Care has allowed health care providers within ED and hospital settings to be informed with patient medical history and goals/preferences/values (94, 95). Although the impact from this system is still in the preliminary stages, intuitively, managemental and relational continuity of care should also improve if coordinated and consistent care is provided over time from a provider that a patient trusts. Currently, primary care providers in Alberta are using their

own electronic medical record systems that are not connected to Connect Care. This represents a potential missed opportunity to support continuity across all levels of health care in Alberta. Given the essential role of primary care in effectively managing individuals with CKD and reducing avoidable acute care encounters, further research is needed to understand the barriers (i.e., experience, knowledge, technical support, financial support, time constraints) that exist for such linkages to be made in the future.

As discussed, the findings from this study inform a larger issue surrounding poor continuity of care and high rates of potentially preventable acute care utilization among those with less advanced stages of CKD. The underlying upstream reasons that contribute to poor continuity of care and why patients choose to seek medical care at walk-in clinics, virtual platforms, hospitals, and/or EDs (instead of their usual primary care provider) are unknown. Recent initiatives within Alberta have adopted the use of virtual care/telehealth platforms as a means of increasing access to care, particularly during the COVID-19 pandemic. These modalities may improve access at the expense of continuity and would require further evaluation to determine their effectiveness in chronic disease management. Another extension could use a qualitative approach to explore patients' continuity of care and acute care-seeking experiences. Patient-reported outcome/experience measures have been used to monitor chronic conditions, symptoms, mental health, quality of life, perceived effect of treatment, and patient empowerment/self-management over time, particularly within primary care settings (96-99). Incorporating these measures into future prospective studies may inform solutions to this complex problem. Linkages to provincial primary care electronic medical records would be another valuable avenue that could be pursued to gain insight into the clinical

and social determinants of health that are not available in administrative and laboratory data. For example, the Canadian Primary Care Sentinel Surveillance Network is one potential data source that could be linked to provincial administrative data to further understand chronic disease continuity and how this is related to the rate of acute care use for potentially preventable reasons.

3.6 Knowledge Translation of this Study

Through end-of-grant knowledge translation, the project findings will be disseminated using a multi-faceted approach to various audiences. Advice on the optimal modes of dissemination will be sought from the thesis committee and an experienced knowledge translational broker. Visually appealing and concise social media posts on Twitter will be generated to inform the general public, patients, and academic researchers. Primary care providers and nephrologists will be educated about the findings during presentations at the North American Primary Care Research Group Annual Conference and the Canadian Society of Nephrology Annual General Meeting. A virtual meeting will also be scheduled with the core committee of the Kidney Health Section of the Medicine Strategic Clinical Network (KHSCN) within Alberta Health Services to ensure that they are aware and informed of the findings. The KHSCN is a multi-stakeholder organization that meaningfully incorporates the patient perspective in all of their activities and seeks to improve patient outcomes and experience. During this core meeting, feedback will be sought from the patient advisors to identify additional dissemination methods that will target CKD patients.

3.7 Conclusions

This thesis project reveals the current state of continuity of care received among individuals with CKD through the following key findings. Specifically, we found that approximately one in five individuals with CKD had poor continuity of care with their usual primary care provider. The rates of all-cause and potentially preventable acute care use were significantly higher among those with poor continuity care compared to those with moderate and high continuity of care.

Individuals with CKD in Canada have voiced the need for ED and hospitalization avoidance strategies. This research suggests that reliance on acute care for common CKD-related conditions may be reduced through healthcare models and policies that strengthen patient-provider relationships at the primary care level among individuals with less advanced CKD. Future directions that would expand this work include the development of targeted interventions aimed at specific conditions that drive potentially preventable acute care utilization (e.g., heart failure) in this population. Improving the coordination and transition between primary and nephrology care for individuals with CKD is another area that should be explored. As this work describes one aspect of continuity of primary care among the CKD population, future research exploring other domains of continuity (informational and managemental) may uncover additional mechanisms to improve patient experiences, patient-centred care, and health outcomes.

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APPENDICES:

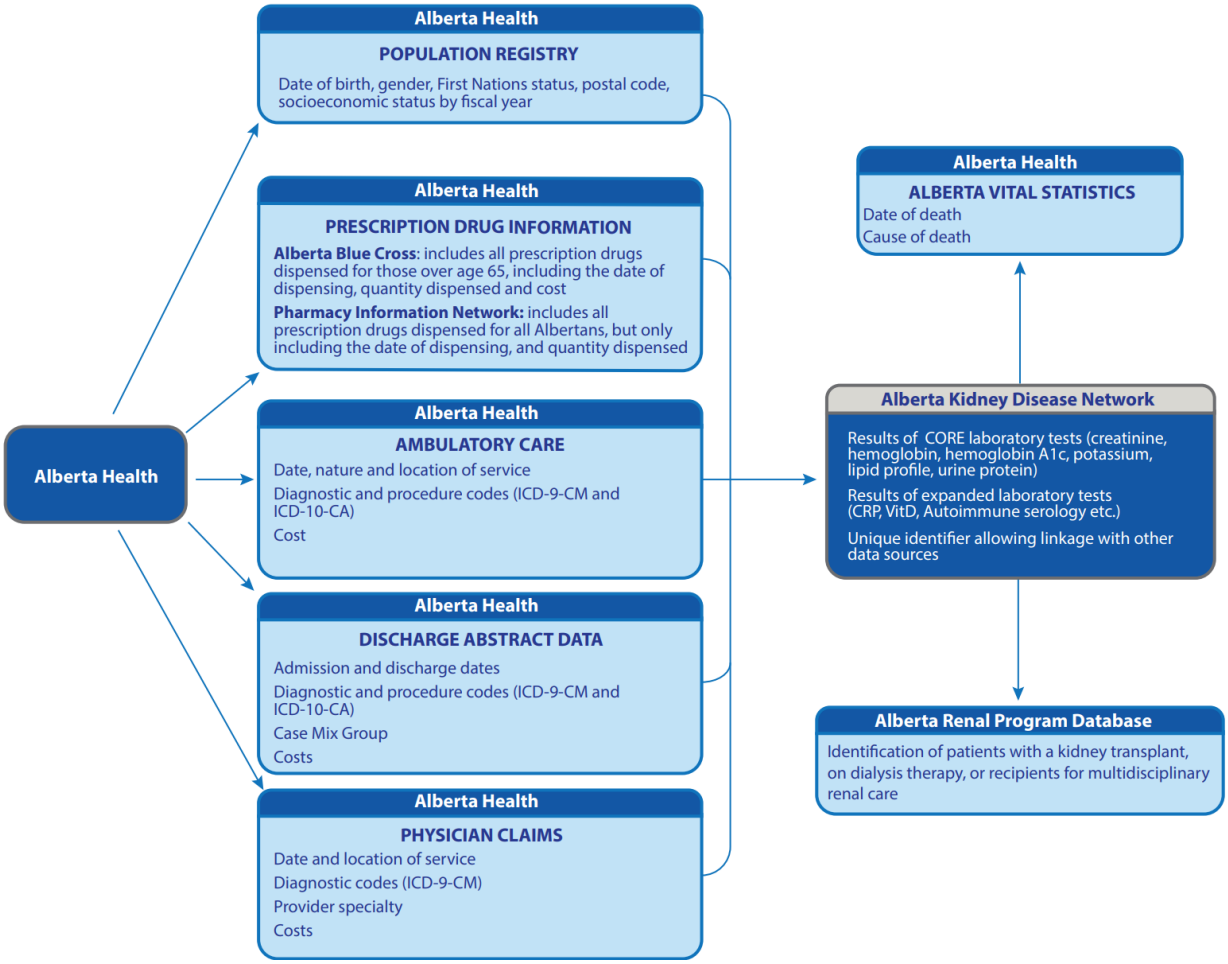
Appendix A: Prognosis of CKD by estimated Glomerular Filtration Rate (eGFR) and Albuminuria Categories (2)

Prognosis of CKD by GFR and Albuminuria Categories

GFR categories (ml/min/1.73 m²) Description and range				Albuminuria categories Description and range		
				A1	**A2**	**A3**
				Normal to mildly increased	Moderately increased	Severely increased
				<30 mg/g <3 mg/mmol	30-299 mg/g 3-29 mg/mmol	≥300 mg/g ≥30 mg/mmol
	G1	Normal or high	≥90			
	G2	Mildly decreased	60-90			
	G3a	Mildly to moderately decreased	45-59			
	G3b	Moderately to severely decreased	30-44			
	G4	Severely decreased	15-29			
	G5	Kidney failure	<15			

Green: low risk (if no other markers of kidney disease, no CKD); Yellow: moderately increased risk; Orange: high risk; Red, very high risk.
KDIGO 2012

Appendix B: Overview of the Alberta Kidney Disease Network (AKDN) Data Structure (48)



Appendix C: Usual Provider of Care (UPC) Index Equation (50)

$$\text{UPC index} = \frac{n_i}{N}$$

$$n_i = \max(n_1, n_2, n_3, \ldots.)$$

Where:

n_i = number of visits to a main provider by patient i

n_1 = number of visits to provider 1

n_2 = number of visits to provider 2

n_3 = number of visits to provider 3

N = total number of patient i's visits to any provider

Appendix D. Diagnostic coding used to define ambulatory care-sensitive conditions related to chronic kidney disease (CKD)

CKD-related ambulatory care-sensitive conditions	ICD-10-CA
Volume Overload	E87.7
Hyperkalemia	E87.5
Malignant Hypertension	I10.1
Heart Failure	I09.9
	I11.0
	I13.0
	I13.2
	I25.5
	I42.0
	I42.5–I42.9
	I43.x
	I50.x

Abbreviations: ICD-10-CA: International Statistical Classification of Diseases and Health Related Problems, Tenth Revision, Canada

Appendix E. Relationship between categories for albuminuria and proteinuria.

		Albuminuria Categories		
		Normal to mildly increased (A1)	**Moderately increased (A2)**	**Severely increased (A3)**
Measures	**Albumin-to-creatinine ratio (ACR), mg/mmol**	< 3	3 - 30	> 30
	Protein-to-creatinine ratio (PCR), mg/mmol	< 15	15- 50	> 50
	Urine dipstick/ protein reagent strip	Negative to trace	Trace to +	+ or greater

Appendix F. The Reporting of studies Conducted using Observational Routinely collected Data (RECORD) checklist of items, extended from the STROBE statement, to be included in observational studies using routinely collected health data (57, 58)

	Item No.	STROBE items	Location in manuscript where items are reported	RECORD items	Location in manuscript where items are reported
Title and abstract					
	1	(a) Indicate the study's design with a commonly used term in the title or the abstract (b) Provide in the abstract an informative and balanced summary of what was done and what was found	11, 12	RECORD 1.1: The type of data used should be specified in the title or abstract. When possible, the name of the databases used should be included. RECORD 1.2: If applicable, the geographic region and timeframe within which the study took place should be reported in the title or abstract. RECORD 1.3: If linkage between databases was conducted for the study, this should be clearly stated in the title or abstract.	11, 12
Introduction					
Background rationale	2	Explain the scientific background and rationale for the investigation being reported	14, 15		
Objectives	3	State specific objectives, including any prespecified hypotheses	14, 15		
Methods					
Study Design	4	Present key elements of study design early in the paper	16, 17		
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	16, 17		
Participants	6	*(a) Cohort study* - Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study* - Give the eligibility criteria, and the sources and methods of case ascertainment and control	16, 17	RECORD 6.1: The methods of study population selection (such as codes or algorithms used to identify subjects) should be listed in detail. If this is not possible, an explanation should be provided. RECORD 6.2: Any validation studies of the codes or algorithms used to select the population should be referenced. If validation was conducted for this	16, 17, 58, 60

		selection. Give the rationale for the choice of cases and controls *Cross-sectional study* - Give the eligibility criteria, and the sources and methods of selection of participants *(b) Cohort study* - For matched studies, give matching criteria and number of exposed and unexposed *Case-control study* - For matched studies, give matching criteria and the number of controls per case		study and not published elsewhere, detailed methods and results should be provided. RECORD 6.3: If the study involved linkage of databases, consider use of a flow diagram or other graphical display to demonstrate the data linkage process, including the number of individuals with linked data at each stage.	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable.	17, 18, 60	RECORD 7.1: A complete list of codes and algorithms used to classify exposures, outcomes, confounders, and effect modifiers should be provided. If these cannot be reported, an explanation should be provided.	17, 18, 60
Data sources/ measurement	8	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	17, 18, 58		
Bias	9	Describe any efforts to address potential sources of bias	18, 19		
Study size	10	Explain how the study size was arrived at	16, 17		
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	17, 18, 19		
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) *Cohort study* - If applicable, explain how loss to follow-up was addressed *Case-control study* - If applicable, explain how matching of cases and controls was addressed	19, 20		

		Cross-sectional study - If applicable, describe analytical methods taking account of sampling strategy (e) Describe any sensitivity analyses			
Data access and cleaning methods		..		RECORD 12.1: Authors should describe the extent to which the investigators had access to the database population used to create the study population. RECORD 12.2: Authors should provide information on the data cleaning methods used in the study.	16, 58
Linkage		..		RECORD 12.3: State whether the study included person-level, institutional-level, or other data linkage across two or more databases. The methods of linkage and methods of linkage quality evaluation should be provided.	16, 17, 58
Results					
Participants	13	(a) Report the numbers of individuals at each stage of the study (*e.g.*, numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed) (b) Give reasons for non-participation at each stage. (c) Consider use of a flow diagram	20, 34	RECORD 13.1: Describe in detail the selection of the persons included in the study (*i.e.*, study population selection) including filtering based on data quality, data availability and linkage. The selection of included persons can be described in the text and/or by means of the study flow diagram.	20 – 23, 34
Descriptive data	14	(a) Give characteristics of study participants (*e.g.*, demographic, clinical, social) and information on exposures and potential confounders (b) Indicate the number of participants with missing data for each variable of interest (c) *Cohort study* - summarise follow-up time (*e.g.*, average and total amount)	20 – 21		
Outcome data	15	*Cohort study* - Report numbers of outcome events or summary measures over time *Case-control study* - Report numbers in each exposure category, or summary measures of exposure *Cross-sectional study* - Report numbers of outcome events or summary measures	20 – 23		

Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval). Make clear which confounders were adjusted for and why they were included (b) Report category boundaries when continuous variables were categorized (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	20 – 23		
Other analyses	17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses	20 – 23		
Discussion					
Key results	18	Summarise key results with reference to study objectives	23		
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	27 – 28	RECORD 19.1: Discuss the implications of using data that were not created or collected to answer the specific research question(s). Include discussion of misclassification bias, unmeasured confounding, missing data, and changing eligibility over time, as they pertain to the study being reported.	27 – 28
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	24 – 27		
Other Information					
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	29		
Accessibility of protocol, raw data, and programming code		..		RECORD 22.1: Authors should provide information on how to access any supplemental information such as the study protocol, raw data, or programming code.	29

Appendix G. Patient demographic and clinical characteristics by continuity of primary care overall and across CKD stage

	Variable	Level of relational continuity of primary care			Overall
		Poor (<50%)	Moderate (50 – 74%)	High (75-100%)	
CKD Stage 3a	Age, mean (SD)	74.9 (12.2)	74.4 (11.0)	75.1 (10.2)	74.8 (10.8)
	Female, n (%)	5,336 (58.3)	8,785 (56.7)	14,763 (54.1)	28,884 (55.6)
	Urban location of residence, n (%)	7,594 (83.0)	13,237 (85.5)	24,944 (91.5)	45,775 (88.2)
	Albuminuria, n (%)				
	Normal/mild (A1)	4,848 (53.0)	8,940 (57.7)	16,221 (59.5)	30,009 (57.8)
	Moderate (A2)	965 (10.5)	1,606 (10.4)	2,937 (10.8)	5,508 (10.6)
	Severe (A3)	547 (6.0)	772 (5.0)	1,208 (4.4)	2,527 (4.9)
	Unmeasured	2,793 (30.5)	4,171 (26.9)	6,908 (25.3)	13,872 (26.7)
	Median household income quintile, n (%)				
	1 (lowest)	2,524 (27.6)	3,904 (25.2)	6,520 (23.9)	12,948 (24.9)
	2	2,042 (22.3)	3,503 (22.6)	6,037 (22.1)	11,582 (22.3)
	3	1,655 (18.1)	2,969 (19.2)	5,376 (19.7)	10,000 (19.3)
	4	1,355 (14.8)	2,314 (14.9)	4,249 (15.6)	7,918 (15.3)
	5 (highest)	1,266 (13.8)	2,394 (15.5)	4,559 (16.7)	8,219 (15.8)
	6 = Unknown	311 (3.4)	405 (2.6)	533 (2.0)	1,249 (2.4)
	Number of comorbidities, mean (SD)	3.6 (2.2)	3.1 (1.9)	2.7 (1.7)	3.0 (1.9)
	Number of specialists seen, mean (SD)	3.8 (2.9)	3.3 (2.6)	2.9 (2.3)	3.2 (2.5)
CKD Stage 3b	Age, mean (SD)	78.0 (12.2)	77.8 (11.2)	78.1 (10.3)	78.0 (11.0)
	Female, n (%)	3,158 (61.4)	4,699 (59.0)	7,589 (57.0)	15,446 (58.5)
	Urban location of residence, n (%)	4,153 (80.7)	6,684 (84.0)	11,982 (90.0)	22,819 (86.4)
	Albuminuria, n (%)				
	Normal/mild (A1)	2,258 (43.9)	3,717 (46.7)	6,520 (49.0)	12,495 (47.3)
	Moderate (A2)	722 (14.0)	1,149 (14.4)	1,948 (14.6)	3,819 (14.5)
	Severe (A3)	487 (9.5)	697 (8.8)	1,078 (8.1)	2,262 (8.6)
	Unmeasured	1,678 (32.6)	2,397 (30.1)	3,767 (28.3)	7,842 (29.7)
	Median household income quintile, n (%)				
	1 (lowest)	1,540 (29.9)	2,276 (28.6)	3,538 (26.6)	7,354 (27.8)
	2	1,195 (23.2)	1,804 (22.7)	3,064 (23.0)	6,063 (23.0)
	3	973 (18.9)	1,571 (19.7)	2,647 (19.9)	5,191 (19.7)
	4	665 (12.9)	1,063 (13.4)	1,846 (13.9)	3,574 (13.5)
	5 (highest)	579 (11.3)	1,012 (12.7)	1,923 (14.4)	3,514 (13.3)
	6 = Unknown	193 (3.8)	234 (2.9)	295 (2.2)	722 (2.7)
	Number of comorbidities, mean (SD)	3.2 (1.8)	3.7 (2.0)	4.2 (2.2)	3.6 (2.0)
	Number of specialists seen, mean (SD)	4.1 (2.9)	3.6 (2.6)	3.2 (2.3)	3.5 (2.6)
CKD Stage 4	Age, mean (SD)	76.6 (14.8)	77.1 (13.2)	77.8 (12.0)	77.3 (13.1)
	Female, n (%)	1,077 (58.4)	1,418 (56.7)	2,131 (56.1)	4,626 (56.8)
	Urban location of residence, n (%)	1,474 (79.9)	2,057 (82.3)	3,413 (89.9)	6,944 (85.3)
	Albuminuria, n (%)				
	Normal/mild (A1)	495 (26.8)	801 (32.1)	1,250 (32.9)	2,546 (31.3)
	Moderate (A2)	334 (18.1)	466 (18.7)	775 (20.4)	1,575 (19.4)
	Severe (A3)	406 (22.0)	538 (21.5)	693 (18.3)	1,637 (20.1)
	Unmeasured	610 (33.1)	694 (27.8)	1,079 (28.4)	2,383 (29.3)
	Median household income quintile, n (%)				
	1 (lowest)	563 (30.5)	764 (30.6)	1,072 (28.2)	2,399 (29.5)
	2	436 (23.6)	586 (23.5)	935 (24.6)	1,957 (24.0)
	3	330 (17.9)	472 (18.9)	712 (18.8)	1,514 (18.6)
	4	226 (12.3)	310 (12.4)	481 (12.7)	1,017 (12.5)
	5 (highest)	217 (11.8)	280 (11.2)	504 (13.3)	1,001 (12.3)
	6 = Unknown	73 (4.0)	87 (3.5)	93 (2.5)	253 (3.11)
	Number of comorbidities, mean (SD)	4.6 (2.3)	4.1 (2.2)	3.6 (1.9)	4.0 (2.1)
	Number of specialists seen, mean (SD)	4.5 (3.0)	4.0 (2.8)	3.5 (2.5)	3.9 (2.7)

Appendix H. All-cause hospitalization characteristics by level of continuity of primary care, overall and across CKD stage

	Variable	Level of relational continuity of primary care			Overall,
		Poor (<50%)	Moderate (50 – 74%)	High (75-100%)	
Overall	Number of individuals	7,938	11,020	15,852	34,810
	Total number of hospitalizations (% of all hospitalizations)	19,835 (25.4)	25,551 (32.8)	32,602 (41.8)	77,988 (100.0)
	Number of hospitalizations, median (IQR)	0 (0 – 2)	0 (0 – 1)	0 (0 – 1)	0 (0 – 1)
	Person-time, years (% of all person-time)	32,328.8 (17.9)	53,698.6 (29.7)	94,520.5 (52.4)	180,547.9 (100.0)
	Length of hospital stays, days, mean (SD)	13.7 (21.1)	12.8 (19.2)	12.7 (20.0)	12.9 (20.0)
	Length of hospital stays, days, median (IQR)	0 (0 – 7)	0 (0 – 5)	0 (0 – 4)	0 (0 – 5)
	Cumulative length of hospital stays, days, median (IQR)	15 (6 – 42)	13 (5 – 39)	11 (4 – 33)	13 (5 – 37)
	Unadjusted hospitalization rate (per 1,000 p-y) (95% CI)	613.5 (605.6 – 622.7)	475.8 (470.2 – 481.9)	344.9 (341.9 – 349.4)	432.0 (429.5 – 435.6)
CKD Stage 3a	Number of individuals	3,684	5,320	7,798	16,802
	Total number of hospitalizations (% of all hospitalizations)	8,282 (24.5)	10,919 (32.4)	14,543 (43.1)	33,744 (100.0)
	Number of hospitalizations, median (IQR)	0 (0 – 1)	0 (0 – 1)	0 (0 – 1)	0 (0 – 1)
	Person-time, years (% of all person-time)	17,409.1 (16.9)	30,430.3 (29.5)	55,277.2 (53.6)	103,116.6 (100.0)
	Length of hospital stays, days, mean (SD)	13.0 (22.4)	12.2 (20.8)	11.2 (18.1)	11.9 (20.0)
	Length of hospital stays, days, median (IQR)	0 (0 – 4.5)	0 (0 – 3)	0 (0 – 2)	0 (0 – 3)
	Cumulative length of hospital stays, days median (IQR)	12 (4 – 35)	10 (4 – 30)	9 (4 – 24)	10 (4 – 29)
	Unadjusted hospitalization rate (per 1,000 p-y) (95% CI)	475.7 (465.6 – 486.1)	358.8 (352.2 – 365.6)	263.1 (258.9 – 267.4)	327.2 (323.8 – 330.8)
CKD Stage 3b	Number of individuals	2,974	4,105	5,942	13,021
	Total number of hospitalizations (% of all hospitalizations)	7,823 (25.2)	10,187 (32.9)	12,983 (41.9)	30,993 (100.0)
	Number of hospitalizations, median (IQR)	1 (0 – 2)	1 (0 – 2)	0 (0 – 1)	0 (0 – 2)
	Person-time, years (% of all person-time)	11,014.5 (18.6)	17,789.3 (30.0)	30,451.5 (51.4)	59,255.4 (100.0)
	Length of hospital stays, days, mean (SD)	14.1 (19.7)	13.3 (17.8)	13.7 (21.6)	13.6 (20.1)
	Length of hospital stays, days, median (IQR)	2.7 (0 – 9)	1 (0 – 7.5)	0 (0 – 6.1)	0 (0 – 7)
	Cumulative length of hospital stays, days median (IQR)	17 (6 – 45)	16 (6 – 45)	14 (5 – 38)	15 (5 – 42)
	Unadjusted hospitalization rate (per 1,000 p-y) (95% CI)	710.2 (694.7 – 726.2)	572.6 (561.6 – 583.9)	426.4 (419.1 – 433.8)	523.0 (517.3 – 528.9)
CKD Stage 4	Number of individuals	1,280	1,595	2,112	4,987
	Total number of hospitalizations (% of all hospitalizations)	3,730 (28.1)	4,445 (33.5)	5,076 (38.3)	13,251 (100.0)
	Number of hospitalizations, median (IQR)	1 (0 – 3)	1 (0 – 3)	1 (0 – 2)	1 (0 – 2)
	Person-time, years (% of all person-time)	3,877 (21.6)	5,458.8 (30.4)	8,593.7 (47.9)	17,929.9 (100.0)
	Length of hospital stays, days, mean (SD)	15.1 (20.6)	13.8 (17.4)	15.7 (21.2)	14.9 (19.9)
	Length of hospital stays, days, median (IQR)	5.5 (0 – 13)	4 (0 – 11)	2 (0 – 10.8)	4 (0 – 11)
	Cumulative length of hospital stays, days median (IQR)	23 (9 – 55)	20 (7 – 50)	20 (7 – 49)	21 (8 – 51)
	Unadjusted hospitalization rate (per 1,000 p-y) (95% CI)	962.1 (931.6 – 993.4)	814.3 (790.7 – 838.6)	590.7 (574.6 – 607.1)	739.0 (726.6 – 751.7)

Appendix I. All-cause Emergency Department (ED) visit characteristics by level of continuity of primary care, overall and across CKD stage

	Variable	Level of relational continuity of primary care			Overall
		Poor (<50%)	Moderate (50 – 74%)	High (75-100%)	
Overall	Number of individuals	11,234	16,237	23,681	51,152
	Total number of ED visits (%)	56,809 (27.8)	70,147 (34.3)	77,659 (38.0)	204,615 (100.0)
	Number of ED visits, median (IQR)	2 (0 – 4)	1 (0 – 3)	1 (0 – 2)	1 (0 – 3)
	Person-time, years (% of all person-time)	32,328.8 (17.9)	53,698.6 (29.7)	94,520.5 (52.4)	180,547.9 (100.0)
	Unadjusted ED visit rate (per 1,000 p-y) (95% CI)	1,757.2 (1,744.3 – 1,773.3)	1,306.3 (1,297.2 – 1,316.5)	823.4 (817.6 – 829.2)	1,133.3 (1,129.9 – 1,139.8)
CKD Stage 3a	Number of individuals	5,739	8,582	12,568	26,889
	Total number of ED visits (%)	25,137 (26.8)	32,359 (34.6)	36,134 (38.6)	93,630 (100.0)
	Number of ED visits, median (IQR)	1 (0 – 3)	1 (0 – 2)	0 (0 – 2)	1 (0 – 2)
	Person-time, years (% of all person-time)	17,409.1 (16.9)	30,430.3 (29.5)	55,277.2 (53.6)	103,116.6 (100.0)
	Unadjusted ED visit rate (per 1,000 p-y) (95% CI)	1,443.9 (1,426.2 – 1,461.9)	1,063.4 (1,051.9 – 1,075.0)	653.7 (647.0 – 660.5)	908.0 (902.2 – 913.8)
CKD Stage 3b	Number of individuals	3,930	5,673	8,318	17,921
	Total number of ED visits (%)	22,244 (28.1)	26,978 (34.1)	29,928 (37.8)	79,150 (100.0)
	Number of ED visits, median (IQR)	2 (1 – 5)	2 (0 – 4)	1 (0 – 3)	1 (0 – 4)
	Person-time, years (% of all person-time)	11,014.5 (18.6)	17,789.3 (30.0)	30,451.5 (51.4)	59,255.4 (100.0)
	Unadjusted ED visit rate (per 1,000 p-y) (95% CI)	2,019.5 (1,993.2 – 2,046.2)	1,516.5 (1,498.5 – 1,534.7)	982.8 (971.8 – 994.1)	1,335.7 (1,326.5 – 1,345.1)
CKD Stage 4	Number of individuals	1,565	1,982	2,795	6,342
	Total number of ED visits (%)	9,428 (29.6)	10,810 (34.0)	11,597 (36.4)	31,835 (100.0)
	Number of ED visits, median (IQR)	3 (1 – 6)	2 (1 – 6)	2 (0 – 4)	2 (1 – 5)
	Person-time, years (% of all person-time)	3,877 (21.6)	5,458.8 (30.4)	8,593.7 (47.9)	17,929.9 (100.0)
	Unadjusted ED visit rate (per 1,000 p-y) (95% CI)	2,431.8 (2,382.9 – 2,481.1)	1,980.3 (1,943.3 – 2,018.0)	1,349.5 (1,325.1 – 1,374.3)	1,775.5 (1,756.1 – 1795.1)

Appendix J. Number and percentage of encounters for individual CKD-related ACSC hospitalizations and emergency department visits

		Level of continuity of primary care			
		High	**Moderate**	**Poor**	**Overall**
Hospitalizations	# of ACSC encounters	2,730	2,045	1,714	6,489
	% of all ACSC encounters	42.1	31.5	26.4	100.0
	Volume overload	20	2	5	27
	% of all Volume overload encounters	74.0	0.7	1.9	100.0
	Hyperkalemia	76	69	71	216
	% of all Hyperkalemia encounters	35.2	31.9	32.9	100.0
	Malignant hypertension	5	3	4	12
	% of all Malignant hypertension encounters	41.7	25.0	33.3	100.0
	Heart failure	2,653	1,989	1,649	6,291
	% of all Heart failure encounters	42.2	31.6	26.2	100.0
Emergency Department Visits	# of ACSC encounters	3,441	2,726	2,294	8,461
	% of all ACSC encounters	40.7	32.2	27.1	100.0
	Volume overload	25	7	10	42
	% of all Volume overload encounters	59.5	16.7	23.8	100.0
	Hyperkalemia	419	365	332	1,116
	% of all Hyperkalemia encounters	37.5	32.7	29.7	100.0
	Malignant hypertension	14	5	6	25
	% of all Malignant hypertension encounters	56.0	20.0	24.0	100.0
	Heart failure	3,057	2,425	2,024	7,506
	% of all Heart failure encounters	40.7	32.3	27.0	100.0

Appendix K. Ambulatory care-sensitive condition (ACSC) related hospitalization characteristics by level of continuity of primary care, overall and across CKD stage

	Variable	Level of relational continuity of primary care			Overall
		Poor (<50%)	Moderate (50 – 74%)	High (75-100%)	
Overall	Number of individuals	1,095	1,369	1,842	4,306
	Total number of ACSC hospitalizations (%)	1,714 (26.4)	2,045 (31.5)	2,730 (42.1)	6,489 (100.0)
	Number of ACSC hospitalizations, median (IQR)	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)
	Person-time, years (% of all person-time)	32,328.8 (17.9)	53,698.6 (29.7)	94,520.5 (52.4)	180,547.9 (100.0)
	Unadjusted ACSC hospitalization rate (per 1,000 p-y) (95% CI)	53.1 (50.6 – 55.6)	38.1 (36.5 – 39.8)	28.9 (27.9 – 30.1)	36.0 (35.1 – 36.9)
CKD Stage 3a	Number of individuals	391	489	706	1,586
	Total number of ACSC hospitalizations (%)	594	689	1,024	2,307
	Number of ACSC hospitalizations, median (IQR)	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)
	Person-time, years (% of all person-time)	17,409.1 (16.9)	30,430.3 (29.5)	55,277.2 (53.6)	103,116.6 (100.0)
	Unadjusted ACSC hospitalization rate (per 1,000 p-y) (95% CI)	34.1 (31.5 – 37.0)	22.6 (21.0 – 24.4)	18.5 (17.4 – 19.7)	22.4 (21.5 – 23.3)
CKD Stage 3b	Number of individuals	453	555	762	1,770
	Total number of ACSC hospitalizations (%)	699	817	1,154	2,670
	Number of ACSC hospitalizations, median (IQR)	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)
	Person-time, years (% of all person-time)	11,014.5 (18.6)	17,789.3 (30.0)	30,451.5 (51.4)	59,255.4 (100.0)
	Unadjusted ACSC hospitalization rate (per 1,000 p-y) (95% CI)	63.5 (58.9 – 68.3)	45.9 (42.9 – 49.2)	37.9 (35.8 – 40.2)	45.1 (43.4 – 46.8)
CKD Stage 4	Number of individuals	251	325	374	950
	Total number of ACSC hospitalizations (%)	421	539	552	1,512
	Number of ACSC hospitalizations, median (IQR)	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)
	Person-time, years (% of all person-time)	3,877 (21.6)	5,458.8 (30.4)	8,593.7 (47.9)	17,929.9 (100.0)
	Unadjusted ACSC hospitalization rate (per 1,000 p-y) (95% CI)	108.6 (98.7 0 119.5)	98.7 (90.7 – 107.4)	64.2 (59.1 – 69.8)	84.3 (80.2 – 88.7)

Appendix L. Ambulatory care-sensitive condition (ACSC) related Emergency Department (ED) characteristics by level of continuity of primary care, overall and across CKD stage

	Variable	Level of relational continuity of primary care			Overall
		Poor (<50%)	Moderate (50 – 74%)	High (75-100%)	
Overall	Number of individuals	1,414	1,731	2,272	5,417
	Total number of ACSC ED visits (%)	2,294 (27.1)	2,726 (32.2)	3,441 (40.7)	8,461 (100.0)
	Number of ACSC ED visits, median (IQR)	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)
	Person-time, years (% of all person-time)	32,328.8 (17.9)	53,698.6 (29.7)	94,520.5 (52.4)	180,547.9 (100.0)
	Unadjusted ACSC ED visit rate (per 1,000 p-y) (95% CI)	71.0 (68.2 – 74.0)	50.8 (48.9 – 62.7)	36.5 (35.3 – 37.7)	46.9 (45.9 – 47.9)
CKD Stage 3a	Number of individuals	514	633	876	2,023
	Total number of ACSC ED visits (%)	827	972	1,283	3,082
	Number of ACSC ED visits, median (IQR)	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)
	Person-time, years (% of all person-time)	17,409.1 (16.9)	30,430.3 (29.5)	55,277.2 (53.6)	103,116.6 (100.0)
	Unadjusted ACSC ED visit rate (per 1,000 p-y) (95% CI)	47.5 (44.4 – 50.9)	31.9 (30.0 – 34.0)	23.2 (22.0 – 24.5)	29.9 (28.9 – 31.0)
CKD Stage 3b	Number of individuals	569	695	920	2,184
	Total number of ACSC ED visits (%)	935	1,080	1,415	3,430
	Number of ACSC ED visits, median (IQR)	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)
	Person-time, years (% of all person-time)	11,014.5 (18.6)	17,789.3 (30.0)	30,451.5 (51.4)	59,255.4 (100.0)
	Unadjusted ACSC ED visit rate (per 1,000 p-y) (95% CI)	85.9 (79.6 – 90.5)	60.7 (57.2 – 64.4)	46.5 (44.1 – 49.0)	57.9 (56.0 – 59.9)
CKD Stage 4	Number of individuals	331	403	476	1,210
	Total number of ACSC ED visits (%)	532	674	743	1,949
	Number of ACSC ED visits, median (IQR)	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)	0 (0 – 0)
	Person-time, years (% of all person-time)	3,877 (21.6)	5,458.8 (30.4)	8,593.7 (47.9)	17,929.9 (100.0)
	Unadjusted ACSC ED visit rate (per 1,000 p-y) (95% CI)	137.2 (126.0 – 149.4)	123.5 (114.5 – 133.2)	86.5 (80.5 – 92.9)	108.7 (104.0 – 113.6)