Innovations and Opportunities for Primary Health Care after Hospital Discharge: An Application of Causal Inference Methods in Health Services Research

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ABSTRACT

Hospital readmissions have been of wide policy interest, either as a quality measure of hospital care or as a marker of poor integration of the health care delivery system. As many as half of all hospital readmissions may be preventable, indicating an opportunity for containing cost and for improving the quality of patient care. Many contemporary efforts to address this have promoted better care coordination, of which outpatient follow-up after discharge has been a key intervention point in medical care. Transforming health systems have also given rise to a number of innovations in primary care delivery targeting care coordination. In Quebec, this led to the system-wide implementation of multidisciplinary team-based primary care practices. My work focuses on how primary health care delivery and organization may contribute to reducing readmission and other adverse post-discharge care events among elderly or chronically ill patients. Specifically, I investigated the delivery of outpatient follow-up care by type of care (primary or specialized care) and timing in its capacity to affect hospital readmission, and whether new models of team-based primary care delivery were associated with better rates of outpatient physician follow-up and lower rates of adverse events in the period after hospital discharge.

For this thesis, I linked outpatient and inpatient claims data on more than 300 000 patients hospitalized for any cause excluding pregnancy/birth or mental health, representing more than 600 000 hospital admissions from 2002-2009 in Quebec, Canada. Throughout this work, I applied methods to deal with challenges specific to the research questions addressed, including causal inference methods and the use of flexible parametric survival models for competing risks.

In the first manuscript, I assessed the relationship between timing and type of post-discharge outpatient follow-up and hospital readmission, and found large absolute reductions in risk, particularly if outpatient follow-up occurred within at least 3 weeks of discharge and/or was provided by a primary care physician rather than by

a medical specialist. In the second manuscript, I examined the relationship between enrolment in multidisciplinary team-based primary care practices and physician follow-up within 30 days of hospital discharge. I also examined whether the relationship varied by patient morbidity level. This study showed that patients enrolled in new team-based primary care models had similar or lower rates of follow-up visits by a primary care physician, and lower rates of follow-up with a medical specialist. Patients with very high morbidity, however, had higher rates of follow-up with a primary care physician if they were enrolled in the new models. Due to data limitations, outpatient follow-up by nurses practicing in primary care teams was not included, which could compensate for a share of the difference in timely post-discharge follow-up care between delivery models. Future research is needed to test this hypothesis. In the third manuscript, I estimated the cumulative incidence functions of readmission, emergency department (ED) visits and mortality in the 90-days after hospital discharge by whether patients were enrolled in new team-based primary care practices or enrolled in traditional practices. I found that patients enrolled in team-based practices had an incidence of readmission similar to that of traditional practices, but a lower incidence of post-discharge ED visit and mortality, especially among the most complex patients.

Collectively, this work makes a number of novel contributions to the existing body of evidence on strategies to reduce hospital readmissions. First, it provides evidence towards a causal effect of post-discharge outpatient follow-up on reducing the risk of 30-day readmission, and contributes further to our understanding of an optimal delivery of outpatient follow-up, in terms of the timeliness and type to yield better results. Second, despite their clear potential for reducing adverse events in the post-discharge period, new models of multidisciplinary team-based primary care delivery implemented system-wide did not show strong evidence of improved performance, suggesting that more targeted or intensive policy efforts than what are currently deployed towards improving the care transition may be needed to improve patient outcomes. Practitioners and policy-makers in Quebec could work towards new ways to improve rates of timely follow-up as an effective strategy to reduce readmission. This may include targeting innovations and additional

resources to support post-discharge follow-up such as information technology platforms and enhancing the role of primary care nurses.

ABRÉGÉ

Les réadmissions à l'hôpital continuent de soulever un vif intérêt politique, non seulement en tant qu'indicateurs de la qualité des soins en milieu hospitalier, mais également parce qu'elles peuvent être symptomatiques des lacunes au niveau du système des soins et services de santé. Près la moitié des réadmissions pourraient être évitées, ce qui représente une occasion unique de réduire les coûts tout en permettant d'améliorer la qualité des soins aux patients. Parmi les tentatives visant à remédier à cette situation, on remarque un effort important vers une meilleure coordination des soins médicaux, principalement entre les milieux internes et externes de soins et services. L'évolution du système de santé a également donné naissance à de nombreuses innovations dans la prestation des soins et services de première ligne soulignant l'importance d'une meilleure coordination. Au Québec, ceci a permis l'implantation à grande échelle de nouvelles pratiques basées sur des équipes multidisciplinaires de soins et services de première ligne. Cette thèse explore la manière avec laquelle la prestation tout comme l'organisation des soins et services de santé de première ligne pourraient ensemble contribuer à réduire le nombre de réadmissions et autres évènements indésirables dans la période suivant le congé hospitalier, et plus précisément chez les personnes âgées ou atteintes d'une malade chronique. Afin de mesurer leur capacité à prévenir une réadmission en milieu hospitalier, je me suis particulièrement intéressé aux visites de suivi externe selon le type de soins (soins primaires ou spécialisés), et selon le moment auquel ces soins ont été reçus. J'ai de plus cherché à savoir si les nouveaux modèles de prestation de soins de santé provenant d'équipes multidisciplinaires de soins et services de première ligne pouvaient également diminuer l'occurrence d'évènements indésirables dans la période suivant le congé du patient. À cette fin, j'ai extrait les données de facturations des médecins provenant autant de consultations internes et externes sur plus de 300 000 patients ayant été hospitalisés, toutes causes confondues (à l'exception

d'une grossesse, d'une naissance ou d'un problème de santé mentale), ce qui englobe plus de 600 000 admissions entre 2002-2009 dans la province de Québec au Canada. Tout au long de ce travail, j'ai utilisé différentes stratégies afin de surmonter les défis méthodologiques soulevés par ces questions de recherche, incluant les méthodes d'inférence causale ainsi que l'utilisation de modèles de survie paramétriques flexibles tenant compte des risques concurrents.

Dans le premier manuscrit, j'ai estimé l'effet de la consultation externe après le congé du patient sur les réadmissions, selon le type de consultation et selon le moment de prestation. J'ai remarqué une importante diminution absolue du risque de réadmission, particulièrement si ce suivi en externe avait eu lieu dans les trois premières semaines suivant le congé ou si le patient avait été vu en première ligne ou en médecine spécialisée. Dans le second manuscrit, j'ai comparé les taux de visites de suivi externe suivant un congé hospitalier selon le type de pratique de soins et services de première ligne, soit multidisciplinaire ou traditionnelle (cabinet privé ou clinique solo). J'ai également essayé de comprendre de quelle façon le niveau de morbidité du patient pouvait influencer cette relation. Ces analyses ont démontré que les patients inscrits à une pratique multidisciplinaire de soins et services de première ligne avaient des taux de suivi externe en première ligne inférieurs ou similaires, et des taux de suivi en médecine spécialisée inférieurs à ceux des patients inscrits à une pratique traditionnelle. Les patients ayant un niveau très élevé de morbidité ont profité quant à eux de meilleurs taux de suivi en première ligne s'ils étaient inscrits une pratique multidisciplinaire de soins et services de première ligne. À noter que ces résultats ne tiennent pas compte du suivi effectué par les infirmières pratiquant en première ligne, ce qui pourrait expliquer une partie des différences observées. Cette hypothèse nécessite d'être vérifiée empiriquement dans le futur.

Dans le troisième manuscrit, je me suis penché sur les taux de réadmission, de visite à l'urgence, et de mortalité dans les 90 premiers jours suivant le congé selon que les patients étaient inscrits à une pratique multidisciplinaire de soins

de première ligne ou inscrits à une pratique traditionnelle. Or, les patients inscrits à une pratique multidisciplinaire ont montré une incidence de réadmission comparable à celle des patients suivis en pratique traditionnelle, mais ces mêmes patients ont par contre présenté un taux inférieur de visites à l'urgence ainsi qu'un taux inférieur de mortalité, en particulier chez les patients les plus complexes.

Globalement, ce travail apporte plusieurs nouveautés à l'ensemble des preuves déjà existantes quant aux stratégies mises de l'avant pour réduire le nombre de réadmissions. En premier lieu, ce travail souligne l'évidence que les visites de suivi externe après le congé sont associées à une diminution importante du risque de réadmission ; ainsi les visites de suivi en temps opportun, et surtout dans une pratique de soins de première ligne, pourraient bien être la cible des politiques futures afin d'améliorer la qualité des soins. Dans un deuxième temps, nos données suggèrent que les nouveaux modèles d'équipes multidisciplinaires de soins et services de première ligne montrent un véritable potentiel pour réduire les effets indésirables ; par contre, des efforts mieux ciblés ou plus intensifs pourraient être nécessaires afin de prévenir de façon efficace les réadmissions. Dans cette optique, les médecins et les décideurs politiques pourraient travailler à développer de nouvelles approches afin d'améliorer le taux de visites de suivi faites en temps opportun. De nouvelles stratégies jumelées à des ressources supplémentaires dans les pratiques de soins et services de première ligne œuvrant en équipe, telles que l'informatisation des systèmes et un changement du rôle des infirmières dans la continuité des soins, pourraient également faire partie de la solution.

STATEMENT OF ORIGINALITY

This work makes several novel contributions to the knowledge and science of health services about the period following hospital discharge. I identified a critical time window at which outpatient physician follow-up following discharge yields the maximum reduction in readmissions, and I generated evidence in support of emphasizing outpatient follow-up in the primary care setting, in particular for the high health care users. I applied a systems approach to this research, combining examinations of processes of care, outcome measures, and system-wide innovations in primary care delivery to provide a more comprehensive profile of service quality in the period after hospital discharge. This was done using the largest sample to date in this topic area, and the most rigorous methodological approach, including the first application of time-specific propensity scores in health services research. This work is also the first to contribute knowledge on the incidence of post-discharge outcome and process measures, such as readmissions and timely outpatient physician follow-up visits, as well as how they vary across patient morbidity levels, and by whether patients are enrolled in multidisciplinary team-based or in traditional primary care practices. As new models of primary care delivery are being implemented worldwide, the evidence produced by this research can provide guidance for future efforts at scaling up innovations to improve the care transition from hospital to community. Throughout, advanced epidemiological methods were used to generate least biased estimates. I declare this work as my own in design, execution and drafting carried out under the supervision and mentorship of my committee members.

CONTRIBUTION OF AUTHORS

Manuscript 1: Riverin BD, Strumpf E, Naimi AI, Li P. "Optimal delivery of outpatient follow-up to reduce readmission after hospital discharge: an analysis using time-specific propensity scores"

Manuscript 2: Riverin BD, Li P, Naimi AI, Diop M, Provost S, Strumpf E. "Team-based innovations in primary care delivery in Canada and outpatient physician follow-up after hospital discharge"

Manuscript 3: Riverin BD, Strumpf E, Naimi AI, Li P. "Readmission, post-discharge emergency department visits and mortality in the context of Canadian primary care innovations"

As lead author of each manuscript presented in this thesis, I developed the research objectives and methodological approaches, I executed all data management and statistical analyses, and I wrote the first drafts. This was done under the supervision of Erin Strumpf (co-supervisor), Patricia Li (co-supervisor) and Ashley Naimi (committee member). All listed co-authors on the manuscripts presented in this thesis have participated in the concept and design of this research, in the analysis and interpretation of the data, in the revising of the manuscript, and all have approved the manuscripts as presented.

Erin Strumpf is an Associate Professor at the Department of Epidemiology, Biostatistics and Occupational Health and at the Department of Economics at McGill University. As my supervisor and expert in health economics and health policy, Dr Strumpf provided guidance and mentorship on the substantive, methodological and practical aspects of the three manuscripts; her support was essential to the quality and relevance of this research.

Patricia Li is a Clinician-Scientist at the Montreal Children's Hospital and Associate Member at the Department of Epidemiology, Biostatistics and Occupational Health at McGill University. As my supervisor and expert in primary

health care delivery and health services research, Dr Li contributed extensively to all three manuscripts, in particular to make this research relevant and accessible to the key stakeholders.

Ashley Naimi is Assistant Professor at The University of Pittsburgh Graduate School of Public Health. As member of my committee and expert in causal inference methods, Dr Naimi provided invaluable guidance in the methodological aspects of this work, in particular with regards to causal inference methods and competing risk analysis.

Mamadou Diop is a research assistant working with Erin Strumpf and a Master's student in epidemiology at Université de Montréal. Mr. Diop provided advice in data management and data linkage of administrative databases, and contributed to the conception and revision of my second manuscript.

Sylvie Provost is medical advisor for the Direction de la santé publique de Montréal. Dr Provost provided extensive insight and input towards the interpretation of findings in the second manuscript.

DEDICATION

To Jordan, from whom I learned that there is no greater accomplishment than to be kind and fair to the people you love.

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"I never lose an opportunity of urging a practical beginning, however small, for it is wonderful how often in such matters the mustard-seed germinates and roots itself."

— Florence Nightingale, quoted in *The Life of Florence Nightingale* (1)

STATEMENT OF FINANCIAL SUPPORT

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ACCRONYMS AND ABBREVIATIONS

Abbreviation	Definition
AMI	acute myocardial infarction
CHF	congestive heart failure
CI	confidence interval
CIHI	Canadian Institute for Health Information
COPD	chronic obstructive pulmonary disease
ED	emergency department
FMG	Family Medicine Group
HR	hazard ratio
IQR	interquartile range
PC	primary care
PCP	primary care physician
Q	quintile
RAMQ	Régie de l'assurance maladie du Québec
RUB	resource utilization band
US	United States of America

CHAPTER 1: GENERAL INTRODUCTION

1.1 Introduction

The ageing population and the rapidly increasing number and complexity of patients living with chronic illness requires that our health system be responsive to changing health care needs. (2) In 2013, Canadian seniors represented 15.3% of the total population. (3) The vast majority of seniors have at least one chronic disease, and approximately half of them have three or more. (4-6) Patients with multiple chronic conditions account for a disproportionate share of total health care costs, and their number is expected to continue rising. (7-9)

Seniors and chronically ill patients, and above all multimorbid patients that see multiple health care professionals in primary or specialty care settings may commonly experience fragmentation of care. (10) Care transitions from one level of care to another, in particular, may leave these patients vulnerable to gaps in their care, and contribute to unnecessary use of health services. (11-13) Estimates from the United States (US) suggested that up to $45 billion in annual spending may be attributed to inadequate management of care transitions, (14, 15) and hospital readmissions alone have been associated with a cost to the Medicare program of $17 billion, or 20% of total Medicare's hospital payments. In Canada, 1 in 10 dollars spent on inpatient care (excluding physician fees for services) is attributed to hospital readmissions, and seniors are approximately 30% more likely to be readmitted than adults.

As such, high rates of hospital readmissions have been a cost-control target of various strategies and interventions at multiple levels of health care, including US legislative initiatives under the Affordable Care Act to financially penalize hospitals with excess risk-adjusted readmission rates and incentivize the delivery of timely outpatient follow-up care after hospital discharge. (14, 16-18) Practice-level efforts (or *bottom-up interventions*) which are typically intensive and costly (e.g. discharge planning, case management, scheduled outpatient visits, etc.) and implemented locally have been shown to effectively reduce 30-day readmissions.

(19) To date, there has been virtually no investigations into system-wide innovations and opportunities to reduce readmissions and other adverse post-discharge outcomes at the population level. The current work is concerned with elderly or chronically ill patients experiencing a transition in care from hospital to community, and with the capacity (competence possessed) and the capability (competence that can be developed) of primary health care delivery to improve the care for these patients, and help contain health system costs.

1.2 Aims and Objectives

This thesis is entitled "Innovations and Opportunities for Primary Health Care after Hospital Discharge" because it aims to generate new knowledge 1) about existing innovations in primary care delivery implemented across the province of Quebec, and 2) to guide future policies and guidelines in the opportunity area of outpatient follow-up, which has been promoted as a key intervention point for effective care transition strategies to reduce readmissions.

Among hospitalized elderly or chronically ill patients and across patient morbidity levels, the specific objectives of this research were as follows:

Objective 1. To estimate the effect of the precise timing and type of outpatient follow-up visits (i.e. primary care physician or medical specialist) on readmission in the 60 days following discharge.

Objective 2. To estimate the relationship between enrolment in multidisciplinary team-based primary care practices and physician follow-up visits in the 30 days following discharge.

Objective 3. To estimate the relationship between enrolment in multidisciplinary team-based primary care practices and readmissions, ED visits and mortality in the 90 days following discharge.

1.3 Organization

In the following section (Chapter 2), I review the patient transition from hospital to the community, delineating the patterns of care, the burden of adverse events after hospital discharge with an emphasis on hospital readmissions, and the strategies

put forth or assessed for their potential to improve patient care and reduce adverse outcomes. I also provide a description of the health system reforms to primary care delivery that occurred in Quebec since 2000, and report some of the evidence from observational studies. In Chapter 3, I describe the dataset, and I also explain in more detail some of the advanced epidemiological methods used in this research to better handle various biases. Chapter 4 (first manuscript) investigates the delivery of timely outpatient follow-up after discharge to identify the optimal timing and type of follow-up (with a primary care physician or with a medical specialist) across the different levels of patient morbidity. The subsequent two chapters (Chapter 5 and Chapter 6, which contain manuscripts 2 and 3, respectively) examine how team-based models of primary care delivery known as Family Medicine Groups (FMG) in Quebec were associated with timely post-discharge follow-up and with readmission, post-discharge ED visits and mortality. Finally, Chapter 7 summarizes findings from the three studies and discusses the implications and future directions for research, for policy and for practice. A full list of references cited in this thesis as well as appendices not included in the manuscripts then follow.

CHAPTER 2: BACKGROUND

2.1 Patterns of Post-Hospital Care Transitions

In a 2003 Position Statement the *American Geriatrics Society* (13) defined transitional care as follows:

> "[A] set of actions designed to ensure the co-ordination and continuity of healthcare as patients transfer between different locations or different levels of care within the same location. Representative locations include (but are not limited to) hospitals, subacute and post-acute nursing facilities, the patient's home, primary and specialty care offices, and assisted living and long-term care facilities."

Coleman and colleagues (20) provided a comprehensive description of the frequency and complexity of post-hospital care transitions over a 30-day time period following hospitalization among Medicare beneficiaries, including transitions to and from a patient's home, skilled nursing or rehabilitation facilities (SNF in Figure 1), ED and acute care hospitals. The authors observed 46 distinct patterns in that time period (Figure 1). Immediately following a first acute hospitalization, the majority of patients (73.7%) were discharged to their residence (R in Figure 1), while some were transferred to a skilled nursing or rehabilitation facility (16.5%) or remained in the hospital care system (i.e. transferred within the existing hospital or to a different hospital; 9.6%). (20) These patterns varied in complexity: most patients were only transferred once; approximately 1 in 3 patients were transferred twice or more; and approximately 1 in 8 surviving patients were transferred from lower- to higher-intensity care environments.

Figure 2.1 Health Care Transition Patterns after Hospital Discharge, from Coleman (20)

In a large study conducted in 2011 among 28 103 Medicare beneficiaries, Sato and colleagues (21) extended their examination of transition patterns to transitions occurring beyond 30 days after discharge and for a larger number of institutional settings. Twenty-two percent of the population in this study experienced at least one care transition annually, half of which involved a single hospitalization and a return to home, while the other half experienced complex and multiple transitions. Consistent with Coleman and colleagues, (20) these findings show that post-hospital transitions are common and can be very complex and ongoing, thereby increasing the risk of mismanagement or medical errors. (13, 22, 23)

2.2 Adverse Outcomes and Events Following Hospitalization

Poorly executed transitions may generate excess healthcare costs, (24) medical errors and adverse medication events, (13, 25-27) and poor patient health outcomes. (27-29) *Adverse events* are defined as "an injury resulting from medical

management rather than the underlying disease," which may result in *adverse outcomes,* including unanticipated visits to higher-intensity care environments (e.g. hospital readmission) or death. (27) Forster and colleagues conducted structured interviews with patients recently discharged home from the hospital and found that out of three incident adverse events, one was deemed preventable (i.e. injury that could have been avoided had no error or system failure occurred) and another was deemed ameliorable (i.e. severity of injury could have been reduced substantially had the patient been managed differently). (27) Additionally, more than two thirds of incident adverse events were related to adverse medication events that occurred in the early post-discharge period, and the rest were related to procedures during the index hospitalization, infections or falls. (27, 30) In a separate multisite prospective study, Forster and colleagues reported that of all adverse events, 27% led to a readmission (56/204), 17% to an ED visit (34/204) and 3% to death (7/204). (30) In addition, one quarter of the readmissions, ED visits and deaths were classified as adverse events. (30)

2.2.1 Hospital Readmissions

Hospital readmissions occur frequently, particularly among the elderly or chronically ill, and are costly to the health care system. Estimates from the Canadian Institute for Health Information (CIHI) suggested that 8.5% of patients were readmitted within 30 days (excluding mental health) costing $1.8 billion per year to the system. (31) The study by Jencks and colleagues (24) analyzed inpatient claims for more than 11 million Medicare beneficiaries discharged from 4 926 hospitals in the U. S. between October 2003 and September 2004, and found that 19.6% of elderly patients were readmitted to a hospital within 30 days, accounting for approximately 20% of total Medicare hospital payments. The all-cause readmission rates and associated health spending among Medicare beneficiaries has remained relatively stable over time. (32)

Hospital readmissions are objectively measured patient outcomes often considered to reflect the quality of inpatient care. Countries such as Canada (Canadian Institute of Health Information), the U. S. (Centers for Medicare and Medicaid Services),

Australia (Australian Institute of Health and Welfare) and the United Kingdom (National Centre for Health Outcomes Development) publicly report 30-day (or 28-day in the U. K.) readmission rates for specific medical conditions or for any cause. This is done in an attempt to inform patients, monitor performance and promote quality improvement. (33)

Numerous efforts by van Walraven and colleagues at understanding hospital readmissions have highlighted the highly heterogeneous nature of this measure, warranting caution to use as performance or quality indicator. (34-39) Substantial variations in rates of readmission by geographic location, (24, 31, 32) by deprivation level of geographic area, (31, 40) and by chronic disease and morbidity level (32) have been reported in the U. S. and elsewhere. The wide range of readmission rates reported in the literature suggest that their numbers can be reduced.

The proportion of readmissions that are deemed avoidable or preventable, however, is unknown; estimates vary substantially across studies ranging from 5% to 79% (median 27.1%). (36) The choice of time window (i.e. the difference in days between the dates of initial discharge and readmission) has been shown to affect the ratio of avoidable readmissions, (41-43) with the 30-day evaluation timeframe for measure specification being the most commonly used, albeit arbitrarily. (44) A multicenter prospective cohort study conducted by van Walraven and colleagues found that the proportion of readmissions deemed avoidable was highest early after hospital discharge from an index admission, and decreased significantly with increasing time following discharge. (39)

Hospital readmissions may reflect a number of underlying factors unrelated to hospital or health system performance. A readmission will depend on disease progression and on decisions made at the interface between patients or caregivers and the multiple components and characteristics of health systems (i.e., organisations and providers). (44) A non-exhaustive list of factors influencing hospital readmission rates that were identified from published literature syntheses (45-51) is presented in Table 2.1.

Patient-level factors such as age, gender, and specific disease condition at index admission, comorbidities, and previous health utilization are routinely collected in administrative databases. Other factors believed to be strongly correlated with the likelihood of readmission (e.g. disease severity, functional limitations and family/social support) are not. Characteristics of physicians, hospitalists or outpatient physicians, may also be associated with readmission; for example, physicians with fewer years in practice, a narrower scope of practice or less confidence with specific patient populations may be more likely to refer/admit patients to the hospital.

Similarly, outpatient and inpatient practice organization, such as interdisciplinary teams, and physician payment mechanisms may also affect readmission rates. The large number of factors and the complex mechanisms that are thought to contribute to potentially avoidable hospital readmissions make attempts to draw inference about performance or quality of care based on this indicator challenging.

Table 2.1: Factors contributing to potentially avoidable hospital readmissions, adapted from Snyderman and colleagues (51)

Patient factors	Examples
Demographic / socioeconomic	Age, gender, race/ethnicity Marital status Social support Stable housing status Ability to pay (e.g. medications, equipment, services)
Medical	Responsible diagnosis (e.g. AMI, CHF, COPD) Severity of illness Multimorbidity Polypharmacy Functional limitations (e.g. vision loss)
Nonadherence	Medication-related: cost, psychosocial complexity of issues, adverse effects, adverse drug events, complex regimens Nonmedication-related: diet, physical activity, fluid intake, weight monitoring
Utilization of health care services	Transportation and distance to hospital Health insurance coverage Difficulty navigating the health care system Prior hospitalizations Length of hospital stay

Health beliefs, knowledge and understanding of medical conditions	Fearful of medical system Delays seeking help Cultural background Language skills Cognitive abilities Health literacy
Process of care factors - Physician	**Examples**
Diagnostic uncertainty	Limited confidence Risk aversion Scope of practice
Outpatient care Suboptimal monitoring of chronic conditions	Awareness of alternatives for hospital admissions Availability and time Reimbursement for case management Reimbursement of interdisciplinary team members
Patient-provider relationship	Communication skills Trust issues
Process of care factors – Hospital/practice	**Examples**
Quality of inpatient care	Discharge planning and instructions Optimal time for discharge Assessment of patient clinical stability Medication reconciliation
Quality of outpatient care	Adherence to guidelines (e.g. patient receives optimal post-discharge outpatient care) Medication reconciliation
Access to primary care	No follow-up appointments available No access in evening or weekends
Provider-provider miscommunication	Suboptimal or untimely communication between health care providers (e.g. hospitalist to primary care physician)
Continuity of care	Failure to transmit patient information to and from hospital, subspecialists, and other providers
Health care professional not available to offer medical advice after hospital discharge	Follow-up visit or call Online patient portal After-hours provider on call Providers unable to return calls during day

Increasingly, hospital readmissions are considered as markers of health systems failure in implementing adequate processes of care involved in care transitions *across the care settings* (i.e. beyond quality of inpatient care). Kripalani and colleagues reviewed common challenges in ensuring effective care transitions, which included the discontinuity between hospitalists and primary care physicians and lack of timely information transfer between care settings, the discrepancies

between medication regimens pre- and post-discharge, and the increasing economic pressures that may alter both the discharge process and the responsibilities placed on the patients for self-care after discharge. (25) This broadened understanding gives rise to new actionable targets to help in reducing hospital readmissions, and also to a new level of complexity with respect to the factors driving hospital readmissions.

2.2.2 Emergency Department Visits

Shortly after an initial discharge, patients may return to the emergency department (ED), and subsequently return home or be readmitted, depending primarily on the stability and severity of their health condition. ED visits are another adverse outcome following hospital discharge that may reflect a failure of health systems in ensuring a smooth transition from hospital to the community. (12, 52-56)

Although post-discharge ED visits are less studied than readmissions, their frequency of occurrence and their high variability make this indicator similarly actionable for improving quality and cost. A cohort study using administrative health databases reported that 23.8% of patients discharged from an urban academic hospital returned to the ED within 30 days (N = 15 519 discharges). (56) Lower incidence of post-discharge ED visits within 30 days were found in larger cohort studies by Vashi and colleagues (7.5%; N = 5 032 254 discharges among all patient and insurance types), (54) and by Kocher and colleagues (17.3%; N = 2 456 021 discharges among Medical surgical patients). (15) Vashi and colleagues also pointed out that 30-day incidence of ED visits following discharge ranged from 2% to 28%, depending on the most responsible diagnosis at initial discharge. Further, approximately half of patients returning to the ED after a hospital discharge are then admitted to the hospital, making it the primary source of readmission. (15, 54, 56) Mark V. Williams in a 2013 editorial to *JAMA* recommended that "ED [visits] after hospitalization should also be monitored and assessed as a quality measure to complement 30-day readmissions." (57)

2.2.3 Mortality

Reducing mortality is a goal generally valued by all – individuals, health care workers and policy-makers alike. In most instances, mortality can be reliably and objectively measured and is often interpreted as the ultimate adverse outcome. (58) Mortality rates are generally highest in the early period after hospital discharge and decrease with time, in particular for patients with certain health conditions like heart failure. (59) Thirty-day mortality rates are used internationally to measure the quality of inpatient care across establishments. (58, 60, 61) The Centers for Medicare and Medicaid Services (CMS) began publicly reporting 30-day risk-standardized mortality rates for specific medical conditions (acute myocardial infarction (AMI), chronic obstructive pulmonary disease (COPD), heart failure (HF), pneumonia and stroke) in July 2015 as a measure reflecting a broad set of healthcare activities that may affect patients' survival, including quality of care during hospitalization and their transition to the outpatient setting. (62) Like hospital readmission and ED visits, however, post-discharge mortality rates may be limited in their utility to measure quality if there is incomplete risk adjustment. (60)

2.3 Risk Adjustment and Risk Prediction

When using observational data to compare outcomes across units of interest (e.g., comparing patient post-discharge outcomes by hospitals), risk adjustment methods must be used to account for systematic differences between these groups that are outside the control of the units in question, in particular with respect to the comorbidity burden, or case mix. Iezzoni explains the rationale behind risk adjustment in "Risk adjustment for performance measurement" (63) as follows:

> Health care plans, hospitals, general practitioner practices or other health-care providers are not selected randomly. Many factors affect the way people link with their sources of care, including the nature of their health needs (e.g. acuity and severity of illness); financial resources; geography; previous health-care experiences; and their preferences, values and expectations of health services. Not surprisingly, there may be wide variations in the mix of persons covered by different health plans, hospitals, general practitioner practices and other health care

providers. These differences can have consequences. For example, older persons with multiple chronic conditions require more health services than younger healthier people and are thus more costly and complicated to treat. Most importantly from a quality measurement perspective, persons with complex illnesses, multiple coexisting conditions or other significant risk factors are more likely to do poorly than healthier individuals, even with the best possible care.

Several approaches have been used for risk adjustment, most of which involve statistical models and the use of health care utilization information as primary source of data. Generally speaking, these approaches are used to calculate patients' risks of experiencing adverse outcomes, or serve to classify patients into risk groups and/or levels of comorbidity burden. Increasingly, more sophisticated statistical modelling techniques such as smoothing techniques are being used to improve predictive performance and risk adjustment. It should also be noted that slight variations in the methods used will influence the risk-adjusted rates of outcomes and comparisons thereof, (64-67) suggesting that caution is warranted to avoid unfair or inappropriate inference about performance.

Summary measures of comorbidity burden may be used for risk adjustment or risk stratification. One specific example is the Johns Hopkins Adjusted Clinical Groups (ACGs), a person-focused approach frequently used worldwide. (68) Austin and colleagues (69) summarized the ACG system as follows:

> The ACG system assigns each [International Classification of Diseases] (ICD; 9 version, 9-CM version, or 10 version) codes to 1 of 32 diagnosis clusters known as the Aggregated Diagnosis Groups (ADG). Individual diseases or conditions are placed into a single ADG based on 5 clinical dimensions: duration of the condition, severity of the condition, diagnostic uncertainty, etiology of the condition, and specialty care involvement. ICD codes within the same ADG are similar in both clinical criteria and expected need for healthcare resource. […] Importantly, the ADG/ACG definitions do not rely solely on the use of

inpatient health administrative data, but also use data contained in ambulatory healthcare data.

Statistical models that included age, sex and the Johns Hopkins ADGs have been shown to have good accuracy in predicting mortality among various patient populations (c-statistic $\geq$ 0.84). (67, 69-71) One disadvantage of the ADGs compared to other approaches using administrative data such as the Charlson comorbidity index or the Elixhauser comorbidities may be its lack of transparency in the assignment of ICD-9/10 codes to different categories. (69)

Risk adjustment procedures have been the subject of controversy since hospital readmissions became a publicly reported performance measure used to determine hospital payments. This controversy stems from debates on the attributional validity of this performance indicator, or the degree to which observed differences in the rates of readmissions are causally related to performance, and not to other contributing factors. (63) Accordingly, attributional validity may require that a conceptual model linking the various dimensions of health systems be developed to assist in statistical model building and in interpreting comparisons of performance measures. (63)

There has also been extensive amount of research on risk prediction models for readmissions. (72) The interest in predicting patients at highest-risk of readmission is tied to the belief that targeting high-risk patients is more cost-effective than a population approach, although this has never been verified empirically. The current thesis is not concerned with risk prediction; nevertheless, the literature on this topic has contributed extensive knowledge towards a better understanding of risk factors.

2.4 Conceptual Framework of Health Service Utilization

I present in Figure 2.2 a conceptual framework based on empirical evidence and expert knowledge to broadly encode the causal structure linking patient characteristics, processes of care and outcomes of care. This conceptual framework is adapted from the Behavioral Model of Health Services Use by Andersen & Davidson. (73, 74) Starting with the boxes associated with "Patient Factors," this framework suggests that a community/individual's use of health services is a

function of: 1) their predisposition to use services, 2) factors that enable or impede use, and 3) need for care. The special needs of elderly or chronically ill patients experiencing a transition in care (e.g. Increased Service Needs) and predisposing characteristics (e.g. Health and Functional Status) were incorporated as they are important determinants of health service utilization in this population, in particular in the period following hospital discharge.

Enabling resources may include family/caregiver support, marital status, and social or other contextual support resources. Predisposing factors may include the patient's age and sex, education level, race/ethnicity, and employment status. Processes of care, defined as the "interactions between the health care providers and patients over time" are conceptualized to mediate the path between the *need for care* and *outcomes of care*. (75) In the period following hospital discharge, this may include elements of an ideal transition in care, for example, quality of post-discharge care, timely access to needed services and care coordination across the different health settings. Outcomes of care, including hospital readmissions, ED visits and mortality after hospital discharge, may be a result of a patient's characteristics or of the interaction between patients and processes of care. Contextual characteristics (e.g., geographical location, community age structure, supply of medical personnel and facilities) can directly impact processes of care and influence use of health services. Hospitals and outpatient clinics, in particular primary care practices, are conceptualized to have varying degrees of those processes that may influence one's use of health services, including quality, patient-centeredness, comprehensiveness, accessibility and care coordination. (76) Arrows that are bi-directional reflect the possibility of feedback effects over time. The dotted boxes indicate the variables that could potentially be modified by targeted interventions to reduce outcomes of care, including hospital readmissions.
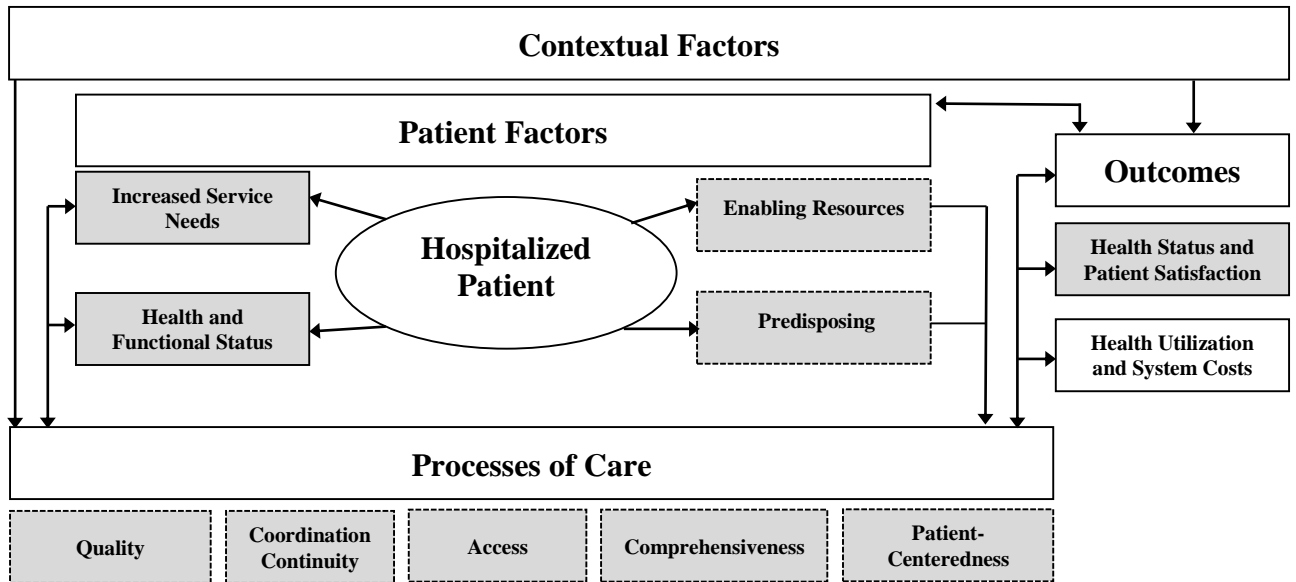
Figure 2.2 Conceptual framework adapted from the Behavioural Model of Health Services Use (74)

2.5 Strategies to Reduce Readmissions

Initiatives to reduce hospital readmissions are varied, ranging from local (*bottom-up*) interventions, such as hospital-initiated discharge interventions (e.g., discharge planning, patient education, medication reconciliation), through low-powered incentives such as public reporting of readmission rates (i.e., nobody can lay claims to any gain that may result), to high-powered incentives such as financial penalties (i.e., gains flow directly into the parties transacting). Since 2012, the Hospital Readmission Reduction Program in the U. S. imposes penalties to hospitals for excess risk-standardized readmission rates for specific conditions at index admission (acute myocardial infarction, heart failure, pneumonia or chronic obstructive pulmonary disease). Despite the controversy around penalizing hospitals for high readmission rates, this policy has intensified efforts to reduce readmissions. (44, 77) Accordingly, a number of reviews on strategies to prevent 30-day hospital readmissions have been published in recent years. The following sub-sections summarize the evidence gathered and synthesized in these reviews.

2.5.1 Classification

Hansen and colleagues (78) have categorized interventions to reduce readmissions into three domains: 1) pre-discharge interventions, 2) post-discharge interventions, and 3) bridging interventions (i.e. interventions active both before and after discharge). In their systematic review of the literature, these authors found that pre-discharge interventions were the most commonly assessed. Such interventions are typically initiated during the hospitalization, and include patient education and discharge planning, medication reconciliation and scheduling of a follow-up appointment before discharge. Post-discharge interventions identified in the review included timely outpatient follow-up, timely communication of patient to an outpatient provider, phone follow-up or patient-activated hotlines and home visits. Bridging interventions correspond to patient-centered discharge instructions that emphasize the longitudinal relationship spanning throughout the hospitalization and into the post-discharge period; these typically involve a transition coach (e.g. nurse) or same-provider continuity (e.g. inpatient physician continues to manage patient in ambulatory setting).

2.5.2 Characteristics and Effectiveness

According the same work by Hansen and colleagues published in 2011, (78) few interventions to reduce readmissions were tested in isolation, and most studies used non-experimental designs. In a literature review, they identified 16 randomized controlled trials, 5 of which reported reductions in 30-day readmissions, including 1 focusing on discharge planning for high risk patients (11%-point reduction) and 4 testing multicomponent discharge bundles. Overall, the authors of this review found evidence that intensive multifaceted interventions were efficacious in reducing readmissions, but there was no such evidence about any singular intervention tested. The authors also pointed out that the vast majority of studies were limited by their low quality designs, with limited internal and external validity. They reported that randomized controlled trials enrolled few patients, and observational studies often failed to adequately describe interventions and adjust for contextual factors (hospital and community). (78)

Leppin and colleagues (19) developed an approach to examine the effect of intervention characteristics (and varying degrees thereof) on hospital readmissions. They adapted the taxonomy by Hansen and colleagues (78) to characterize interventions and quantify their effect across 42 randomized trials published until 2013, most of which were judged to be at low risk of bias. These authors found that interventions involving multiple patient interactions and several meaningfully involved participants (e.g. physician, nurse, and caregiver) were 30% to 40% more effective than other interventions. The pooled random effects relative risk (RR) for the effect of tested interventions was 0.82 (95% confidence interval (CI) 0.73 to 0.91); $I^2 = 32\%$). (19)

Kripalani and colleagues provided a conceptual framework to highlight the key components of an ideal transition in care. (25, 72, 79) This framework draws heavily on the works by Hansen and colleagues (78) and by Naylor's Transitional Care Model, (80) placing patient education and promotion of self-management at the center of an ideal transition, and discharge planning (hospital-based component) and optimal outpatient follow-up (community-based component) on each end of the transition. Based on this framework, the other key components of an ideal care transition from hospital to community include complete, available, clear and timely communication of information, medication safety, social and community supports, advanced care planning, coordinating care across settings and providers, as well as monitoring and managing symptoms after discharge. (25, 72, 79) As the authors suggest, the lack of a key component weakens the care transition, and the lack of several components can potentially reduce patient safety and contribute to adverse events. (79)

The next sub-sections discuss in more details timely outpatient follow-up and primary care-based strategies in their capability and capacity to address the components of an ideal transition in care and affect post-discharge outcomes.

2.5.3 Timely Outpatient Follow-Up after Discharge

Outpatient follow-up has been promoted as a key intervention point in medical care. It provides an opportunity for health providers to ensure that essential components

of an ideal transition in care are addressed, including patient education, medication safety, monitoring and managing disease and coordinating care. Of the post-discharge interventions, outpatient follow-up has been the most studied in isolation, as opposed to as part of a bundle of peri-discharge interventions.

Several observational studies have examined its relationship with readmission rates in various patient populations, and inverse associations were found among surgical patients, (81, 82) patients with heart failure (HF), (83-85) sickle cell disease, (86) chronic obstructive pulmonary disease (COPD), (87, 88) patients receiving hemodialysis, (89) the elderly or chronically ill (90, 91) and for the general hospitalized population. (92, 93) In contrast, a number of studies found no association, including one pragmatic trial (N= 531) and one observational study (N = 3,661) conducted among elderly patients, (94, 95) one large observational study (N = 25,872) in patients hospitalized for acute myocardial infarction, (96) and another small observational study in patients with COPD (N = 839). (97)

Evidence from large observational studies have also suggested that post-discharge outpatient follow-up should be provided in a timely manner, (83, 92, 93) and by providers with whom patients have a continuous relationship. (98, 99) "Timely" is generally defined as ranging from within 7 days to within 30 days after hospital discharge. (78) Different approaches to the study of 'timing' of outpatient follow-up have been taken, each with important limitations to the internal or external validity. Jackson and colleagues (92) examined the incremental effect of receiving follow-up within 3, 7, 14, 21 and 30 days after hospital discharge (e.g. patients receiving follow-up within 7 days are compared to patients not receiving follow-up or later than 7 days) and by clinical risk groups. In sensitivity analyses, these authors stratified by age, sex, and race or restricted to the first discharge for patients with multiple admissions; geographic and community- or practice-level factors were not accounted for, nor was the relationship between death and readmission (i.e. in the event of death, readmission may not occur) and the confoundedness of the exposure itself.

Hernandez and colleagues (83) addressed confounding by illness severity (i.e. patients who are sicker may be more likely to be seen sooner in an outpatient setting) by comparing hospitals with varying rates of outpatient follow-up within specified time intervals on patient-level hospital readmissions. However, such comparison may be biased because hospitals with high rates of early outpatient follow-up likely differ from those without on key components of an ideal transition in care, e.g., discharge planning or timeliness of information transfer. Other smaller studies (N<400) showing contradictory results did not account for time-dependent effects, for time-dependent confounding, or for competing risk by death. (90, 93).

In addition to timing, physician characteristics and practice type of follow-up may also further influence rates of readmissions. Findings from one cohort study showed that follow-up by a physician who has a longitudinal relationship to the patient was associated with lower rates of readmissions than follow-up by a physician without such relationship, (98) while another one found no association. (83) One population-based cohort study of heart failure patients discharged from the ED found that follow-up by both a cardiac specialist and by a primary care physician was associated with lower mortality relative to follow-up by a primary care physician only or to cardiology care only. (100) Another study showed that both post-discharge follow-up care by a primary care physician only, and by a psychiatrist only were similarly associated with lower rates of 180-day readmissions among patients with a mental health diagnosis; these authors, however, restricted the analysis to patients who survived or were not readmitted within 30 days of discharge. (101) From a policy perspective, it remains unclear whether and how the type of follow-up (by primary or specialized care physician, or by both) plays a role in reducing hospital readmissions.

2.5.4 Primary Care-Based Strategies

As Sommers and Cunningham explain, healthcare "reforms […] focusing only on care processes within hospitals may fall short unless efforts to coordinate with community providers – and to encourage patients' access to these providers – receive at least as much attention." (102) As such, the transition interface between

primary and inpatient care represents an opportunity to address system failures that contribute to preventable post-discharge adverse events. To help in preventing readmissions, primary care providers may discuss with patients problems unresolved at the time of discharge, educate patients regarding medications and other therapies, engage them in their care, monitor drug therapies, and monitor/manage the patient's health condition(s). (27) These may be addressed as part of a timely outpatient follow-up visit, home visit, or telephone follow-up.

Many primary care-based interventions have been implemented, but few have been evaluated. Two multi-component interventions within a Patient-Centered Medical Home, a model of primary health care that emphasizes access to a usual source of care (e.g., personal physician or nurse) as well as coordinated and patient-centered care, (103) were found to be associated with 5% to 20% lower rates of hospital readmissions. (104, 105) These consisted of a multidisciplinary team-based practice with scheduled outpatient follow-up within 1 week of discharge. A large quasi-experimental evaluation of a community-based readmission reduction program consisting of follow-up phone calls, home visits and linkage to community resources by transitional care consultants was found to reduce readmissions by 9.3% (relative to before the intervention). (106)

The care transition has not been an area of focus of system-wide primary care transformation. Nevertheless, several characteristics (or processes) of an ideal transition in care align with the objectives of transforming primary health care systems to increase access to care, and improve care coordination and continuity, in particular for medically vulnerable patients. Further, despite more than a decade of large-scale efforts to redesign primary care in many countries around the world, no study to date has explored whether system-wide interventions/policies in primary care implemented at the population level in their capacity/capability to affect process and outcome measures in the care transition period. Systemic approaches to improving on these processes of care in Canada (i.e. care coordination and continuity) have implemented organizational changes to primary health care service delivery; the next sections discuss these changes in more details.

2.6 Primary Health Care Reforms in Quebec and Canada

Primary health care that facilitates timely access to and coordination of care has been correlated with lower rates of unnecessary health care utilization and associated costs. (76, 107-110) In particular, seniors and chronically ill patients rely on strong primary health care to manage their condition(s) and to play a coordinating role in their care. (2, 111) In response to the country's ageing population and rising number of adults with chronic conditions, the Primary Health Care Transition Fund distributed $800 million to Canadian provinces to undergo transformation in primary health care delivery to meet their needs. As a result, initiatives in primary care delivery based on the patient-centered medical home framework (i.e., provide better access to primary care, promote multidisciplinary team-based care, and improve chronic disease management) were implemented across a number of provincial health systems in Canada. (112)

2.6.1 Family Medicine Groups in Quebec

In Quebec, federal investments contributed to the system-wide implementation of new models of multidisciplinary team-based primary care known as Family Medicine Groups. (FMGs) These new models of primary care delivery were designed to improve access, reduce the number of visits to the emergency departments, and facilitate effective care coordination. (107-109, 113-119) The FMG policy effective since 2002 predominantly supports organizational changes to primary care practice; FMGs are designed to unite family physicians (generally 6 to 12 physicians) and other health care professionals (generally 1-2 nurses) to provide primary care for a group of registered patients (1 000-2 200 registered patients per full-time physician). Physicians who join a FMG maintain the same remuneration schemes as non-FMG physicians, which consist predominantly of fee-for-service. FMG physicians and non-FMG primary care physicians also receive a small financial incentive for each vulnerable patient that they register to their practice, i.e., elderly or with eligible chronic health conditions. (120) In 2014, the proportion of vulnerable patients registered with a primary care physician was 40.2% for FMG- and 45.4% for non-FMG physicians. (121)

In addition to these organizational changes, FMGs are intended to offer patients better access through extended hours, regular appointments, walk-in clinics, home visits, and telephonic health advice and emergency on-call services. Nurse specialists, whose salaries are paid by the Ministère de la Santé et des Services Sociaux (MSSS) are integrated within FMG teams and are intended to provide case management, disease prevention and health promotion services. The integration of nurses, however, occurred over time; by 2010, approximately 80% of FMG practices had one or more nurses within their team compared to 25% of traditional primary care practices. (122) Additionally, FMG policy documents support that care coordination should be enhanced by closer links to the health and social services network, such as services from local agencies (e.g., psychosocial support). (123-125) Finally, explicit financial support is allocated for office computerization of FMGs to allow for future implementation of electronic medical records. (126) By 2010, FMGs reported higher rates of electronic medical records use compared to other primary care practices. (121, 122, 127, 128)

A 2015 report by the Auditor General of Quebec highlighted several shortcomings of FMGs. (121) The rate of patient enrolment with FMGs, in particular vulnerable patients has not increased much since their implementation (5.9% increase in the past 5 years). Further, the report noted a lack of transparency and data around the role and activities of nurses practicing in FMGs. At current, FMG-related initiatives by government or by health and social service organizations do not support or monitor improved performance, and the case load associated with vulnerable patients is not adequately accounted for. These shortcomings, and the generally passive role of government and agencies in the implementation, monitoring and evaluation of FMGs (i.e. relying heavily or solely on doctors practicing in FMGs) suggest that efforts are needed to better align the policy with the needs of the population. In particular, the FMG policy has not emphasized the care transition as an area for practice improvement in primary care.

2.6.2 Synthesis of the Evidence on Canadian Primary Care Reforms

Carter, Riverin and colleagues (129) recently summarized the best available evidence on Canadian primary care reforms to assess whether they had any effect on health system measures of health service utilization, processes of care, and physician productivity. The majority of studies that we identified through a systematic search and selection strategy focused on new blended payment models in Ontario (e.g., blended capitation and enhanced fee-for-service), and only 5 studies (3 from Quebec and 2 from Alberta) looked at new team-based models (e.g., group of physicians working with a nurse practitioner). Findings from these studies suggested that team-based models were associated with lower rates of ED visits and better diabetes management, while the evidence of an association with chronic illness care, hospital admissions or patient-reported health was inconclusive.

Only two of the 5 studies dealt analytically with the issue of selection bias (or *self-selection effect*), which stems from the fact that physician (and patient) participation in new models of practice is voluntary. Coyle and colleagues (130) and Rudoler and colleagues (131) examined the characteristics of physicians associated with self-selection into team-based models or blended payment models, respectively. Based on their analyses, physicians joining new team-based models have fewer years in practice, care for patients with lower morbidity and tend to see more patients in various clinical settings. (130) Likewise, physicians participating in newer blended capitation payment models were more likely than physicians practicing in other models (i.e., fee-for-service or enhanced fee-for-service) to care for patients that are less medically and socio-economically vulnerable. (131)

In addition to *self-selection*, the potential for bias is further increased by the large number of factors that may drive these associations, some of which are difficult to measure accurately over time. This makes the estimation of a causal effect of such policy on health systems performance a challenge, and further highlights the need for research to choose measures for which a change over time can be linked (at least, to some degree) to better quality of care for patients, and additionally to lower health system costs.

Accordingly, previous syntheses of primary care reforms in Canada have called for methodologically rigorous evaluations of reforms using appropriate health system performance indicators. (129, 132-134) As noted, a common objective of Canadian transformations in primary care delivery was to improve coordination of care, and ensuring a safe transition to the community after a hospital discharge is but one element of coordinated care that aims to prevent avoidable re-entry in the hospital system. Evidence is lacking to inform decision- and policy-makers on post-discharge measures of quality and processes of care in the context of Canadian primary care reforms.

2.7 Summary of Evidence Gaps

Several evidence gaps exist in the literature regarding health system performance measures (processes and outcomes) in the period shortly after a hospital discharge, including the following:

1) Evidence is inconsistent and limited on the effect of outpatient follow-up on reducing hospital readmissions; the limitations of previous research are due to a small sample size and/or to an analytical approach that fails to account for important sources of bias (e.g. incomplete risk adjustment, time-dependent bias and/or competing risk by death);

2) Evidence is lacking on the critical time window at which the delivery of outpatient follow-up yields the most reduction in the risk of readmission, and on how its effect varies by type of physician (e.g., primary care physician or medical specialist); and by subgroup of patient morbidity level;

3) Evidence is lacking on if and how system-wide policies in primary care are associated with performance measures (process and outcomes) in the care transition period, and whether these associations vary by patient morbidity level; specifically, with respect to:

   a. The delivery of timely outpatient physician follow-up, either by a primary care physician or by a medical specialist;

      b. The incidence of post-hospital discharge readmission, emergency department visits and mortality.

The current thesis aimed to address these gaps in an attempt to inform future research, policies and guidelines to improve patient care and reduce costs associated with the care transition.

CHAPTER 3: DATA AND ANALYTICAL METHODS

The 3 studies are based on data on a cohort of patients extracted from the *Régie de l'assurance maladie du Québec* (RAMQ). Information about the dataset is presented at length in each manuscript; this section provides an overview of the data and analytical methods as well as further details about data structure not presented in the manuscripts.

3.1 Cohort and Dataset

The final dataset that was used for all analyses (referred to as 'dataset') was based on an initial cohort of patients (referred to as 'cohort') extracted from the RAMQ health databases. Patients were selected into the cohort if they were enrolled as 'vulnerable' by a primary care physician during a visit that occurred between November 1, 2002 and January 31, 2005; i.e., at that visit, an incentive code was billed to the RAMQ by the enrolling primary care physician if the patient met RAMQ's description of 'vulnerability' (i.e. 70 years old or more, or having one or more of a set of chronic conditions). The date of enrollment as 'vulnerable' with a primary care physician corresponded to the cohort's index date; administrative health data on the enrolled patient and on the enrolling physician were initially extracted from 2 years before and to 5 years after the index date. Overall, the extraction period spanned from October 1, 2000 to March 31, 2010.

I then built a dataset consisting of all hospitalizations that occurred between the patients' index date to the end of their 5-year follow-up. Data from before the index date were used only to build measures of previous use of health utilization. The unit of observation was the hospital admission (thereafter referred to as the *index admission*), which patients may experience several times during the study period. We defined index admission as a hospital admission for any cause not preceded by an admission in the 30 days prior (i.e. not a 30-day readmission). Transfers between hospitals were treated as one hospital stay, and only hospitalizations that resulted in patients discharged home contributed as a unit of observation. For each

hospitalization, I extracted physician billings within 90 days of hospital discharge as well as data on subsequent hospital admissions.

3.2 Administrative Health Databases

The RAMQ collects information reflecting physician billings and health care service use by individuals registered with Quebec's universal health insurance program. A unique lifetime identifier encrypted from the personal health insurance number allowed for record linkages across 4 databases administered by RAMQ: 1) the Registered Persons File, which contains socio-economic characteristics; 2) the Physician Claims File, which contains physician's services performed in hospital, office or clinic; 3) the Hospital File, which collects information about each hospital visit or stay; and 4) the Physician Information File, which includes information on the enrolling physician. Records were linked on the unique lifetime identifier.

3.2.1 Dataset Structure

Each observation contained the exact date for a hospital admission and discharge, and for any physician services provided up to 90 days after the date of discharge. The time unit for all analyses was the day. Time variables were derived from dates, with time zero ($t = 0$) corresponding to the date of hospital discharge, and counting the number of days that elapsed since a hospital discharge to any encounter that occurred in the 90 days' post-discharge setting, or up to a subsequent admission. The dataset was kept in wide-form, in which information pertaining to a hospital stay and associated post-discharge events (including data points for timing of each event) are contained in a single row.

3.2.2 Patient Enrollment

The RAMQ recorded the dates of patient enrollment as vulnerable during the study period, as well as whether the enrolling physician was affiliated to a FMG. Patients initially enrolled as vulnerable with a primary care physician not affiliated with a FMG may have their enrollment status updated during the study period (i.e., a change in enrollment status may occur if a primary care physician joins/leaves a

FMG during the study period, or if a patient becomes enrolled with a different primary care physician).

3.2.3 Variables and Measures

Details about patient-level variables derived from administrative databases are presented in the 3 manuscripts (main text and appendices). Patient characteristics and previous health services utilization were measured at the time of index hospitalization to reflect pre-exposure characteristics, and were not updated throughout the post-discharge period. Patient characteristics were updated at each index hospitalization, except for measures based on the patient address, such as the material deprivation index and geographical location, which were updated every year on July 1. Physician-level variables were also measured to the date of the index hospital admission, and were updated every year (details are presented in the appendices of the 3 manuscripts). Process and outcome measures were all time-to-event, with $t = 0$ corresponding to the day of hospital discharge.

3.2.4 Follow-up Time after Hospital Discharge

Censoring of follow-up time was set at 30 or 90 days depending on the study question. Outpatient follow-up (exposure studied in Chapter 4 and endpoint studied in Chapter 5) was examined *up to* 30 days of hospital discharge because this timeframe encompasses the timeframes put forth in clinical practice guidelines that consider post-discharge follow-up as a process of care measure (e.g., follow-up within 7 days, 14 days or 30 days after discharge). There is no consensus in the scientific literature on the analytical timeframe for post-discharge outcomes; for this reason, we avoided selecting one timeframe (e.g. 30-day readmission) and analyzed up to 90 days after discharge with an emphasis on presenting results using adjusted cumulative incidence curves. In Chapter 4, only the results on post-discharge outcomes up to 60 days are presented because the results beyond this timeframe were deemed uninformative. (i.e., trend remained stable). In Chapter 6, the results are presented up to 90 days after discharge, with an emphasis on 30-day outcomes to reflect the current policy interest on this timeframe and because it is

thought to be associated with a higher proportion of post-acute events that are deemed avoidable.

3.3 Analytical Framework

To guide my analysis, I used Directed Acyclic Graphs (DAGs) depicting the direction of causal influence for the relevant variables (or set of variables) (Figure 3.1). The relationships under study in each of the manuscript broadly correspond to the path(s) depicted and numbered in Figure 3.1: in Chapter 4 (Effect of Outpatient Follow-Up on Hospital Readmissions), estimates broadly correspond to path 1; in Chapter 5 (Association between Team-Based Primary Care and Timely Physician Follow-Up), estimates broadly correspond to path 2; and in Chapter 6 (Association between Team-Based Primary Care and Post-Discharge Events, including Hospital Readmissions), estimates broadly correspond to the sum of paths 1, 2 and 3 (i.e. total effect); and. The letter U'' denotes a vector of confounding variables that were not routinely collected in administrative health databases (e.g. patient functional limitations, severity of illness), and the letter C' denotes a vector of confounding variables that were 'measured' at hospitalization. The letter S' denotes a vector of variables representing patient and/or physician characteristics or preferences, which in turn may be associated with the choice of (or selection into) a type of primary care practice and with post-discharge processes and outcomes of care. Note that the presence of U' and S' implies that estimates representing the paths (or relationships) in Figure 3.1 may not have a purely causal interpretation. The box around 'Hospital discharge' signifies that, by design, we conditioned on patients having been discharged alive from at least one hospitalization during the study period; I discuss how this may impact the interpretation of the estimates in section 3.4.5.
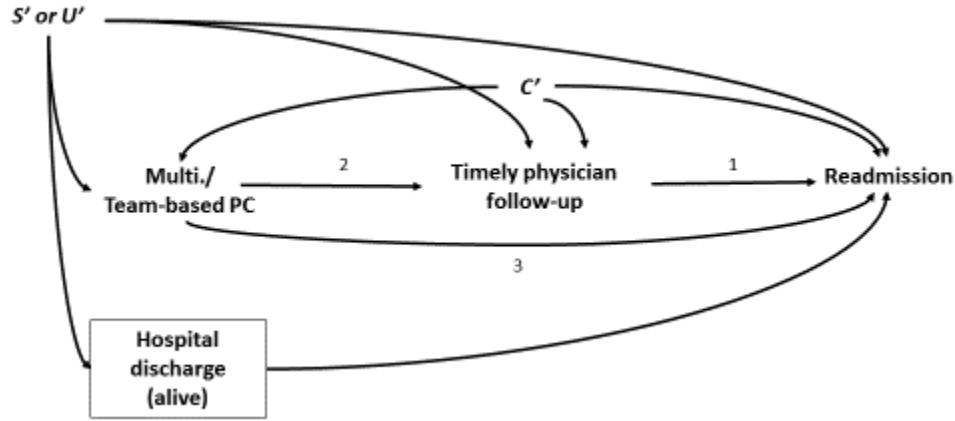
Figure 3.1 Directed acyclic graph (DAG) for the hypothesized causal structure underlying the research objectives

3.3.1 Potential Outcomes Framework

This research makes use of the potential outcomes framework under which causal effects can be characterized provided certain assumptions are met. Rubin (135) and Robins (136) demonstrated that the average causal effect in the population can be defined as the contrast between two *potential* outcomes, that is, the expected value of the outcome *had everyone in the population received an intervention* compared to its counterfactual, i.e., the expected value of the outcome *had everyone not received an intervention.* The average causal effect in the population is based on specific identifiability assumptions: 1) *consistency* : the intervention (denoted A) corresponds to a well-defined intervention such that observing $A = a$ implies that the observed outcome is Y^a; 2) *positivity* : there are exposed and unexposed subjects for every combination of the values taken by measured confounders (137); 3) *exchangeability* : treatment assignment is independent of the potential outcomes Y^a, i.e., no unmeasured (or uncontrolled) confounding between A and Y; and 4) *no interference* : Y_i^a is not affected by treatment of another subject j. (138)

For all practical purposes, the *consistency* of the interventions under study in the following chapters (Chapters 4, 5 and 6) is assumed; i.e., from a policy decision-making perspective, the potential variations in post-discharge physician follow-up (intervention under study in Chapter 4) and in patient enrollment with a FMG at

index admission (intervention under study in Chapters 5 and 6) are considered irrelevant. *Positivity* is also assumed and evidence of random nonpositivity was assessed using diagnostics described in section 3.4.5. *No interference* is also assumed. Lastly, the *exchangeability* assumption is dealt with analytically and to varying degrees depending on the exposure, which I explain in the following sections and in the manuscripts.

3.4 Analytical Approach

Several threats to the validity of this research were dealt with at the analytical stage, specifically using methods in causal inference based on the potential outcomes framework and flexible modelling techniques. I explain these in further details in the following sub-sections.

3.4.1 Causal Inference Methods: Propensity Scores

A successful randomization process ensures exchangeability of exposure groups on both observed and unobserved factors, a requirement for causal inference. The exposures under study in this work (outpatient follow-up and multidisciplinary / team-based primary care models) are not randomized; rather, they are observed and routinely recorded over time in administrative databases, along with other types of information. A comparison of two exposure groups on the probability of an outcome will likely be biased.

Methods in causal inference, such as those based on the propensity score have been used to reduce bias in observational studies. The propensity score, defined as the conditional probability of being exposed (or treated) given the individual's observed covariates, is estimated from the data. It serves to balance covariates across exposure groups in a way that mimics a randomized trial, i.e., the distribution of observed baseline covariates becomes similar in 'exposed' and in 'unexposed' subjects, conditional on the propensity score. Imbalances in unobserved confounders cannot be assessed with propensity score methods. Four methods in statistics use propensity scores: matching, stratification, covariate adjustment, and inverse probability of treatment weighting (IPTW); the latter, which was found to remove bias as efficiently as full matching was used in all the analyses of this work.

(139) Other advantages of using IPTW include the following: makes fewer distributional assumptions about the underlying data, avoids residual confounding due to stratification, avoids the omission of data that arise from matching, and allows to deal with censoring or mediation, if necessary. (140)

3.4.2 Marginal Structural Models and IPTW

Inverse probability of treatment weighting consists of re-weighting each subject in the study sample by the inverse of the conditional probability of treatment actually received given the subject's covariates. Weights are derived from propensity scores, and used to estimate the parameters of a weighted model, or marginal structural model (MSM). MSMs model the marginal probability (or hazard) of potential outcomes. I chose MSMs over the conditional Cox model commonly used in time-to-event analyses to address two main issues: the non-collapsibility of the conditional hazard ratio; (141) and the potential for collider stratification bias. In concept, the marginal treatment effect, such as the one estimated by MSM, also mimics the effect estimated from a randomized trial. Marginal effects on the hazard ratio scale estimated using MSMs and IPTW were found to have negligible bias in the presence of weak treatment-selection process if models were correctly specified. (139)

3.4.3 Flexible Modelling

I used flexible modelling techniques to address issues of model misspecification, both in the propensity score models and in the outcome models. Propensity scores were estimated by either logistic regression (Objective 2 and Objective 3) or using flexible parametric survival models (Objective 1; also referred to as Royston-Parmar models). In all propensity score models, I used restricted cubic splines to account for non-linear relationships between continuous covariates and the likelihood of exposure. Time-dependent effects of covariates and baseline hazard functions were also modeled using restricted cubic splines in parametric survival models for propensity scores (Objective 1). All outcome models were flexible parametric survival models, with restricted cubic splines to model time-dependent effects and baseline hazard functions.

3.4.3.1 Restricted Cubic Splines

Cubic splines consist of separate cubic polynomial functions fitted in a piecewise fashion across a number of user-defined intervals. Restrictions can be imposed on splines to ensure a smooth and believable function even if data is sparse, such as forcing cubic functions within each interval to join at predefined points on the x-axis, forcing functions to have continuous first and second derivatives, and forcing the spline function in the tail ends (i.e. beyond the boundary knots) to be linear. Cubic splines are easy to implement in Stata 14 (142) using the – rcsgen – command, with the option to orthogonalize the derived spline variables for more stable estimates and quicker convergence. (143) For a given variable, the boundary knots are placed at the maximum and maximum value of its distribution, and knots are placed at centiles. The number of knots is defined by the number of degrees of freedom chosen minus 1. Spline variables can be incorporated into any regression model to estimate flexible nonlinear functions.

3.4.3.2 Flexible Parametric Survival Models

Flexible parametric survival models were first proposed by Royston and Parmar (144) as an alternative to the semi-parametric Cox proportional hazards model (hereafter referred to as Royston-Parmar (RP) models). There are several advantages to using this approach over the Cox model, including the ease with which smooth estimates of the baseline hazard and survival functions are provided, the ease with which predictions can be made, the modeling of complex time-dependent effects, and the investigation of absolute as well as relative effects. (145) RP models also go beyond the standard parametric models, such as the Weibull or the exponential model, in that they incorporate flexibility in the shape of survival functions that can be modeled. (143) Specifically, RP models characterize the baseline distribution function as a restricted cubic spline function (as opposed to a linear function) of log time. (143) The functionalities of RP models are programmed in Stata 14 with the – stpm2 – command.

3.4.4 Competing Events

Readmission and other post-discharge care encounters are intricately linked to mortality. (33, 44) The analysis of exposures/interventions aimed at reducing readmissions or ED returns may be biased if such interventions also improve survival, which in turn places the group of patients who survived longer at greater risk of returning to the hospital. In this work, we modeled death as a competing event in the analysis of readmissions, and both death and readmission as competing events in the analysis of ED visits. For this we used a parametric equivalent of the Fine and Gray sub-distribution hazard model (146) proposed by Hinchliffe and Lambert. (147) This approach models the cause-specific hazards, which can then be transformed into the sub-distribution cumulative incidence function (i.e. incidence of an event as a function of follow-up time); both the cause-specific hazards and the sub-distribution cumulative incidence functions are considered in this research to provide a better understanding of how exposures at study may affect the incidence and rate of post-discharge events. (148, 149) The extension of the flexible parametric survival model for competing risks by Hinchliffe and Lambert also provides advantages over the traditional methods, i.e., provides smooth estimates of the cause-specific hazard and cumulative incidence function and can incorporate flexible time-dependent effects. (147)

3.4.5 Interpretation of Estimates

The analytical approach described above generated estimates with specific interpretations. First, all models are conditional on survival during the index hospitalization, i.e. associations found apply only to patients who were discharged alive. We did not consider in-hospital death as a competing event because we assumed that it would have a non-differential impact on the risk set of exposed and unexposed individuals. (153) This assumption seems reasonable given that exposures under study occur after discharge and in the outpatient setting. Second, cumulative incidence obtained from competing risk regression generated estimates corresponding to the incidence of an event for individuals who are still at risk of the event (i.e. has not experienced the event of interest) *or* have experienced a competing event during a specific time interval. (153) In this setting, inference about health system performance based on differences in the cumulative incidence

of a given post-discharge event must also consider other relevant post-discharge events at the same time in order to best inform policy.

3.4.6 Model Specification and IPTW Diagnostics

Propensity score models were chosen by minimizing the value of an information criterion (Aikaike (AIC) or Bayes (BIC)), for instance in selecting the number of knots (or degrees of freedom) of restricted cubic splines, and in deciding whether to include interaction terms or time-dependent effects of covariates. To assess the exposure model specification, in particular with respect to the positivity assumption, I also considered the mean, minimum and maximum values, and the standard error of the estimated stabilized inverse probability weights. I considered as evidence of model misspecification or nonpositivity if the mean of the estimated weights was far from one, had a wide range and extreme values, or if the standard error was large. (150) To improve the validity of the weights, I considered weight truncation; however, truncating the analytical weights estimated in this research did not yield meaningful improvements in precision and so I chose untruncated weights to avoid introducing bias. Finally, I assessed the balance of measured covariates (continuous and dichotomous) between exposed and unexposed groups in the weighted sample by calculating standardized differences. (151, 152)

CHAPTER 4: OPTIMAL DELIVERY OF OUTPATIENT FOLLOW-UP TO REDUCE READMISSION AFTER HOSPITAL DISCHARGE

4.1 Preamble

As stated in previous chapters, the care transition represents a vulnerable period for patients, and many policy- and decision-makers have turned to hospital readmissions as basis for performance targets, mainly because they reflect both a burden to patients and to the health system. Outpatient follow-up after discharge provides a unique opportunity for health providers to ensure that essential components of an ideal transition in care are addressed, and represents an actionable policy target to reduce readmission. The evidence in support of post-discharge follow-up as a strategy to effectively reduce hospital readmissions is inconsistent and is limited, and the evidence of effect at the population level is lacking. Our understanding of the elements that make up the optimal delivery of post-discharge follow-up, in terms of target population, the optimal timing, and the type of health provider in follow-up care is even less clear.

In the first manuscript, I focused on the effect of the timing of outpatient physician follow-up on hospital readmissions at the population level and on the elements that contribute to yield better results, all the while addressing major sources of bias at the analytical stage. This manuscript was invited for publication in *Health Services Research* as "Best of Academy Health Research Meeting 2016;" it is currently in revision.

4.2 Abstract

Objective: To estimate the effect of the precise timing of follow-up care within 30 days on readmission in the 60 days following discharge among hospitalized elderly or chronically ill patients.

Data Sources/Study Setting/Extraction Methods: We extracted insurance billing data on 620 656 admissions for any cause from 2002-2009 in Quebec, Canada.

Study Design: We estimated time-specific propensity scores to mimic randomization of the precise timing (in days) of physician follow-up up to 30 days after discharge. We estimated adjusted effect measures using flexible parametric survival models for competing risk weighted by the inverse-probability-of-treatment.

Principal Findings: The 30-day adjusted cumulative incidence of readmission was 20.2% among patients who did not receive timely physician follow-up, and was reduced by 10.5%-point (95% CI: 10.3% - 10.7%) in patients who received follow-up (30-day hazard ratio: 0.54; 0.53 - 0.56). The largest reduction in risk attributable to physician follow-up (RD) was achieved within 21 days post-discharge (21-day RD: 11.0%-point; 10.8% - 11.2%), after which time there was no additional risk reduction. Larger risk reductions were observed among patients in the highest morbidity level (21-day RD: 16.5%-point; 14.9% - 18.0%) and for follow-up with a primary care physician (30-day RD: 11.0%-point; 10.8% - 11.3%) rather than a medical specialist (30-day RD: 7.3%; 7.0% - 7.5%).

Conclusions: Our study provides evidence that post-discharge outpatient follow-up yields large reductions in the risk of readmission. Future policies to reduce 30-day readmission should emphasize follow-up in the primary care setting within the first 3 weeks of discharge, particularly for medically complex patients.

4.3 Introduction

Hospital readmissions have been a target of health care policy in the United States and in other countries, either as a quality measure of hospital care or as a marker of poor integration of the health care delivery system. That a fair portion of hospital readmission may be preventable indicates an opportunity for containing cost and for improving the quality of patient care. (1, 2) Many contemporary efforts to address this have promoted better care coordination, of which timely outpatient follow-up after discharge has been a key component of intervention. (3, 4) Patients who see a physician shortly after discharge may ask questions about their hospitalization, and physicians may monitor and address problems related to the patient's transition from hospital to community. (5-7) In addition to readmission

penalties under the Affordable Care Act, the Centers for Medicare and Medicaid Services introduced new incentive billing codes effective January 2013 for post-discharge care coordination, including a face-to-face visit within 14 or 7 days after discharge. (8)

The evidence supporting post-discharge follow-up as a strategy to effectively reduce hospital readmissions is inconsistent, with approximately two thirds of studies reporting lower rates of readmission among patients who received post-discharge follow-up and one third showing no association. The evidence on the optimal delivery of post-discharge follow-up is even less clear, notably with regards to the target population, the optimal timing, and the type of follow-up care (primary care or specialty care) to affect 30-day readmission rates. The heterogeneity in the literature examining the association between follow-up care after discharge and readmission rates may be attributed to variations across studies in the clinical characteristics of the study population, in the definition of timely follow-up (i.e. within 7, 14 or 30 days of discharge) and of comparison groups, and in the analytical approach. (9) The vast majority of studies have been observational in design, and there is a lack of evidence from experimental or quasi experimental designs to increase our understanding of the mechanism underlying the role of outpatient follow-up in preventing hospital readmissions.

Measuring the preventive effect of timely outpatient follow-up using observational data presents numerous challenges. First, the probability of receiving physician follow-up may change over the post-discharge period, and failing to account for changing temporal patterns may introduce bias, where timing acts as a confounder and effect measure modifier. Second, patient health status during an admission may also exert a time-dependent effect on the conditional probability of receiving early follow-up. These challenges are further compounded by the consideration that those who died or were readmitted early after discharge are likely different in their propensity to have received follow-up. Finally, previous studies that have examined the association between the timing of outpatient follow-up and hospital readmission did not employ flexible methods to characterize this complex relationship. Methodologically rigorous large-scale studies are needed in this area to inform the

development of policies and clinical guidelines for the optimal delivery of outpatient follow-up, in particular to meet the needs of a growing chronically ill population.

In this study, we sought to address these knowledge gaps and methodological challenges by deriving time-specific propensity scores to mimic randomization on the precise timing of follow-up and by using flexible time-dependent survival analysis to examine its effect on the cumulative incidence of readmission. Our goal was to identify the critical time window at which post-discharge follow-up yields the most reduction in the risk of readmission among elderly or chronically ill patients. We also estimated independent and joint effects by type of physician follow-up and effect heterogeneity by patient morbidity level.

4.4 Setting, Study Design and Cohort

We conducted an observational study using a population-based claims database that includes continuously insured patients under the universal public health insurance plan in the province of Québec. Québec is Canada's largest province by area and second largest by population with 8.2 million inhabitants. Approximately 96% of residents have public health insurance which covers all services provided in-hospital and by a general practitioner or by a medical specialist regardless of where the service is provided (e.g. outpatient clinics or hospitals). (10) The Régie de l'Assurance Maladie du Québec (RAMQ) administers the plan and pays doctors directly for the services that they provide.

For this study, we linked data from RAMQ databases using a unique lifetime identifier encrypted from the personal health insurance number. RAMQ databases contain information on patient demographics, physician claims, and hospital admissions. We also linked information on the specialty of the billing physician for all physician services, and characteristics of the registering primary care physician (i.e., primary care physician who enroll a patient into their practice), including practice type and characteristics, number of patients and services provided, and income source. Primary and specialist medical care in Quebec is predominantly funded via fee-for-service payments, with only a small portion of primary care

physicians paid in part by salary for services provided within community health centers (less than 5% of physicians receive more than 20% of their income from salary; our data). In this study, primary care physician refers to a physician that specialized in family medicine, while medical specialist refers to a physician that specialized in any other medical fields (e.g. internal medicine or surgery).

Patients were selected into the original cohort if they were enrolled by a primary care physician from November 2002 to January 2005. Since 2002 in Québec, primary care physicians enroll patients into their practice as 'vulnerable patients' by billing an incentive fee code if a patient is 70 years old or above or has one or more specified chronic health conditions, including chronic obstructive pulmonary disease (COPD), moderate to severe asthma, pneumonia, cardiovascular disease, cancer associated with chemotherapy or radiotherapy treatments, cancer in a terminal phase, diabetes, alcohol or hard drug withdrawal, drug addiction treated with methadone, HIV/AIDS, or a degenerative disease of the nervous system. (11) For each included patient, 5 years of health insurance billing data was extracted beginning on the date of their enrolment as vulnerable, as well as two years prior to enrolment.

For this analysis, we created a dataset consisting of all hospital admissions that occurred during the 5-year follow-up corresponding to an overall study period between November 2002 and December 2009. The unit of analysis was the index discharge, which we defined as a hospital admission for any cause that resulted in a discharge to home. We excluded index admissions to long-term care facilities, and those that resulted in a discharge or a transfer to another facility. We further excluded index admissions for mental health and pregnancy/child birth using principal diagnosis codes (International Classification of Disease (ICD), 9th and 10th revisions), same day readmissions, admissions with in-hospital death, pediatric admissions, admissions with a hospital stay lasting 30 days or more, and admissions from Northern Quebec. We extracted billing data on the index admission and on any medical service (outpatient or inpatient) provided in the 90 days following the hospital discharge, including the date and type (primary care or

specialty care) of all outpatient services. Each patient may contribute data for more than one index admission.

4.4 Methods

4.4.1 Outcome Variable

We considered the time to a readmission for any cause as our primary outcome variable. For each index admission, we counted the number of days that elapsed since discharge to the day a patient was readmitted. All observations were censored at 60 days after hospital discharge. Because the choice of time window has been shown to affect the ratio of avoidable readmissions, (12-14) we considered the cumulative incidence at different intervals after hospital discharge (7, 14, 21, 30 and 60 days).

4.4.2 Exposure Variable

Our main exposure variable was the receipt of follow-up care by any physician in the 30 days after discharge from an index admission. We first identified outpatient services defined as any physician service billed in establishments other than the emergency department, including hospital outpatient clinics and office-based practices. The primary exposure variable took the value of 1 if a patient had at least one outpatient visit occurring within 30 days of hospital discharge and prior to a hospital readmission or death, and 0 otherwise. We also recorded the time to the first outpatient visit, by counting the number of days that elapsed since the patient was discharged to the day that the first outpatient service of any type was billed.

4.4.3 Control Variables

We controlled for a number of patient-, physician- and hospital-level factors that are associated with the receipt of post-discharge follow-up and are plausible risk factors of readmission. At the patient level, we included age, sex, neighborhood socio-economic status, and residential geographic location category. We used a material deprivation index based on small geographic units (population of 400 to 700 persons) as a measure of neighborhood socio-economic status, and a categorical variable developed by the Quebec National Institute of Public Health to

represent the patient's residential geographic location as a function of the proximity to an urban center and to a tertiary or secondary referral hospital. (15-17)

Patient health and health utilization were represented by the following variables measured at index admission: length of index hospital stay, cumulative number of previous admissions since study entry, the time since previous use of inpatient care, relative intensity of hospital resource use, (18) and major diagnostic category. We also used as covariate in the main analysis a measure of patient morbidity level calculated using the Johns Hopkins ACG Case-Mix System and based on diagnostic codes for both inpatient and outpatient utilization in the calendar year preceding the index admission. Patients were thus categorized into one of three Resource Utilization Bands (RUB; moderate morbidity, high morbidity or very high morbidity)) to represent their expected use of health resources and overall morbidity burden. (19) Finally, we included characteristics of the enrolling primary care physician (age, sex, years in practice, the total number of patients, and income source, e.g., short-term care establishment, salary, emergency services) and indicator variables for each hospital and calendar year of index admission. We used indicator variables or single imputation for missing data on covariates.

4.4.4 Stratifying Variable

We stratified our analyses by patient morbidity level as defined by one of three RUB, and by type of physician follow-up provided. For the latter we considered the receipt of follow-up care by a primary care physician only, by a medical specialist only, or the receipt of follow-up care by both a primary care physician and by a medical specialist.

4.4.5 Statistical Analysis

Time-Specific Propensity Score Models

The propensity score was first described by Rosenbaum and Rubin in 1983 as "the conditional probability of assignment to a particular treatment given a vector of observed covariates." (20) Accordingly, the distribution of the propensity score in a population should reflect the underlying propensity of receiving treatment given

covariates, which in our case includes the timing of post-discharge follow-up. To account for changes in exposure patterns over time we implemented a time-specific approach to propensity scores, which has been used previously in three observational studies of pharmacologic treatments, and was shown to perform better than the conventional approach (i.e. probability of treatment averaged over time) for confounding adjustment. (21-23) Conceptually, our time-specific PS model aims to emulate randomization of patients to receiving outpatient follow-up on either of the 30 days following discharge, thus balancing observed confounders on each post-discharge day. Intuitively, we expect that this approach is more convincing than pseudo-randomizing patients to receiving follow-up within 30 days or not (binary decision), and more appropriate for examining the effect of timing.

Time-specific propensity scores were estimated using flexible parametric survival regression. (24) This technique models the effect of covariates on the probability of treatment received on each day after discharge, and allows for flexibility in modeling baseline hazard and in incorporating complex time-dependent effects through the use of restricted cubic splines. (25, 26) We considered evidence of model fit for propensity score models based on the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) (e.g. for selecting degrees of freedom in modelling continuous covariates, baseline hazard and time-dependent effects using restricted cubic splines). We estimated separate propensity score models to investigate effect heterogeneity by type of follow-up care (primary care physician, medical specialist, or both) using a similar approach. Details of propensity score models are presented in Appendix 4.1.

Inverse-Probability-Weights

We used stabilized IPW to balance control variables across exposure groups (i.e. received follow-up at time t vs. did not receive follow-up). To obtain stabilized IPW, we derived from an unadjusted PS model the predicted probability of treatment actually received, then we divided this probability by the conditional predicted probability of treatment actually received derived from fully adjusted PS

models. To examine the effects by subgroup of patient morbidity, the probability in the numerator of the stabilized weights was conditional on the patient morbidity level. To examine independent and joint effects by type of physician follow-up, we multiplied the stabilized weight for follow-up by primary care physician and the stabilized weight for follow-up by a medical specialist. We assessed the validity of analytical weights according to published balance diagnostics in propensity score and IPW analysis. (27)

Marginal Structural Models

We estimated and modelled the sub-distribution cumulative incidence functions of readmission using flexible parametric survival models adapted to account for competing risk by death. (28) All models were weighted by IPW to estimate marginal differences in cumulative incidence functions (i.e. the cumulative incidence of readmission had everyone received follow-up minus the cumulative incidence of readmission had everyone not receive follow-up). In analyses of independent and joint effects by type of physician follow-up, estimates correspond to controlled direct effects, e.g., independent effect corresponds to the marginal effect of follow-up by a primary care physician had everyone not received follow-up by a medical specialist. We used the clustered bootstrap to obtain 95% confidence intervals (CIs). We used Stata MP 14 for all analyses.

Sensitivity Analyses

In sensitivity analyses, we compared propensity score and IPW diagnostics and effect estimates over time by whether propensity scores were derived using a time-specific approach or using a conventional approach via logistic regression.

4.5 Results

We included a total of 312 377 patients representing 620 656 index admissions. Major causes of index admission included chronic obstructive pulmonary disease (6.7%), heart disease (6.7%), congestive heart failure (4.5%) and pneumonia (4.4%) (detailed list of major causes shown in Appendix 4.3). As expected, the distribution of baseline characteristics measured at index admission differed across

exposure groups, and some of these differences were relatively large (Table 4.1). Notably, patients who did not receive follow-up care were more likely to be 80 years or older, have longer hospital stays and use more resources during the index admission. Similarly, a higher proportion of female patients, patients with 3 previous admissions or more, or patients that live in rural areas or neighborhoods with high material deprivation did not receive follow-up. These differences demonstrate that an approach to address confounding, such as IPW, is needed to estimate causal effects.

Table 4.1 Patient characteristics at index admission, Quebec (Canada) 2002-09

Characteristics and Measures	No. (%)	
	Received Follow-Up Within 30 Days of Discharge (N = 395 014)	Did Not Receive Follow-up Within 30 Days of Discharge (N = 225 642)
Sex, female	202 268 (51.2)	124 972 (55.4)
Age, y		
18 - 34	2 284 (0.6)	1 480 (0.7)
35 - 49	13 992 (3.5)	6 558 (2.9)
50 - 64	63 551 (16.1)	28 294 (12.5)
65 - 79	195 295 (49.4)	100 664 (44.6)
≥ 80	119 892 (30.4)	88 646 (39.3)
Length of hospital stay, days		
0 - 2	98 779 (25.0)	48 230 (21.4)
3 - 6	130 755 (33.1)	70 786 (31.4)
7 - 13	107 812 (27.3)	63 751 (28.25)
14 - 20	37 386 (9.5)	25 575 (11.3)
21 - 30	20 282 (5.1)	17 210 (7.6)
No. of previous admissions		
0	129 625 (32.8)	69 000 (31.0)
1	95 901 (24.3)	53 038 (23.5)
2	60 548 (15.3)	34 002 (15.1)
≥ 3	108 940 (27.6)	68 702 (30.5)
Time since previous admission		
1 month or less	40 401 (10.2)	21 911 (9.7)
1 to 3 months	44 801 (11.3)	25 657 (11.4)
3 to 6 months	35 525 (9.0)	21 384 (9.5)
6 months to 1 year	43 775 (11.1)	26 336 (11.7)
≥ 1 year	100 887 (25.5)	60 454 (26.8)
Cost of hospitalizations,[*] median (IQR)	$4,351 ($2,852 - $6,948)	$4,581 ($2,950 - $7,560)
Morbidity, %		
Moderate	64 264 (16.3)	41 684 (18.5)
High	111 242 (28.2)	62 720 (27.8)
Very high	219 508 (55.6)	121 238 (53.7)
Time since enrolment with primary care physician		
3 months or less	29 786 (7.5)	13 802 (6.1)
3 to 6 months	26 461 (6.7)	12 887 (5.7)

6 months to 1 year	48 372 (12.3)	27 899 (12.4)
1 to 2 years	88 168 (22.3)	48 821 (21.6)
≥ 2 years	202 227 (51.2)	122 233 (54.2)
Material deprivation quintile		
Q1 (low)	55 175 (14.0)	27 782 (12.3)
Q2	65 434 (16.6)	34 948 (15.5)
Q3	78 484 (19.9)	43 085 (19.1)
Q4	84 729 (21.5)	48 168 (21.4)
Q5 (high)	85 773 (21.7)	54 073 (24.0)
Geographical region		
Urban/university	135 206 (34.2)	74 226 (32.9)
Suburban	159 604 (40.4)	83 530 (37.0)
Intermediate	80 112 (20.3)	50 782 (22.5)
Rural	19 227 (4.9)	16 064 (7.1)

Missing: Material deprivation quintile: 25.419 (6.4%) and 17,586 (7.8%) in patients who received follow-up and those who did not, respectively; Geographical region: 865 (0.2%) and 1,040 (0.5%) in patients who received follow-up and those who did not, respectively.
*Costs in current Canadian dollars are based on resource intensity weights for an admission multiplied by its unit cost per fiscal year.

We present in Appendix 4.2 the unadjusted cumulative incidence of follow-up care in the 30 days following hospital discharge by type of follow-up. Approximately 3 out of 5 elderly or chronically ill patients discharged from a hospital received follow-up within 30 days, and approximately two thirds of patients who received follow-up (any type) did so within the first two weeks of hospital discharge (Appendix 4.3). Major causes of 30-day readmission are also presented in Appendix 4.3. Figure 4.1 depicts the unadjusted cumulative incidence of readmission up to 60 days after discharge by whether a patient received post-discharge follow-up within 30 days by any physician, by a primary care physician only, by a medical specialist only, or by both. This figure illustrates that patients who received post-discharge follow-up, regardless of type, have a lower incidence of readmission. Specifically, patients with lower incidence of readmission are also much more likely to have received follow-up with a primary care physician or by both primary care physician and medical specialist. This figure also illustrates that the largest difference in cumulative incidence of readmission between patients who received follow-up and those who did not was reached by approximately 21 days after discharge.

Figure 4.1 Unadjusted cumulative incidence of readmission by whether patient received post-discharge follow-up within 30 days
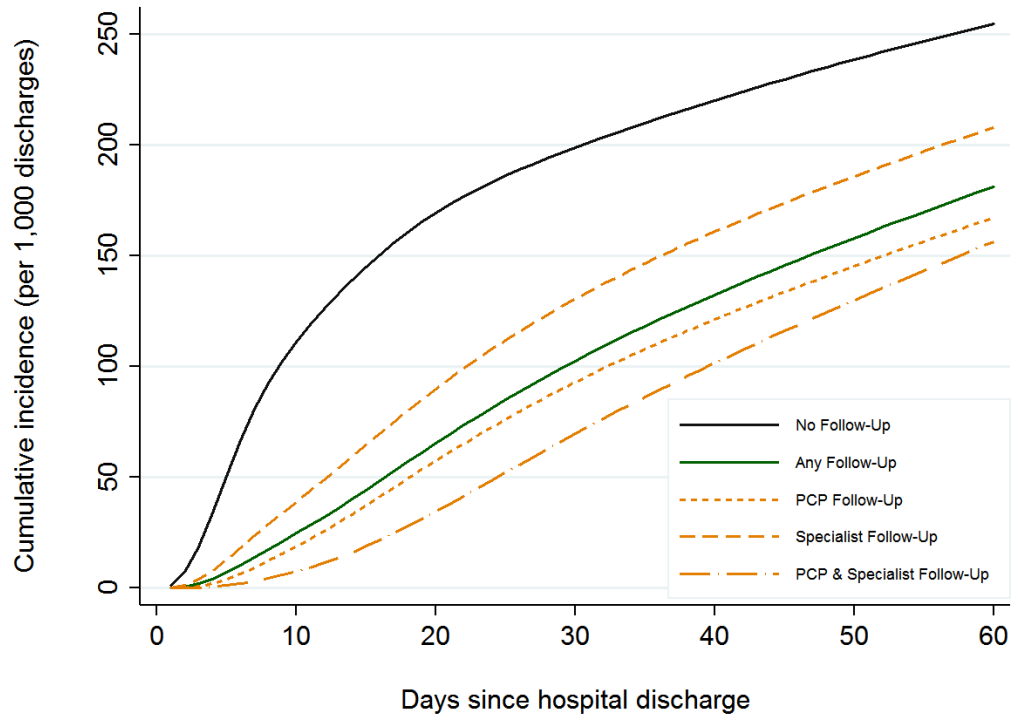
The stabilized inverse-probability-weights estimated had a mean close to 1, small standard errors and a reasonable range (Appendix 4.4). (27, 29) After weighting, we calculated standardized differences on covariates by whether patients received follow-up or not for each day after discharge up to 30 days and we found no differences greater than 10%.

Table 4.2 presents the results obtained from marginal structural survival models weighted by IPW, which correspond to the reduction in cumulative incidence of readmission attributable to outpatient follow-up. Our main results (Any physician; Full sample) show that post-discharge follow-up care was associated with reductions in the risk of readmission corresponding to 105 fewer hospital readmissions within 30 days per 1 000 discharges. We observed the largest reduction by the 21st post-discharge day, after which time there was no additional reduction in the incidence of readmission (Table 4.2).

Table 4.2 Adjusted difference in cumulative incidence* of readmission between patients who received post-discharge follow-up and those who did not

Days since hospital discharge	Adjusted difference per 1,000 discharges (95% CI)			
	Full sample N = 620 656	Morbidity Level		
		Moderate N = 105 948	High N = 173 962	Very High N = 340 746
Follow-up with any physician				
7	67.8 (66.7 – 69.0)	20.5 (19.0 – 21.9)	40.7 (34.2 – 47.2)	101.2 (86.6 – 115.9)
14	102.5 (100.9 – 104.1)	32.0 (29.9 – 34.1)	63.4 (56.1 – 70.8)	151.7 (135.8 – 167.6)
21	110.0 (108.2 – 111.7)	36.1 (33.6 – 38.5)	71.5 (64.1 – 78.8)	164.6 (149.2 – 180.0)
30	105.2 (103.2 – 107.2)	36.5 (33.8 – 39.3)	72.0 (64.5 – 79.6)	159.1 (143.8 – 174.4)
60	87.8 (85.5 – 90.1)	34.0 (30.5 – 37.5)	65.0 (57.1 – 72.9)	129.1 (114.4 – 143.8)
Follow-up with a primary care physician (independent effect)[1]				
7	69.6 (68.3 – 71.0)	20.3 (17.8 – 22.8)	30.3 (10.2 – 50.5)	80.3 (29.0 – 131.7)
14	104.4 (102.5 – 106.2)	32.4 (29.7 – 35.1)	61.0 (45.1 – 76.9)	150.6 (114.8 – 186.6)
21	113.0 (110.8 – 115.2)	37.4 (34.3 – 40.6)	73.8 (59.1 – 88.5)	172.9 (141.5 – 204.2)
30	110.3 (107.8 – 112.9)	38.8 (35.1 – 42.5)	76.8 (62.5 – 91.0)	171.5 (142.5 – 200.4)
60	97.0 (93.7 – 100.3)	37.3 (32.6 – 41.9)	70.1 (57.3 – 82.8)	140.8 (117.1 – 164.4)
Follow-up with a medical specialist (independent effect)[2]				
7	55.3 (54.0 – 56.6)	17.3 (15.7 – 19.0)	38.0 (29.8 – 46.2)	92.2 (74.0 – 110.4)
14	78.5 (76.6 – 80.4)	25.1 (22.6 – 27.6)	50.3 (41.2 – 59.5)	118.9 (99.0 – 138.7)
21	79.9 (77.6 – 82.1)	27.2 (24.2 – 30.3)	54.0 (44.6 – 63.4)	122.8 (102.8 – 142.9)
30	72.5 (69.9 – 75.0)	27.0 (23.5 – 30.5)	53.6 (43.7 – 63.4)	116.6 (96.4 – 136.7)
60	55.2 (52.2 – 58.2)	25.4 (20.9 – 29.9)	50.3 (39.5 – 61.1)	96.8 (77.0 – 116.6)
Follow-up with a primary care physician and medical specialist (joint effect)[3]				
7	77.6 (76.4 – 78.7)	23.4 (22.0 – 24.8)	67.5 (22.3 – 112.8)	118.2 (51.6 – 184.7)
14	125.8 (124.1 – 127.5)	39.5 (37.4 – 41.7)	109.6 (69.3 – 149.9)	224.7 (156.6 – 292.7)
21	141.0 (138.9 – 143.1)	46.7 (43.0 – 49.4)	116.7 (86.9 – 146.4)	247.8 (194.3 – 301.2)
30	136.9 (134.4 – 139.4)	47.8 (44.3 – 51.4)	108.5 (85.5 – 131.4)	230.6 (188.0 – 273.3)
60	115.1 (111.6 – 118.5)	43.8 (38.4 – 49.2)	87.0 (68.8 – 105.2)	173.0 (140.1 – 205.9)

[1]Independent effect corresponding to effect of follow-up by a primary care physician *had everyone not receive follow-up by a medical specialist* within 30 days of discharge.

[2] Independent effect corresponding to effect of follow-up by a medical specialist *had everyone not receive follow-up by a primary care physician* within 30 days of discharge.

[3]Joint effect corresponding to the reduction in the cumulative incidence of readmission *had everyone received both follow-up by a medical specialist and by a primary care physician* within 30 days of discharge.

We illustrate the results from our subgroup analysis by patient morbidity level in Figure 4.2 (estimates also shown in Table 4.2; right-hand side), which showed largest absolute reductions in the risk of readmission among patients with very high morbidity, and modest to large risk reductions among those in the moderate or high morbidity levels. Similar to our main results, the risk reduction attributable to follow-up care was largest by the 21st day after discharge among patients in the highest morbidity level; however, this was not the case among patients in the

moderate and high morbidity levels, where the reduction in risk increased up to 30 days after discharge.

Figure 4.2 Reduction in cumulative incidence of hospital readmissions (per 1 000 discharges) attributable to outpatient follow-up with any physician, by day since hospital discharge and by patient morbidity level
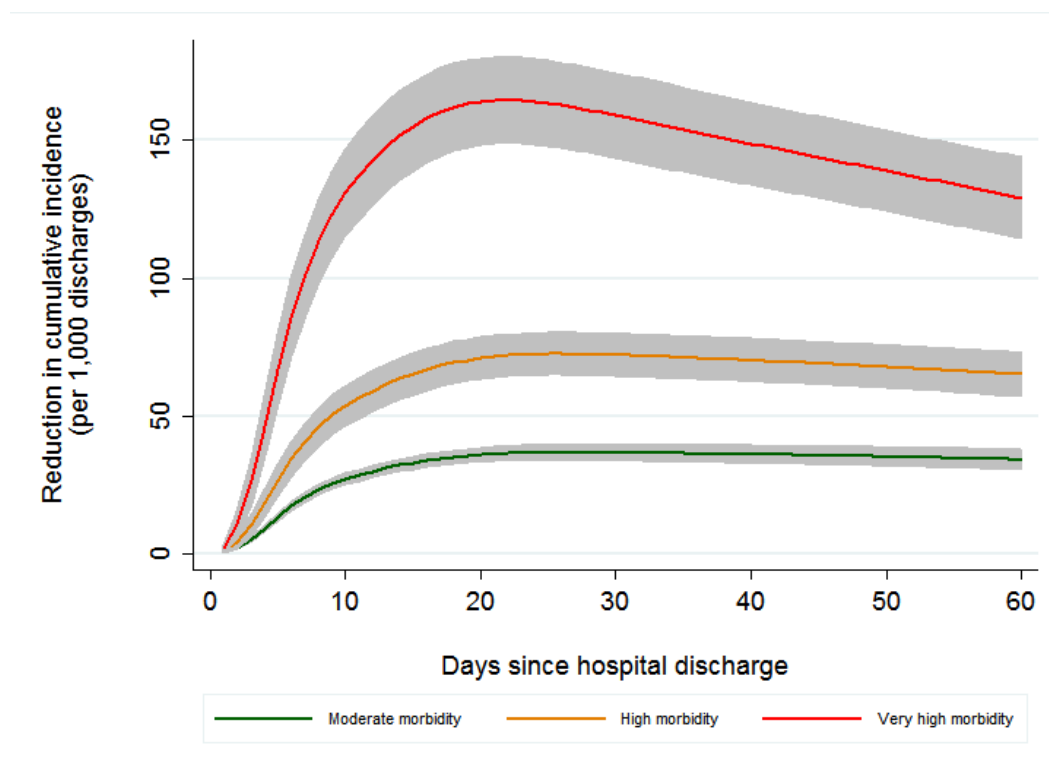
We also present in Table 4.2 (and in the form of figures in Appendix 4.5) the independent and joint effects by type of physician follow-up (primary care physician, medical specialist, or both). These followed similar temporal patterns as our main results (i.e., largest reduction in cumulative incidence attained by 21 days). Further, approximately 73 fewer 30-day hospital readmission per 1 000 were attributable to the independent effect of follow-up by a medical specialist, while 110 fewer readmissions were attributable to the independent effect of follow-up care by a primary care physician. Receiving post-discharge follow-up care by both a primary care physician and by a medical specialist led to 137 fewer readmissions within 30 days of discharge, i.e. less than the sum of independent effects.

4.5.1 Sensitivity Analyses

The distribution of propensity scores by day since hospital discharge are presented in Appendix 4.6. Propensity scores estimated by parametric survival models reflected changes in the probability of receiving post-discharge follow-up, and as expected, those estimated by logistic regression did not (probability of receiving follow-up is averaged over the post-discharge period). Diagnostics based on mean stabilized IPW, standard errors, range and standardized differences were comparable across PS specifications (Appendix 4.6). We also graphed the mean stabilized IPW by day since hospital discharge, and compared to the IPW used in the main analysis. Mean IPW based on propensity scores by logistic regression were further away from 1 in the early post-discharge period; both specifications of weights were similar beyond 2 weeks after discharge (see Appendix 4.6). Compared to our main results, results based on propensity scores from logistic regression slightly overestimated the effect of follow-up in the early post-discharge period and slightly underestimated the effect in the later post-discharge period.

4.6 Discussion

This study contributes evidence that meaningful reductions in the risk of readmission can be achieved by ensuring timely follow-up after discharge for elderly or chronically ill patients hospitalized for any cause. In Quebec, this population accounts for more than 100 000 discharges each year, and our results show that at least 11 000 of them may be avoided if timely follow-up is provided. We have identified a critical time window of within 21 days after discharge at which follow-up should occur to yield the maximum risk reduction. Our findings also show that post-discharge care with a primary care physician is associated with greater reduction in the risk of readmission. Risk reductions were meaningful and statistically significant in all three patient morbidity subgroups included in our study. We linked inpatient and outpatient claims data from a cohort which represents nearly the entire population of elderly or chronically ill patients in Quebec, and we used a time-specific propensity score approach to remove potential sources of bias in our estimates. Our study comprises one of the largest and most methodologically rigorous study to date to examine outpatient follow-up care and readmissions.

We highlight mechanisms through which the optimal delivery of post-discharge follow-up care can be achieved, by assessing timing and independent effects by type of provider follow-up across various levels of patient morbidity. We found no additional reduction in the risk of readmission if physician follow-up was provided after 21 days following hospital discharge for patients in the highest morbidity subgroup. We also observed risk reduction across all patient subgroups as early as within 7 days of discharge, suggesting that follow-up should be provided as early as necessary, and at least within 21 days of discharge. We also found that the reduction in risk of readmission was more important among patients with very high morbidity, which likely reflects both a larger background risk of readmission and the unique care needs of a medically complex population. Finally, our findings suggest that the effect of post-discharge follow-up by a primary care physician contributed more towards reducing the risk of readmission than follow-up by a medical specialist.

Previous research had generated mixed results on the association between post-discharge follow-up and readmission. A number of observational studies report that various patient populations receiving outpatient follow-up have a lower risk of 30-day readmission, including surgical patients, (9, 30) medical patients, (31-37) and for the adult and elderly or chronically ill hospitalized population. (38-41) We are able to find a similar correlation in our data, but make a new contribution to the existing body of evidence by providing plausibly causal estimates of the effect of outpatient follow-up care on readmissions.

Previous studies examining the timing of follow-up had important limitations, which we believe to have addressed to some degree with our analytical approach. The study by Jackson et al., (N = 65 085 discharges) calculated within clinical risk groups the incremental differences in risk of 30-day readmission by whether patients received follow-up within 3, 7, 14, 21 and 30 days after hospital discharge. (40) Similar to our study, these authors found large inverse associations between early follow-up and readmission, but they did not account for geographic-, physician- and hospital-level factors, for time-dependent effects of covariates nor for competing risk by death. Similarly, a large observational study (N = 30 136

patients) found that hospitals with higher rates of outpatient physician follow-up within 7 days of discharge were associated with approximately 10% lower rates of readmission (relative effect) among patients with heart failure; this association was not significant when examining rates of follow-up within 14 days. (31) These authors addressed confounding by illness severity (i.e. patients who are sicker may be more likely to be seen sooner in an outpatient setting) by design (i.e. comparing hospitals instead of patients), and accounted for competing risk by death. However, the validity of hospital-level comparisons (i.e. comparing hospitals with high rates of early outpatient follow-up) is limited if differences on key components of an ideal transition in care are not accounted for (e.g., discharge planning or timeliness of information transfer); in our study, we use patient-level data and we account for hospital differences in a fixed-effect analysis, and we further account for time-dependent effects of patient's health and health utilization on receipt of follow-up. To date, no other study had incorporated the time-dependency of outpatient follow-up, both with respect to the exposure (i.e., probability of receiving follow-up changes over the post-discharge period), and with respect to the outcome (i.e., timing effect of post-discharge follow-up on hospital readmission).

Further, our estimate of an approximately 16%-point reduction in the risk of readmission among patients with a very high morbidity level is more conservative than results by Jackson et al. reporting important variations by patient's medical complexity, including more than 20%-point reduction in the risk of readmission among patients with multiple chronic conditions, and more than 30%-point among those with high clinical complexity. (40) The discrepancy may be explained by different categorization of patient clinical complexity, and by differences in our methodological approach, which, as noted, included better adjustment for more covariates acting as important confounders, flexible modeling of time-dependent effects and accounting for competing risk by death. Finally, few studies have investigated the type of post-discharge physician follow-up in reducing readmission rates, either by a primary care physician or by a medical specialist. Such studies contributed mixed associational evidence. (30, 31, 42, 43)

This study has limitations. Claims data do not fully capture severity of illness and functional status, which could have biased our findings in either direction. For example, patients at very high risk of readmission due to the severity of their condition or due to functional limitations may 1) have not been able to receive follow-up within 30 days or 2) have received home care following their discharge from hospital (which do not appear in our data); either of these scenarios would have biased our results away from the null. Other unmeasured factors such as mental health and peer or community support after discharge could have had a similar impact on our results. In contrast, our lack of data on nurse follow-up (nurses are paid by salary in Quebec and do not bill for the services that they provide) after discharge could have biased our results towards the null if patients receiving follow-up by a nurse may be less likely to see a physician and also less likely to be readmitted to the hospital. Understanding the full scope of how outpatient care affects readmission, including the role of nurses, is particularly important given the context of primary health care reforms focused on team-based care (e.g. the Patient-Centered Medical Home) that are being promoted as potential solutions to care fragmentation and system inefficiencies.

This study has methodological strengths. We estimated time-specific propensity scores to mimic randomization to receiving post-discharge follow-up care on any one day within 30 days of discharge; which addresses confounding for both the receipt and timing of follow-up. Our sensitivity analyses contributed evidence that this novel approach performed better than propensity scores estimated by logistic regression in the early days after discharge (i.e. within 14 days). Further, the flexible modelling approach that we used to characterize the timeliness of follow-up care and its time-dependent effect on the risk of readmission allowed us to draw inference on the critical time window that provided the most benefit to patients, particularly for those with a very high level of morbidity. We also improved on past research in the field by accounting for competing risk by death.

4.7 Implications for Policy and Practice

The evidence we provide supports policy and practice initiatives to ensure early follow-up. In addition, our findings add to the existing literature on the timing of post-discharge follow-up, which may be helpful to decision-makers in designing policies, and to guideline developers and researchers in forming or selecting indicators of quality of care in the acute post-discharge period. Lastly, our results suggest that primary care physicians play an important role in reducing readmissions. Primary care physicians are uniquely positioned to address issues related to the care transition from hospital to community and to the coordination of care, which sometimes involves multiple care providers. (44) This may represent an area of opportunity for policies, including such as payment incentives for care coordination activities or supporting standardized information technologies and the team-based medical home model. More research is needed to better understand and confirm these findings.

4.8 Conclusion

Timely physician follow-up after hospital discharge may prevent a very large number of hospital readmissions among the elderly or chronically ill, corresponding to approximately a 46% relative decrease in the rates of 30-day readmissions. This further highlights that timely outpatient follow-up represents an important intervention point in medical care to improve patient outcomes and reduce costs. Our findings suggest that follow-up should occur as early as necessary, and at least within 21 days after hospital discharge. Further, primary care physician follow-up may contribute more to reducing the risk of readmission than follow-up with a medical specialist; future investigations to address this hypothesis are needed. Future policies to reduce 30-day readmission should target timely post-discharge follow-up and emphasize follow-up in the primary care setting within the first 3 weeks of discharge, particularly for high-morbidity patients.

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APPENDICES

Appendix 4.1. Statistical Models

	Exposure (propensity score model)	Outcome
Type	Flexible parametric survival	Flexible parametric with competing risk
Baseline hazard function	r.c.s. (8 d.f.)	r.c.s. (8 d.f.)
Exposure		
FUPCARE30 (bin.)	-	I/t.d., r.c.s. (3d.f.)
Patient demographics		
FEMALE (bin.)	I	-
AGE (c)	r.c.s. (4 d.f.)	-
TIMEREG (5 cat.)	I	-
GEO (5 cat.)	I	-
MATDEP (6 cat.)	I	-
SOCDEP (6 cat.)	I	-
FMG (bin.)	I	-
Patient health status		
RUB (3 cat.)	I	I (e.m.m)
DIAG (17 cat.)	I	-
AMI_COPD_HF (bin.)	I	-
LOS (quintiles)	I	-
RIW (quintiles)	I	-
NBADM (c)	r.c.s. (3d.f.)	-
TIMEDISCHG (10)	I	-
Registering physician		
PCPFEMALE (bin.)	I	-
PCPNBPAT (c)	r.c.s. (4 d.f.)	-
PCPPRACTICE (5 cat.)	I	-
PCPSALARY (6 cat.)	I	-
PCPHOSP (6 cat.)	I	-
Contextual		
YEAR (7 cat.)	I	-
HOSP (105 cat.)	I	-
Time-dependent effects		
FUPCARE30xTIME	-	r.c.s. (3d.f.)
RUBCATxTIME	r.c.s. (3d.f.)	r.c.s. (3d.f.) (e.m.m)
RIWxTIME	r.c.s. (3d.f.)	-
LOSxTIME	r.c.s. (3d.f.)	-
Two-way interactions		
GEO1xRUB3	I	-
GEO2xRUB3	I	-
GEO3xRUB3	I	-
FMGxMATDEP*	I	-

RUB2xMATDEP*	I	-
RUB3xMATDEP*	I	-
RUBCATxYEAR	I	-

*The letter I denotes an indicator function

Abbreviations: na, not applicable; bin., binary; cat., categories; r.c.s., restricted cubic splines; d.f., degrees of freedom; c, continuous FUPCARE30: 0 – did not received follow-up with any physician, 1 – received follow-up with any physician; FEMALE: 0 – male, 1 – female; YEAR: calendar years from 2002-2003 to 2009-2010; RUB: 1 – moderate morbidity, 2 – high morbidity, 3 – very high morbidity; DIAG: principal diagnosis groupings; HOSP: indicator for each hospital; GEO: 1 – urban/university, 2 – suburban/peripheral, 3 – intermediate, 4 – rural, 5 – missing; MATDEP: 0 -missing, 1 – low material deprivation quintile, 5 – high material deprivation quintile; SOCDEP: 0 -missing, 1 – low social deprivation quintile, 5 – high social deprivation quintile; FMG: 0 – enrolled in traditional PC, 1 – enrolled in FMG ; PCPPRACTICE: 0 – missing, 1 – 5 years in practice or less, 2 – 6 to 10 years in practice, 3 – 11 to 20 years in practice, 4 – more than 20 years in practice; PCPSALARY: 0 – missing, 1 – less than 20% of PCP income from salary, 2 – between 20% and 39%, 3 – between 40% and 59%, 4 – between 60% and 79%, 5 – 80% or more; PCPHOSP: 0 – missing, 1 – less than 20% of PCP income from short term care establishment, 2 – between 20% and 39%, 3 – between 40% and 59%, 4 – between 60% and 79%, 5 – 80% or more; RIW: relative intensity weight; LOS: length of hospital stay (in days); PCPNBPAT: mean number of PCP enrolled patients; TIMEREG: time (in days) since enrolment with PCP; NBADM: number of hospital admissions preceding index admission, calculated from two years before study entry; TIMEDISCHG: time (in days) since last hospital discharge.

Appendix 4.2. Cumulative incidence of post-discharge follow-up

Follow-up type Days since discharge	Per 1 000 discharges
Any physician	
≤ 3	75.0
≤ 7	237.3
≤ 14	418.3
≤ 21	527.6
≤ 30	626.3
Primary care physician	
≤ 3	35.8
≤ 7	115.7
≤ 14	217.7
≤ 21	295.1
≤ 30	371.9
Medical specialist	
≤ 3	39.3
≤ 7	135.9
≤ 14	248.6
≤ 21	326.0
≤ 30	411.5

*Accounts for competing events (death and readmission).

Appendix 4.3 Causes of index admission and 30-day readmission

Table A4.3.1. Major causes of index admissions

	Total
Chronic obstructive pulmonary disease	41 608 (6.7)
Coronary atherosclerosis and other heart disease	41 360 (6.7)
Congestive heart failure	28 137 (4.5)
Pneumonia	27 175 (4.4)
Cardiac dysrhythmias	23 523 (3.8)
Acute myocardial infarction	20 581 (3.3)
Osteoarthritis	17 668 (2.9)
Fracture of neck of femur (hip)	11 613 (1.9)
Nonspecific chest pain	10 549 (1.7)
Urinary tract infections	9 831 (1.6)
Cancer of bronchus, lung	9 193 (1.5)
Acute cerebrovascular disease	9 061 (1.5)
Delirium dementia and amnestic and other cognitive disorders	8 335 (1.3)
Residual codes; unclassified	7 851 (1.3)
Other aftercare***	7 792 (1.3)
Intestinal infection	7 193 (1.2)
Cancer of colon	6 804 (1.1)
Syncope	6 779 (1.1)
Skin and subcutaneous tissue infections	6 447 (1.0)
Spondylosis; intervertebral disc disorders; other back problems	6 358 (1.0)
Codes not defined	47 053 (7.6)

*Based on Clinical Classification Software (CCS) for ICD-9CM and for ICD-10-CM.
**ICD-9-CM and ICD-10-CMCodes for AMI, COPD and CHF were checked manually to match Quebec definitions.
***Includes encounters for follow-up after medical or surgical interventions (e.g., aftercare following organ transplant), encounters for palliative care, long-term and current use of specific medications (e.g. long-term use of opiate analgesic).

Table A4.3.2. Major causes of 30-day readmissions

	Total
Chronic obstructive pulmonary disease	7 032 (8.1)
Congestive heart failure	6 837 (7.9)
Coronary atherosclerosis and other heart disease	3 812 (4.4)
Pneumonia	3 736 (4.3)
Intestinal infection	2 852 (3.3)
Cancer of bronchus, lung	2 537 (2.9)
Complications of surgical procedure or medical care	2 530 (2.9)
Other aftercare[***]	2 398 (2.8)
Cardiac dysrhythmias	2 355 (2.7)
Acute myocardial infarction	1 939 (2.2)
Delirium dementia and amnestic and other cognitive disorders	1 362 (1.6)
Complication of device; implant or graft	1 169 (1.4)
Residual codes; unclassified	1 152 (1.3)
Cancer of colon	1 059 (1.2)
Urinary tract infections	1 049 (1.2)
Nonspecific chest pain	968 (1.1)
Secondary malignancies	963 (1.1)
Acute cerebrovascular disease	911 (1.1)
Other lower respiratory disease	905 (1.0)
Maintenance chemotherapy; radiotherapy	871 (1.0)
Codes not defined	5 692 (6.6)

[*]Based on Clinical Classification Software (CCS) for ICD-9CM and for ICD-10-CM.
[**]ICD-9-CM and ICD-10-CMCodes for AMI, COPD and CHF were checked manually to match Quebec definitions.
[***]Includes encounters for follow-up after medical or surgical interventions (e.g., aftercare following organ transplant), encounters for palliative care, long-term and current use of specific medications (e.g. long-term use of opiate analgesic).

Appendix 4.4 Description of inverse probability weights[*]

Follow-up type	Mean (SE[**]; range; standardized diff. >10%[***])
Any physician	
Main analysis	1.018 (0.0005; 0.242 – 19.8; no)
Sub-group analysis – moderate morbidity	1.012 (0.0010; 0.389 – 14.8; no)
Sub-group analysis – high morbidity	1.012 (0.0008; 0.345 – 19.1; no)
Sub-group analysis – very high morbidity	1.013 (0.0006; 0.311 – 16.1; no)
Primary care physician	
Main analysis	1.009 (0.0006; 0.259 – 21.9; no)
Sub-group analysis – moderate morbidity	1.000 (0.0012; 0.295 – 16.9; no)
Sub-group analysis – high morbidity	1.006 (0.0010; 0.289 – 15.1; no)
Sub-group analysis – very high morbidity	1.012 (0.0009; 0.289 – 16.0; no)
Medical specialist	
Main analysis	1.019 (0.0006; 0.152 – 18.8; no)
Sub-group analysis – moderate morbidity	1.008 (0.0011; 0.259 – 10.8; no)
Sub-group analysis – high morbidity	1.014 (0.0010; 0.218 – 17.5; no)
Sub-group analysis – very high morbidity	1.017 (0.0008; 0.197 – 19.3; no)

[*]We interpreted as evidence of positivity or propensity score model misspecification if the mean of the stabilized weight was far from one or if there were extreme values.

[**]Clustered standard errors.

[***]Calculated for each day after discharge. Corresponds to the difference between groups divided by the pooled standard error. We interpreted a value greater than 10% as a meaningful difference between the groups. Standardized differences are less sensitive to sample size.

Appendix 4.5 Illustration of results from Table 4.3 of main manuscript

Figure A4.5.1. Reduction in cumulative incidence[*] of hospital readmissions (per 1 000 discharges) attributable to outpatient follow-up with any physician, by day since hospital discharge
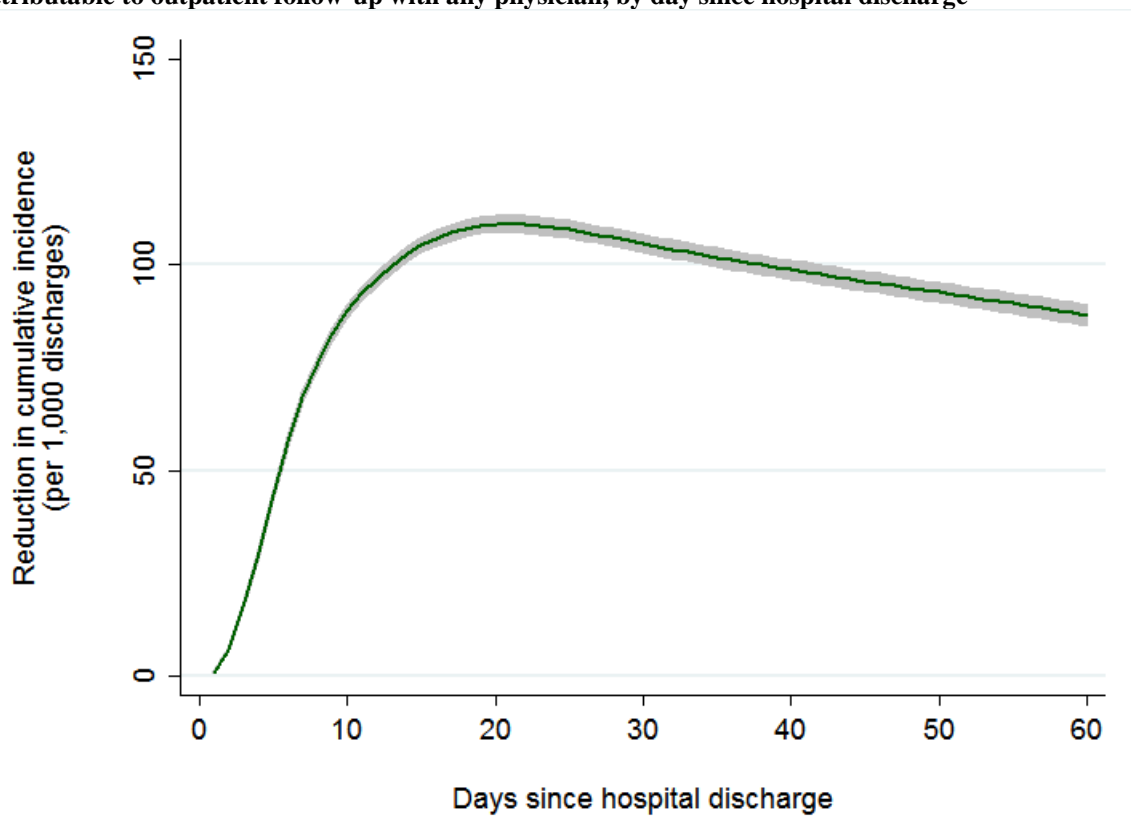
[*]Accounts for competing risk by death.

Figure A4.5.2. Reduction in cumulative incidence of hospital readmissions (per 1,000 discharges) attributable to outpatient follow-up, by day since hospital discharge and by type of physician follow-up

Primary care physician (independent effect)	Medical specialist (independent effect)	Both (joint effect)
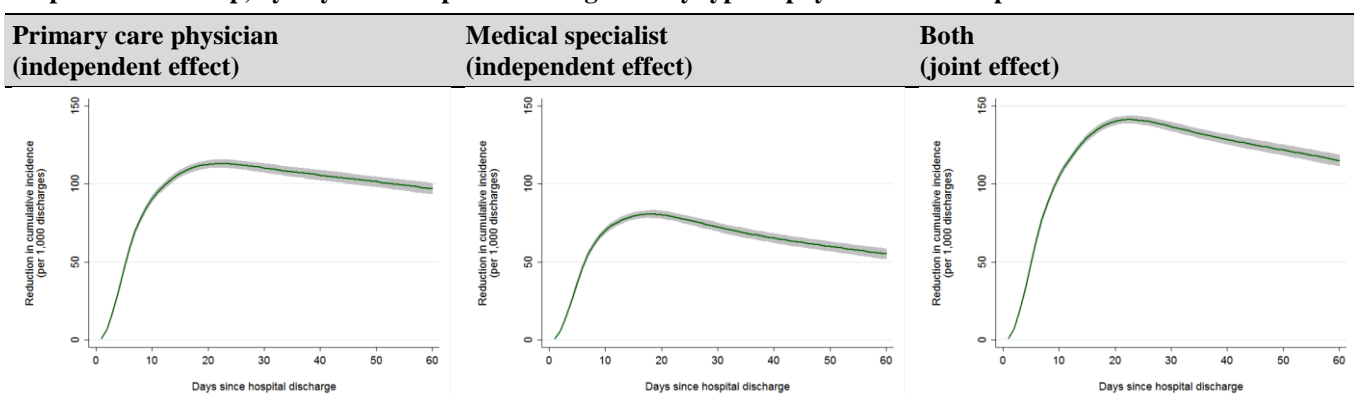
[*]Accounts for competing risk by death.

Appendix 4.6 Sensitivity analysis on propensity score model specification

Figure A4.6.1 Propensity score distribution among exposed by day since hospital discharge

PS models	Any Follow-Up	PCP Follow-Up	Medical Specialist Follow-Up
Time-specific PS			
Conventional PS (logistic regression)			

Abbreviations: PCP, primary care physician.
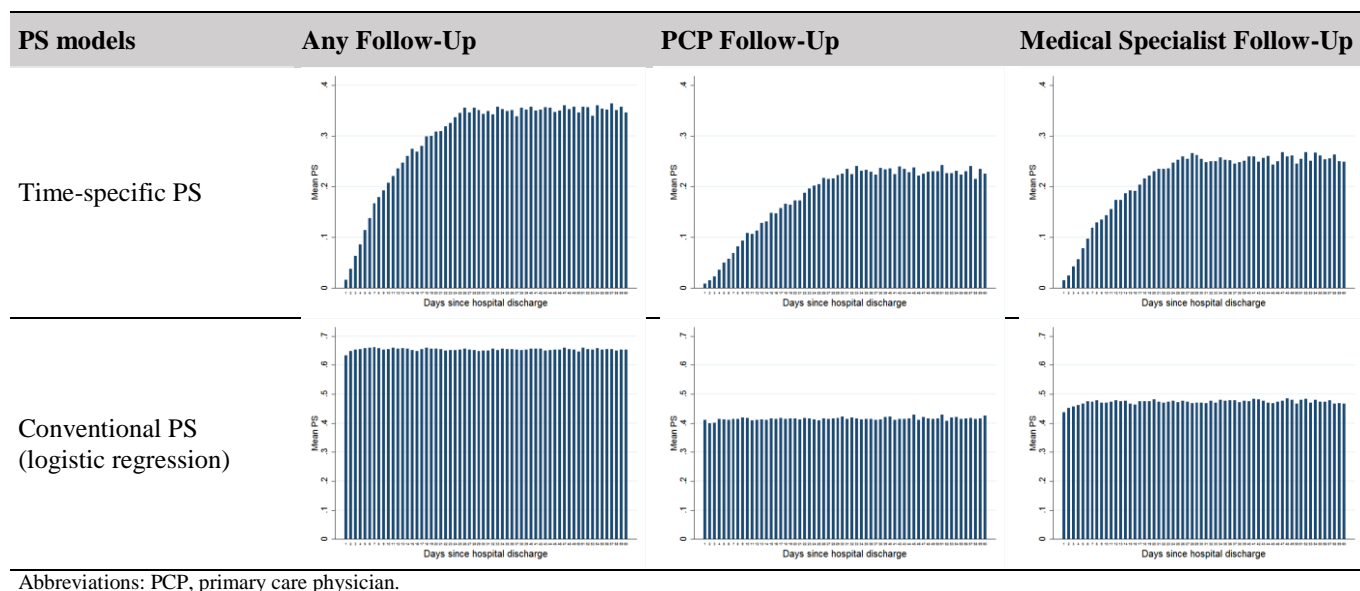
Table A4.6.1 Comparison of inverse-probability-weights for main analysis

PS models	Mean (SE**; range; standardized diff. >10%)		
	Any Follow-Up	PCP Follow-Up	Medical Specialist Follow-Up
Time-specific PS	1.018 (0.0005; 0.242 – 19.8; no)	1.009 (0.0006; 0.259 – 21.9; no)	1.019 (0.0006; 0.152 – 18.8; no)
Conventional PS (logistic regression)	1.000 (0.0004; 0.368 – 71.3; no)	1.001 (0.0006; 0.473 – 21.4; no)	1.000 (0.0005; 0.432 – 19.8; no)

Abbreviations: PCP, primary care physician.

Figure A4.6.2 Mean of inverse-probability-weights by days since discharge and by PS model

Any Follow-Up	PCP Follow-Up	Medical Specialist Follow-Up

Abbreviations: PCP, primary care physician.
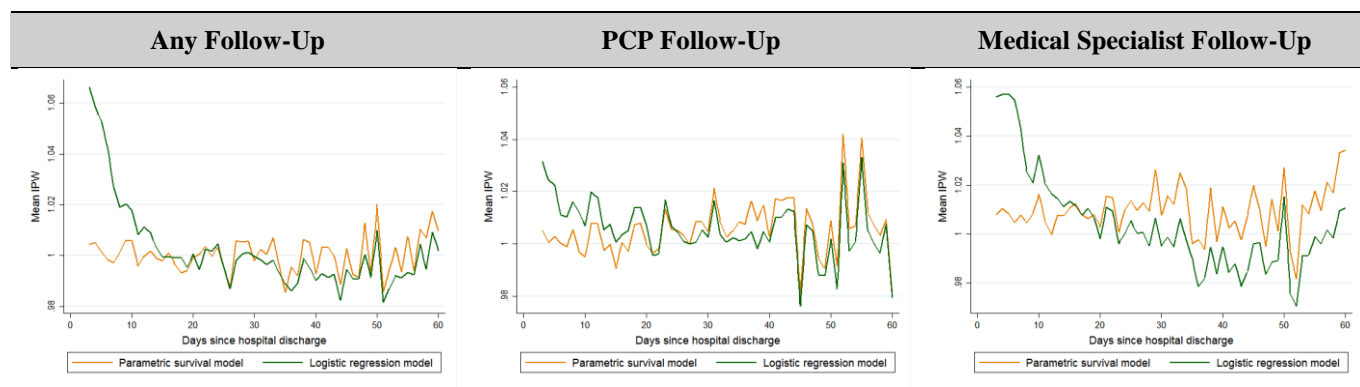
Table A4.6.2 Adjusted difference in cumulative incidence[*] of readmission between patients who received post-discharge follow-up and those who did not, by PS model specification

Follow-up type Days since discharge	Adjusted Difference Per 1 000 Discharges (95% CI[**])	
	PS model	
	Parametric survival analysis[1]	**Logistic regression**
Any physician		
7	67.8 (66.7 – 69.0)	72.8 (71.6 – 74.1)
14	102.5 (100.9 – 104.1)	106.9 (105.2 – 108.5)
21	110.0 (108.2 – 111.7)	111.8 (109.9 – 113.7)
30	105.2 (103.2 – 107.2)	104.0 (101.9 – 106.0)
60	87.8 (85.5 – 90.1)	79.5 (77.1 – 81.8)
Primary care physician (only)[1]		
7	69.6 (68.3 – 71.0)	76.6 (75.1 – 78.0)
14	104.4 (102.5 – 106.2)	111.6 (109.5 – 113.6)
21	113.0 (110.8 – 115.2)	118.7 (116.3 – 121.1)
30	110.3 (107.8 – 112.9)	114.1 (111.4 – 116.8)
60	97.0 (93.7 – 100.3)	96.3 (93.0 – 99.7)
Medical specialist (only)[2]		
7	55.3 (54.0 – 56.6)	61.6 (60.1 – 63.0)
14	78.5 (76.6 – 80.4)	84.9 (82.9 – 87.0)
21	79.9 (77.6 – 82.1)	84.4 (82.0 – 86.7)
30	72.5 (69.9 – 75.0)	74.4 (71.8 – 77.0)
60	55.2 (52.2 – 58.2)	51.7 (48.6 – 54.7)
Primary care physician and medical specialist (jointly)[3]		
7	77.6 (76.4 – 78.7)	85.4 (84.1 – 86.6)
14	125.8 (124.1 – 127.5)	134.9 (133.2 – 136.7)
21	141.0 (138.9 – 143.1)	147.7 (145.5 – 149.8)
30	136.9 (134.4 – 139.4)	138.9 (136.4 – 141.5)
60	115.1 (111.6 – 118.5)	105.7 (102.2 – 109.1)

Abbreviations: PS, propensity score.
[*]Accounts for competing events (death and readmission).
[**]Clustered bootstrap 95% CIs.
[1]Results are presented in Table 4.3 of main document.

CHAPTER 5: TEAM-BASED INNOVATIONS IN PRIMARY CARE DELIVERY IN CANADA AND OUTPATIENT PHYSICIAN FOLLOW-UP AFTER HOSPITAL DISCHARGE

5.1 Preamble

The evidence presented in the previous chapters, including the results in Chapter 5, demonstrate support for care coordination strategies aimed at the care transition period to reduce hospital readmissions. The Family Medicine Group (FMG) policy toward primary health care reform in Quebec, Canada has targeted organizational changes to care delivery and health care workforce, resulting in the creation of new multidisciplinary team-based primary care practices. A stated goal of the FMG policy was to improve access and care coordination. More than 10 years after their implementation, we do not know how FMGs compare to traditional primary care practices with respect to process (Chapter 5) or outcome measures (Chapter 6) of quality of care in the period after hospital discharge.

In this second manuscript, I describe how timely outpatient physician follow-up after hospital discharge (a process of care measure) is associated with the newly implemented team-based care models in Quebec, and whether this association varies by type of provider follow-up or by different patient subgroups. This manuscript was accepted for publication in *CMAJ Open.*

5.2 Abstract

Background: Outpatient follow-up has been a key intervention point to address gaps in care after hospital discharge. We sought to estimate the relationship between enrolment in new team-based primary care practices and 30-day post-discharge physician follow-up among hospitalized elderly or chronically ill patients in Quebec, Canada.

Methods: This is a population-based cohort study using health utilization data. We used marginal structural models to estimate adjusted rates of follow-up with a primary care physician or with a medical specialist by primary care delivery models.

Results: We extracted billing data on 312,377 patients representing 620,656 index admissions for any cause from 2002-2009. Thirty-day rates of follow-up were 374 primary care physician visits and 422 medical specialist visits per 1,000 discharges. Rates of primary care physician follow-up were similar across primary care delivery models, except for very highly morbid patients who had significantly higher rates if they were enrolled in team-based primary care practices (30-day rate difference (RD): 13.3 more follow-up visits per 1,000 discharges, 95% confidence interval (CI) 6.8 to 19.8). Rates of follow-up with a medical specialist were lower among patients enrolled in team-based practices, particularly within 15 days of hospital discharge (15-day RD: 25.1 fewer follow-up visits per 1,000 discharges, 95% CI 21.1 to 29.1).

Interpretation: Our study found lower rates of post-discharge follow-up with a medical specialist among elderly or chronically ill patients enrolled in team-based compared to those in traditional primary care practices, and higher rates of primary care physician follow-up in patients with very high morbidity.

5.3 Introduction

Hospitalized patients often face gaps in continuity of care, particularly in the period immediately after discharge, which can place them at high risk of major negative health outcomes. (1) Timely outpatient follow-up after hospital discharge is essential for effective care transition strategies; it represents an opportunity for patients to ask questions about their hospitalization and for physicians to monitor and address problems related to the patient's transition from hospital to community. (2-4) Patients receiving early outpatient follow-up after hospitalization have lower risk of death, unplanned readmission and emergency department visits and account for lower annual expenditures. (3, 5-11) Recognizing the role of follow-up visits in reducing readmissions, the Centers for Medicare and Medicaid Services in the

United States introduced new billing codes effective January 2013 for post-discharge care coordination, including a face-to-face visit within 14 or 7 days after discharge. (12) For patients hospitalized for common causes of admission such as heart failure, chronic obstructive pulmonary disease and acute myocardial infarction, clinical guidelines recommend that follow-up should occur within 2 weeks or 1 month after discharge. (2, 6, 13-19)

There is consensus that health systems with high-performing primary care achieve better results on a number of fronts, including better processes of care, better health outcomes and lower overall costs of health care. (20) Transforming health systems have given rise to a number of innovations in primary care delivery targeting attributes of primary care such as continuity and coordination of care. Accordingly, since the early 2000s in Canada, jurisdictions have implemented widely new primary care delivery models designed to facilitate access to continuous and coordinated care across the different levels of care. (21-24) Family Medicine Groups in Quebec, Canada were designed as groups of 6-12 family physicians that work with other health care professionals, primarily 1-2 nurses, to provide primary care to registered patients. The Family Medicine Group policy also supports a broad range of initiatives including case management, extended hours, practice computerization, regular scheduled appointments, walk-in clinics, home visits, health advice via telephone, and emergency on-call services. (25) Physicians who join a Family Medicine Group maintain the same remuneration schemes as non-Family Medicine Group physicians, which consist predominantly of fee-for-service. Family Medicine Group physicians and non-Family Medicine Group physicians also receive a small financial incentive for each vulnerable patient that they register to their practice, i.e., elderly or with eligible chronic health conditions. (26) Nurse specialists, whose salaries are paid by the Ministry of Health and Social Services are integrated within Family Medicine Group teams and are intended to provide case management, disease prevention and health promotion services. The traditional model in Quebec predominantly consists of solo (or a small group of) physicians practicing independently i.e. without a primary care nurse or support for the above-mentioned initiatives.

Evidence is lacking on whether such system-wide innovations in primary care delivery have played a role in improving quality and continuity of care in the period following hospital discharge, in particular for patients with chronic conditions. We sought to describe how rates of timely post-discharge physician follow-up vary by whether elderly or chronically ill patients are enrolled in new multidisciplinary team-based primary care practices or in traditional primary care practices. We further explored these variations by responsible diagnosis and by patient morbidity level.

5.4 Methods

5.4.1 Data Source

Data for this analysis included province-wide health insurance claims for inpatient and outpatient services delivered between November 2002 and January 2009 in Quebec. The Régie de l'Assurance Maladie du Québec (RAMQ) pays for health services provided in hospitals and by physicians for all persons registered with Quebec's universal health insurance program. We linked data from RAMQ databases using a unique lifetime identifier encrypted from the personal health insurance number: 1) a registered person file, which contains patient demographics; 2) a physician claims file, which contains physician services performed in hospital, office or clinic; 3) a hospital file, which includes information about each hospital admission; and 4) a physician information file, which contains information on the enrolling primary care physician, including practice type and characteristics, number of patients and services provided, and income source. RAMQ databases also contain information on the specialty of the billing physician for all physician services. Primary and specialist medical care in Quebec is predominantly funded via fee-for-service payments, with only a small portion of primary care physicians paid in part by salary for services provided within community health centers.

5.4.2 Study Setting

This study is based on a cohort of patients which has been described previously. (27, 28) Patients were selected into this cohort if a primary care physician enrolled them as a 'vulnerable patient' between November 2002 and January 2005. Since

late 2002, primary care physicians enroll 'vulnerable patients' into their practice by billing a fee code to the RAMQ if a patient is 70 years old or above or has one or more specified chronic health conditions (Appendix 5.1). (29) This fee code is available to physicians in both new and traditional primary care practices. We extracted 5 years of health insurance billing data for each patient since the date of their enrolment as vulnerable. We considered two analytical samples: 1) hospital admissions for any cause, and 2) hospital admissions for acute myocardial infarction, heart failure and chronic obstructive pulmonary disease, for whom timely follow-up care is specifically recommended in clinical guidelines (referred to as admissions for specific causes to alleviate the text). We identified patients hospitalized for specific conditions using International Classification of Disease (9th and 10th revisions) codes for main diagnosis (see Appendix 5.2). We excluded hospital admissions to long-term care facilities, and those that resulted in a discharge or a transfer to another facility. We further excluded index admissions for mental health and pregnancy/child birth using principal diagnosis codes, same day readmissions, admissions with in-hospital death, paediatric admissions, admissions with a hospital stay lasting 30 days or more, and admissions from Northern Quebec. These represent patient subgroups that likely differ with regards to the patterns of use of and need for primary health care services.

5.4.3 Study design

We used the index admission as the unit of analysis, which we defined as any hospital admission not preceded by a previous admission in the 30 days prior and that resulted in being discharged alive to home. We assigned exposure depending on whether a patient was enrolled with a physician practicing in a multidisciplinary team-based primary care (i.e. Family Medicine Group) or in a traditional primary care practice on the date of their index admission(s). The primary analysis examined time to the first outpatient post-discharge follow-up service provided by 1) a primary care physician or by 2) a medical specialist. This was calculated by counting the number of days that elapsed since the patient was discharged from hospital to the day that any service was billed. Outpatient services include physician services billed in establishments other than the emergency department, including

hospital outpatient clinics and office-based practices. We also examined the time to the first follow-up visit with any physician. Patients may contribute data for more than one index admission and under different exposure levels.

5.4.4 Covariates

All covariates were measured at the index admission. We included patient age, sex, and major diagnostic categories, and the time since enrolment by a primary care physician. We used Quebec's material deprivation index based on the 2006 census dissemination areas as a measure of neighborhood socio-economic status, and a categorical variable developed by the Quebec National Institute of Public Health to represent the patient's residential geographic location as a function of the proximity to an urban center and to a tertiary or secondary referral hospital. We controlled for time since previous use of inpatient care and case-mix adjusted at index admission using two variables: patient morbidity level and intensity of hospital resource use. Patient morbidity level is one of three Resource Utilization Bands (moderate, high or very high morbidity), calculated using the Johns Hopkins ACG Case-Mix System and based on diagnostic codes for both inpatient and outpatient utilization in the calendar year preceding the index admission. Relative Intensity Weights reflect the relative use of hospital resources, adjusted for age, comorbidities and complexity level. We also included physician characteristics (age, sex, years in practice, total number of patients, and income source) and indicator variables for each hospital as covariates.

5.4.5 Statistical Analysis

We estimated propensity scores from a logistic regression of Family Medicine Group enrolment at index admission on predictors. Covariates and model specifications are listed in the Appendix 5.3. We derived stabilized inverse-probability-weights from propensity scores to balance covariates across exposure groups, with standardized differences greater than 10% considered meaningful. We also used inverse-probability-weights to account for left-censoring of observations that occurred on the day of discharge. Competing risks included death as well as readmission or emergency department visit as these higher-level of care encounters

preclude appropriate outpatient post-discharge follow-up care. Finally, we estimated adjusted population-averaged rates and rate differences from marginal structural models using the Royston-Parmar flexible parametric model (extended for competing risks) and restricted cubic splines to model the baseline hazard function and time-dependent effects. (30) (31) We used the clustered bootstrap to obtain 95% confidence intervals (CIs). We used Stata MP 14 for all analyses.

5.5 Results

This study consisted of 351 113 elderly or chronically ill patients hospitalized for any cause between November 2002 and January 2009 in Quebec, representing 749 537 hospital admissions. Of those, we excluded 128 881 admissions (17.2%) from 106,176 patients (Figure 5.1). The study sample included a total of 620 656 index admissions for any cause (312 377 patients), and 90 326 admissions for specific causes (57 143 patients). Table 1 displays patient characteristics at admission (characteristics of patients hospitalized for specific causes are listed in Appendix 5.4). After weighting, there were no standardized differences greater than 10% between patients in team-based and traditional practices (Table 1; for details on analytical weights see Appendix 5.5). (32, 33)

Figure 5.1 Flow diagram
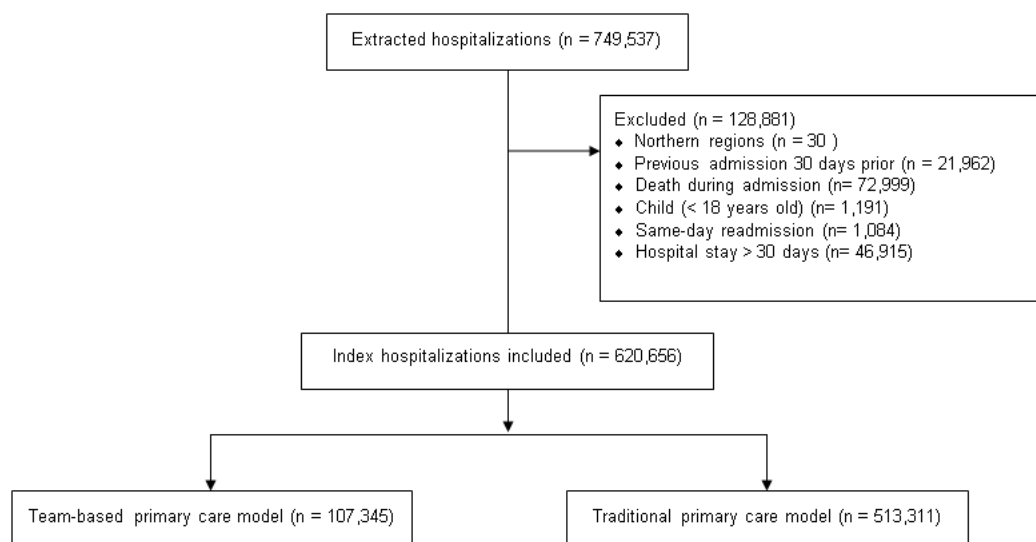
Table 5.1 Characteristics of hospitalized elderly or chronically ill patients at index admission, Quebec (Canada) 2002-2009

| Characteristics | Hospitalized for any cause | | Absolute standardized difference (%) | |
| | Primary care model | | Before weighting | After weighting |
	Team-based	Traditional		
Admissions, n (%)	107 345 (17.3)	513 311 (82.7)	-	-
Sex, n (%)				
Female	56 568 (52.7)	270 672 (52.7)	0.1	1.3
Age (years)				
Mean	73.3	73.3	3.8	3.2
Morbidity, n (%)				
Low-moderate	19 136 (17.8)	86 812 (16.9)	2.4	0.0
High	30 677 (28.6)	143 285 (27.9)	1.5	0.2
Very high	57 532 (53.6)	283 214 (55.2)	3.2	0.2
Hospitalization cost[*]				
Mean	$5,656	$5,656	1.3	0.1
Length of hospital stay (days)				
Mean	7.2	7.2	4.8	0.1
Years since enrolled with primary care physician				
Mean	2.5	2.5	16.2	0.3
Year of index admission, n (%				
2002-2003	9 524 (8.9)	81 184 (15.8)	21.2	1.1
2004	19 088 (17.8)	103 224 (20.1)	5.9	2.2
2005	21 317 (19.9)	105 660 (20.6)	1.8	1.3
2006	19 210 (17.9)	95 528 (18.6)	1.9	0.8
2007	18 556 (17.3)	94 428 (18.4)	2.9	2.8
2008-2009	19 650 (18.3)	33 287 (6.5)	31.0	0.4
Material deprivation quintile, %				
Quintile 1 (low deprivation)	11 166 (10.4)	71 791 (14.0)	11.0	0.1
Quintile 2	17 142 (16.0)	83 240 (16.2)	0.7	0.2
Quintile 3	22 266 (20.7)	99 303 (19.4)	3.5	1.1
Quintile 4	25 249 (23.5)	107 648 (21.0)	6.1	0.1
Quintile 5 (high deprivation)	23 418 (21.8)	116 428 (22.7)	2.1	2.1
Missing	8 104 (7.6)	34 901 (6.8)	2.9	1.7
Geographical region, %				
Urban/university	24 461 (22.8)	184 971 (36.0)	29.4	1.8
Suburban	45 359 (42.3)	197 775 (38.5)	7.6	0.5
Intermediate	30 301 (28.2)	100 593 (19.6)	20.3	0.4
Rural	7 014 (6.5)	28 277 (5.5)	4.3	1.8
Missing	210 (0.2)	1 695 (0.3)	2.6	0.3

Abbreviations: Q, quintile.
[*]Costs in current Canadian dollars are based on resource intensity weights for an admission multiplied by its unit cost per fiscal year.

The unadjusted rates of outpatient physician follow-up visits are displayed in Table 2 by primary care delivery model within 7-, 15- and 30-days since hospital discharge. After adjustment by inverse-probability-weighing, we found no significant differences in the rates of follow-up visit with a primary care physician

across primary care models among patients hospitalized for any cause nor for specific causes (Table 5.3). Adjusted rates of follow-up with a medical specialist remained significantly lower among patients enrolled in team-based primary care (Table 5.3). Similar differences in rates of follow-up by a medical specialist were observed among patients hospitalized for specific causes. When we considered follow-up with any physician, the difference in rates between primary care delivery models occurred within the first 15 days of discharge, and this difference decreased in the third and fourth weeks. At 30-days post-discharge, there remained no significant difference in rates of follow-up by any physician between team-based primary care and traditional primary care practices among patients hospitalized for specific causes (Table 5.3).

Table 5.2 Unadjusted rates of post-discharge outpatient follow-up within specified time interval among hospitalized elderly or chronically ill patients, by primary care delivery models

Target population	Hospitalized for any Cause			Hospitalized for specific causes		
Post-discharge outpatient follow-up	**Rate / 1 000 discharges**			**Rate / 1 000 discharges**		
	Team-based	Traditional	Total	Team-based	Traditional	Total
Primary care physician						
Within 7 days	106.3	118.5	116.4	119.4	130.5	128.5
Within 15 days	205.2	223.2	233.8	246.1	267.1	263.4
Within 30 days	355.4	377.5	373.7	399.8	416.8	413.9
Medical specialist						
Within 7 days	126.0	145.0	141.7	85.2	99.4	97.0
Within 15 days	247.6	276.8	271.8	175.0	196.5	192.9
Within 30 days	397.6	427.6	422.4	299.3	321.6	317.9
Any physician						
Within 7 days	228.2	257.4	252.4	212.7	224.6	222.6
Within 15 days	420.6	468.9	462.3	415.8	428.2	426.1
Within 30 days	649.4	681.9	676.2	645.9	644.8	645.0

Table 5.3 Adjusted[*] difference in rates of post-discharge outpatient follow-up within specified time interval among hospitalized elderly or chronically ill patients

Target population	Hospitalized for any cause	Hospitalized for specific causes
Post-discharge outpatient follow-up	**Rate difference / 1 000 discharges** (95% CI[**])	**Rate difference / 1 000 discharges** (95% CI[**])
Primary care physician		

Within 7 days	-0.7 (-2.1 to 3.6)	1.9 (-6.5 to 10.5)
Within 15 days	1.6 (-2.3 to 5.5)	0.6 (-10.6 to 11.8)
Within 30 days	1.7 (-6.3 to 3.0)	6.2 (-7.1 to 19.5)
Medical specialist		
Within 7 days	-16.9 (-19.9 to -13.9)	-13.7 (-19.9 to -7.5)
Within 15 days	-25.1(-29.1 to- 21.1)	-20.7 (-29.2 to -12.2)
Within 30 days	-25.0 (-29.7 to -20.4)	-21.4 (-32.1 to -10.8)
Any physician		
Within 7 days	-16.1 (-19.9 to -12.3)	-11.9 (-21.8 to -2.0)
Within 15 days	-18.2 (-22.7 to -13.7)	-12.4 (-24.2 to -0.5)
Within 30 days	-13.5 (-17.9 to -9.1)	1.1 (-10.5 to 12.8)

[*]All discharges (N=620 656) were included in the analysis. Adjusted for age, sex, time since enrolment with a primary care physician, geographical location, material and social deprivation quintile, resource utilisation band, major diagnostic group, length of stay, relative intensity weight, number of previous admissions, time since previous discharge, characteristic of enrolling physician (sex, years in practice, income source, total number of patients), calendar year, and hospital (see Appendix 5.4).
[**]Clustered bootstrap 95% CIs.

In Figure 5.2 we present the difference in rates of primary care physician follow-up visits between primary care delivery models by subgroup of patient morbidity level. We found that among patients with a very high level of morbidity, those enrolled in team-based primary care practices were more likely to receive timely follow-up with a primary care physician (Figure 5.2, Panel A). This represents more than 10 additional patients enrolled in team-based primary care receiving follow-up by a primary care physician within 30 days for every 1 000 discharges. On the contrary, among patients with moderate or high morbidity, those enrolled in team-based primary care practices were less likely to receive timely follow-up by a primary care physician (Figure 5.2, Panel A). Rate differences for follow-up visits with a medical specialist did not vary by morbidity level (Figure 5.2, Panel B).

Figure 5.1 Adjusted[*] difference in rates of post-discharge outpatient follow-up between multidisciplinary team-based and traditional primary care practices, by physician type and by morbidity level
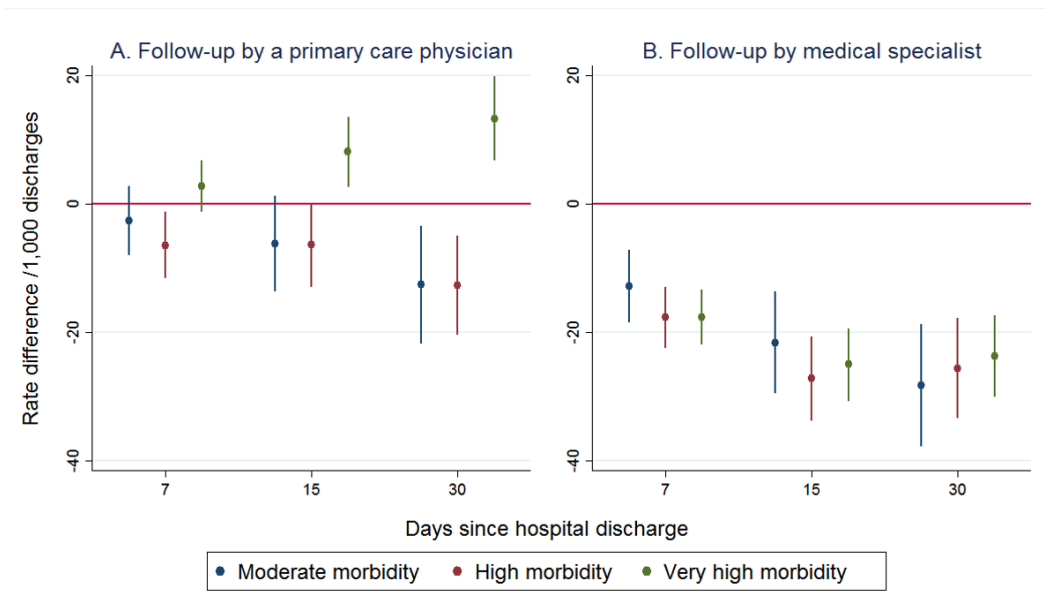
Notes: Vertical lines represent clustered 95% CIs.
[*]All discharges (N=620 656) were included in the analysis. [*]All discharges (N=620 656) were included in the analysis. Adjusted for age, sex, time since enrolment with a primary care physician, geographical location, material and social deprivation quintile, resource utilisation band, major diagnostic group, length of stay, relative intensity weight, number of previous admissions, time since previous discharge, characteristic of enrolling physician (sex, years in practice, income source, total number of patients), calendar year, and hospital (see Appendix 5.4).

5.6 Interpretation

Our study of more than 600 000 discharges that occurred between 2002 and 2009 in Quebec demonstrated differences in timely outpatient care in the post-discharge period for patients enrolled in multidisciplinary team-based primary care practices compared to those enrolled in traditional primary care practices. Overall, patients enrolled in team-based primary care had similar rates of follow-up visits by a primary care physician, and significantly lower rates of follow-up with a medical specialist. Among patients with highest morbidity, multidisciplinary team-based primary care practices were associated with higher rates of timely follow-up with a primary care physician, suggesting that these widely implemented innovations in primary care delivery may have achieved better results in care coordination following hospital discharge for the highest users of the health care system.

In the current study, enrolment in multidisciplinary team-based primary care models at index admission was associated with lower rates of follow-up visits with a medical specialist in the month following discharge. Elsewhere we report better post-discharge outcomes associated with enrollment in team-based primary care for

the most medically complex patients (lower rates of post-discharge emergency department visits, lower rates of post-discharge mortality and similar readmission rates). (34) In this context, we think it is unlikely that the lower rates of follow-up with a medical specialist suggest lesser quality of care in team-based primary care models. We hypothesize that allied health professionals in multidisciplinary teams have substituted for a portion of the needed follow-up care after hospital discharge for those patients with very high morbidity. Alternative explanations are also plausible but difficult to test empirically in our context. For example, physicians in team-based primary care models may provide more comprehensive post-discharge follow-up and that their patients have less need for a medical specialist follow-up. Future research is needed to investigate such explanations to assess whether team-based primary care practices are in fact providing more appropriate (and potentially less costly) care to patients when they are discharged from the hospital. Further, this study finds that one in three elderly or chronically ill patients hospitalized for acute myocardial infarction, heart failure or chronic obstructive pulmonary disease did not receive physician follow-up care within 30 days of discharge, excluding patients seen in the emergency department or seen by other health care professionals. This is considerably less than what was reported in other Canadian jurisdictions, where the large majority of patients (77% to 92%) saw a physician within a month of discharge.

The interpretation of our study's findings is limited by the lack of data on nurses (and/or other allied health professionals) practicing in primary care teams, which prevents us from providing a complete portrait of how team-based primary care delivery models are performing on outpatient follow-up visits in the post-discharge period compared to traditional primary care practices. Data on visits with nurses are not available in Quebec billing data because nurses are paid via salary and do not bill per service for the care they provide. By 2010, the vast majority of Family Medicine Group practices had one or more nurses within their team; this was not the case for traditional primary care practices. (35) The roles and tasks of nurses described in the supporting Family Medicine Group policy documents include systematic follow-up and case management for patients with complex medical

needs; (36) for this reason, some substitution by nurses for family doctors in the post-discharge period may have occurred, and follow-up by nurses may have (directly or indirectly) replaced some share of the fewer visits to a medical specialist occurring within 30-days of hospital discharge among Family Medicine Group patients. This reallocation of health human resources is desirable following organizational reforms in primary care. We were further limited by the fact that administrative health databases lack information on patients' functional status and direct measures of severity of their conditions. Despite our adjustment efforts, unmeasured differences in case-mix across primary care delivery models are still possible. Our results show that the differences in rates of primary care physician follow-up between primary care models were reduced after adjustment for measured covariates, which leads us to believe that our estimates may have been too conservative if residual differences in case mix exist (e.g. patients enrolled in team-based primary care practices are healthier and with less functional limitations). In contrast, covariate adjustment did not reduce the difference in rates of follow-up with a medical specialist between primary care delivery models nearly as much, which provides some intuition that residual confounding is not a major issue for estimates on this outcome. Further, there is always a possibility of selection bias because physician participation and patient enrolment in primary care models depends largely on physician preferences and characteristics. (27) In this study, we included measured characteristics on both treating primary care physicians and patients in the derivation of propensity scores, which likely account for part but not all of this selection bias. Further, we designed this analysis to specifically examine timeliness of follow-up care after discharge; in doing so, we did not examine the volume of services or the comprehensiveness or appropriateness of care after discharge. Finally, we used data for the period between 2002 and 2010; timely access to more recent data in Quebec is essential to assess the current performance of Family Medicine Groups.

5.7 Conclusions and Implications for Practice and Future Research

Seeing a doctor shortly after hospital discharge is often recommended. Our results suggest that system-wide innovations in primary care delivery consisting of

multidisciplinary team-based practices were associated with similar rates of follow-up with a primary care physician, and with lower rates of follow-up with a medical specialist particularly within the first two weeks of hospital discharge, compared to traditional practices. Importantly, our overall results masked heterogeneous associations across subgroups of patient morbidity levels, whereby the most medically complex patients received more follow-up with a primary care physician if they were enrolled in team-based primary care practices, while less complex patients did not. This may suggest that new team-based primary care models perform better on this process of care measure for patients in the highest morbidity level. Further, nurses practicing in primary care teams likely provide some of the timely post-discharge follow-up care, and it is critical that future research empirically test this hypothesis to assess its validity and to best inform future strategies to improve patient- and system-level outcomes in the post-discharge period, including reducing readmissions and emergency department visits. Lastly, given that outpatient post-discharge follow-up may help in reducing hospital readmissions and mortality rates, future research and policies should work towards new ways to improve rates of timely follow-up. This may include targeting innovations and additional resources in team-based primary care delivery such as computerization and the role played by nurses in post-discharge follow-up.

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APPENDICES

Appendix 5.1: Table 1.1 RAMQ definition of vulnerable patients by age or health condition in 2003

Patient defined as vulnerable if:	age	or at least one of the following health conditions:
Criteria	≥ 70 years old	Psychosis, chronic obstructive pulmonary disease (COPD), moderate to severe asthma, pneumonia, cardiovascular disease, cancer associated with past, present, or future chemotherapy or radiotherapy treatments, cancer in a terminal phase, diabetes, alcohol or hard drug withdrawal, drug addiction treated with methadone, HIV/AIDS, or a degenerative disease of the nervous system

Appendix 5.2: Table 2.1 ICD-9/ICD-9-CM and ICD-10 codes to identify hospitalizations for acute myocardial infarction, heart failure and chronic obstructive pulmonary disease[*]

Cause of admission	ICD-9/ICD-9-CM	ICD-10-CA
Acute myocardial infraction	410, 41093	I21, I210, I211, I212, I213, I214, I219, I2101, I2102, I2109, I2111, I2119, I2121, I2129, I2140, I2141, I2142, I2149, I22, I220, I221, I222, I228, I229
Heart failure	428, 4280, 4281, 4289	I0981, I50, I500, I501, I5020, I5021, I5022, I5023, I5030, I5031, I5032, I5033, I5040, I5041, I5042, I5043, I509
COPD	491, 4909, 4910, 4911, 4918, 4919, 912, 492, 4929, 494, 4949, 496, 969, 49692, 49693	J40, J410, J411, J418, J42, J430, J431, J432, J438, J439, J440, J441, J448, J449, J47, J470, J471, J479

[*]Based on Clinical Classification Software (CCS) and Canadian Institute for Health Information; ICD-9-CM and ICD-10-CM codes were checked manually to match Quebec diagnosis codes.

Appendix 5.3: Table 3.1 Characteristics of elderly or chronically ill patients hospitalized for acute myocardial infarction, heart failure or chronic obstructive pulmonary disease, Quebec (Canada) 2002-2009

| Characteristics | Hospitalized for AMI, HF or COPD | | Absolute standardized difference (%) | |
	Team-based PC	Traditional PC	Before weighting	After weighting
Admissions, n (%)	15 740 (17.4)	74 586 (82.6)	-	-
Sex, n (%)				
Female	7 900 (50.2)	37 444 (50.2)	0.0	1.0
Age (years)				
Mean	75.2	75.5	3.3	3.4
Morbidity, n (%)				
Low-moderate	2 017 (12.8)	9 125 (12.2)	1.8	0.0
High	4 552 (28.9)	21 137 (28.3)	1.3	0.1
Very high	9 171 (58.3)	44 324 (59.4)	2.4	0.1
Hospitalization cost[*]				
Mean	$5,271	$5,207	1.9	0.0
Length of hospital stay (days)				
Mean	7.6	7.9	4.9	0.3
Years since enrolled with primary care physician				
Mean	2.6	2.3	21.3	4.2
Year of index admission, n (%				
2002-2003	1 410 (9.0)	11 688 (15.7)	20.5	0.4
2004	2 565 (16.3)	14 454 (19.4)	8.1	4.2
2005	2 816 (17.9)	13 785 (18.5)	1.5	0.2
2006	2 858 (18.2)	14 542 (19.5)	3.4	0.3
2007	2 985 (19.0)	15 177 (20.4)	3.5	2.5
2008-2009	3 106 (19.7)	4 940 (6.6)	33.8	3.0
Material deprivation quintile, %				
Quintile 1 (low deprivation)	1 328(8.4)	8 663 (11.6)	10.6	1.7
Quintile 2	2 297 (14.6)	11 394 (15.3)	1.9	0.6
Quintile 3	3 260 (20.7)	14 600 (19.6)	2.8	1.2
Quintile 4	3 914 (24.9)	16 364 (21.9)	6.9	1.0
Quintile 5 (high)	3 710 (23.6)	18 008 (24.1)	1.3	4.2
Missing	1 231 (7.8)	5 557 (7.5)	1.4	4.1
Geographical region, %				
Urban/university	3 355 (21.3)	25 016 (33.5)	27.7	0.7
Suburban	6 530 (41.5)	28 609 (38.4)	6.4	0.2
Intermediate	4 829 (30.7)	16 321 (21.9)	20.1	0.7
Rural	992 (6.3)	4 315 (5.8)	2.2	0.8
Missing	34 (0.2)	325 (0.4)	3.9	1.6

Abbreviations: AMI, acute myocardial infarction; HF, heart failure; COPD, chronic obstructive pulmonary disease; Q, quintile.

[*]Costs in current Canadian dollars are based on resource intensity weights for an admission multiplied by its unit cost per fiscal year.

Appendix 5.4: Table 4.1 Statistical models

Propensity model	Exposure	Censoring	Competing risk	Outcome
Regression type	Logistic	Royston-Parmar	Royston-Parmar	Royston-Parmar
Baseline distribution function	na	r.c.s. (8 d.f.)	r.c.s. (8 d.f.)	r.c.s. (8 d.f.)
Exposure				
FMG (bin.)	-	I	I	I
Patient demographics				
FEMALE (bin.)	I	I	I	-
AGE (c)	r.c.s. (4 d.f.)	-	r.c.s. (3 d.f.)	-
TIMEREG (5 cat.)	I	-	I	-
GEO (5 cat.)	I	-	I	-
MATDEP (6 cat.)	I	I	I	-
SOCDEP (6 cat.)	I	I	I	-
Patient health status				
RUB (3 cat.)	I	I	I	-
DIAG (17 cat.)	I	I	I	-
LOS (c)	linear	-	r.c.s. (4 d.f.)	-
RIW (c)	linear	-	r.c.s. (4 d.f.)	-
NBADM (c)	r.c.s. (3 d.f.)	r.c.s. (3 d.f.)	r.c.s. (3 d.f.)	-
TIMEDISCHG (10)	I	I	I	-
Registering physician				
PCPFEMALE (bin.)	I	-	I	-
PCPNBPAT (c)	r.c.s. (4 d.f.)	-	-	-
PCPPRACTICE (5)	I	-	I	-
PCPSALARY (6)	I	-	I	-
PCPHOSP (6)	I	-	I	-
Contextual				
YEAR (7 cat.)	I	I	I	-
HOSP (105 cat.)	-	I	I	-
Two-way interactions				
FMGxTIME	-	-	-	r.c.s.(3 d.f.)
GEO1xRUB3	I	-	I	-
GEO2xRUB3	I	-	I	-
GEO3xRUB3	I	-	-	-
FMGxMATDEP*	-	-	I	-
RUB2xMATDEP*	-	-	I	-
RUB3xMATDEP*	-	-	I	-
RUBxYEAR	I			

*The letter I denotes an indicator function

Abbreviations: na, not applicable; bin., binary; cat., categories; r.c.s., restricted cubic splines; d.f., degrees of freedom; c, continuous FMG: 0 – enrolled in traditional PC, 1 – enrolled in FMG; FEMALE: 0 – male, 1 – female; YEAR: calendar years from 2002-2003 to 2009-2010; RUB: 1 – low-moderate morbidity, 2 – high morbidity, 3 – very high morbidity; DIAG: principal diagnosis groupings; HOSP: indicator for each hospital; GEO: 1 – urban/university, 2 – suburban/peripheral, 3 – intermediate, 4 – rural, 5 – missing; MATDEP: 0 - missing, 1 – low material deprivation quintile, 5 – high material deprivation quintile; SOCDEP: 0 -missing, 1 – low social deprivation quintile, 5 – high social deprivation quintile; PCPPRACTICE: 0 – missing, 1 – 5 years in practice or less, 2 – 6 to 10 years in practice, 3 – 11 to 20 years in practice, 4 – more than 20 years in

practice; PCPSALARY: 0 – missing, 1 – less than 20% of PCP income from salary, 2 – between 20% and 39%, 3 – between 40% and 59%, 4 – between 60% and 79%, 5 – 80% or more; PCPHOSP: 0 – missing, 1 – less than 20% of PCP income from short term care establishment, 2 – between 20% and 39%, 3 – between 40% and 59%, 4 – between 60% and 79%, 5 – 80% or more; RIW: relative intensity weight; LOS: length of hospital stay (in days); PCPNBPAT: mean number of PCP enrolled patients; TIMEREG: time (in days) since enrolment with PCP; NBADM: number of hospital admissions preceding index admission, calculated from two years before study entry; TIMEDISCHG: time (in days) since last hospital discharge.

Appendix 5.5: Table 5.1 Description of inverse probability weights[*]

Estimated analytical weights	Mean (SE[**]; range)
Enrolment in a team-based PC at index admission	
Main analysis	0.998 (0.0007; 0.187 – 22.0)
Left censoring (follow-up visits provided on the day of discharge)	
Follow-up with a primary care provider	1.024 (0.0003; 0.638 – 1.74)
Follow-up with a medical specialist	1.056 (0.0005; 0.606 – 3.34)
Follow-up with any physician	1.067 (0.0005; 0.406 – 2.67)
Censoring by death	
Main analysis	1.001 (0.0003; 0.973 – 192)
Censoring by hospital readmission	
Main analysis	1.017 (0.0004; 0.759 – 42.9)
Combined weights (exposure weights multiplied by censoring weights)	
Main analysis (PCP follow-up)	1.042 (0.0010; 0.099 – 242.1)
Main analysis (SP follow-up)	1.081 (0.0011; 0.114 – 240.0)
Main analysis (follow-up with any physician)	1.087 (0.0011; 0.083 – 167.7)

Abbreviations: PCP, primary care provider; SP, medical specialist.

[*]We interpreted as evidence of positivity or propensity score model misspecification if the mean of the stabilized weight was far from zero or if there were extreme values. Truncating- the weights at various percentiles did not yield meaningful improvements in precision based on the standard errors; we chose to use untruncated weights to avoid introducing bias in our analyses.

[**]Clustered standard errors.

CHAPTER 6: READMISSION, POST-DISCHARGE EMERGENCY DEPARTMENT VISITS AND MORTALITY IN THE CONTEXT OF CANADIAN PRIMARY CARE INNOVATIONS

6.1 Preamble

Chapter 4 contributed evidence that the timing of outpatient physician follow-up in the period after hospital discharge led to important reductions in hospital readmissions, in particular if delivered within 3 weeks of discharge and by a primary care physician. Findings presented in Chapter 5 suggested that the newly implemented multidisciplinary team-based primary care models in Quebec, Canada (Family Medicine Groups, FMG) had rates of timely post-discharge follow-up by a primary care physician similar to that of traditional primary care practices, except for patients with very high morbidity burden who were more likely to receive follow-up if they were enrolled in the team-based models. We also observed that the rates of post-discharge follow-up with a medical specialist were lower in team-based models, which may indicate a desirable reallocation of resources if nurses practicing in FMGs are providing the needed care; although this hypothesis needs to be explored in future research where data on services provided by nurses is available and reliable.

Using a similar approach as in the previous manuscript (Chapter 5), the third manuscript specifically examines outcome measures in the post-discharge period across team-based and traditional primary care practices, including hospital readmissions, ED visits and mortality. This manuscript was accepted for publication in *CMAJ*.

6.2 Abstract

Background: Strategies to reduce hospital readmission have received substantial attention. However, evidence on the association between population-wide policies

supporting team-based primary care (PC) delivery models and post-discharge outcomes is sparse.

Objective: To assess whether rates of readmission, ED visits and mortality in the 90-days following hospital discharge were different in elderly or chronically ill patients enrolled in team-based PC practices and those enrolled in traditional practices.

Methods: We extracted claims data on 312 377 patients representing 620 656 index admissions for any cause from 2002-2009 in Quebec. We used inverse-probability-weighting to balance exposure groups on covariates, including patient demographics, health status and health utilization, primary care physician characteristics, year and hospital fixed-effects. We used marginal structural survival models to estimate rate differences and hazard ratios.

Results: Rates of readmission at any point in the 90-day post-discharge period were similar across PC delivery models. Patients enrolled in team-based PC practices had lower 30-day rates of ED visits not associated with readmission (7.5 fewer ED visits per 1000 discharges, 95% CI 10.8-4.2). Thirty-day mortality rates were also lower among patients enrolled in team-based PC models (3.8 fewer deaths per 1000 discharges, 95% CI 5.9-1.7). Subgroup analyses revealed that rate differences varied substantially by patient morbidity level.

Conclusions: Our findings suggest that enrollment in the newer team-based PC models in Quebec is associated with lower rates of post-discharge ED visits and mortality. We did not observe differences in readmission rates, which suggests that more targeted or intensive efforts may be needed to affect this outcome.

6.3 Background

Hospital readmissions are costly, representing $1.8 billion in annual health spending in Canada (excluding fees for physician services). (1) In the weeks following discharge, elderly or chronically ill patients are at increased risk for adverse events (e.g. side effects or mistakes related to new medications), and many will return to the hospital. (2-5) Hospital readmission within 30 days of discharge

occur in as many as one in five Medicare patients (65 years and older) hospitalized for any cause in the US, and approximately one in four patients return to the ED within that time. (6-8) Older age, increased comorbidities and complexity of medical condition(s) are associated with using a disproportionate amount of health care resources across various settings (9-12) and with a greater risk of 30-day readmission. (1, 13-15)

Readmissions have been the focus of much policy attention in the United States and elsewhere (e.g. Australia and the United Kingdom) as a potential intervention point and as a quality measure of hospital care. High rates of 30-day readmission may also indicate poor integration of the health care delivery system, one in which care is poorly coordinated across settings (e.g. primary care, home care, hospital and pharmacy). (16, 17) Similarly, post-discharge emergency department visits, which account for approximately 40% of all acute post-discharge care encounters (8) and contribute a meaningful share of hospital spending, (1, 18) have also been proposed as a novel marker of inadequate care coordination. (7, 8, 18) A portion of all-cause hospital readmissions and post-discharge ED visits are deemed preventable, (4, 5, 19, 20) and as such, high population rates of such events represent opportunities to improve care and use health care resources more efficiently.

Interventions to reduce 30-day readmissions and post-discharge ED visits have targeted organizational factors that play a role in care coordination, both in–hospital (care transitions) (21-24) and in outpatient settings (team-based delivery, case management and health information technologies). (25) Most interventions studied have been resource intensive and implemented in local settings. No studies to date has investigated the capacity of innovations in primary care delivery implemented on a large scale to affect post-discharge outcomes. We address this gap by evaluating whether organizational and team changes to primary care delivery in Quebec, Canada are associated with lower rates of readmission and post-discharge ED visits.

6.4 Research Objective

To assess whether rates of readmission, ED visits and mortality in the 90-days following hospital discharge were different in elderly or chronically ill patients enrolled in multidisciplinary team-based PC practices and those enrolled in traditional practices. We performed subgroup analyses by patient morbidity level.

6.5 Setting

Since the early 2000s, Canada has invested over $800 million towards redesigning primary care to meet the needs of a growing population living with chronic illness. Primary care reform initiatives across Canada targeted many of the characteristics of the US Patient-Centered Medical Home, including improved access, continuity and coordination of care. (26-30) Canada's second largest province, Quebec, implemented Family Medicine Groups (FMG) as new models of multidisciplinary team-based primary care. FMGs are designed to unite 6 to 12 family physicians and 1 or 2 nurses to provide primary care for a group of enrolled patients, with a broad range of services including case management, extended hours, regular scheduled appointments, walk-in clinics, home visits, health advice via telephone, and emergency on-call services. (31) By the end of 2005, approximately 100 FMGs (230 sites) were operational in the province of Quebec, though traditional PC models (group or solo practices) remained the dominant type of primary health care organizations at the time. (32)

6.6 Study Design

We used data from a large cohort study based on linkage of administrative health databases between November 2002 and January 2009 in Quebec, Canada. We extracted data on hospital admissions, ED visits and deaths that occurred during the study period and within 90 days after each hospital discharge. We used the *index admission* as the unit of analysis, which we define as any hospital admission not preceded by an admission in the 30 days prior and that resulted in a discharge to home. Patients may contribute data for more than one index admission. We assigned exposure depending on whether a patient was enrolled with a primary care provider practicing in a multidisciplinary team-based PC (FMG) or in a traditional

PC practice on the date of their index admission(s). Patients with several index admissions can contribute data under different exposure levels. We excluded index admissions to long-term care facilities, and those that resulted in a discharge or a transfer to another facility. We further excluded index admissions for mental health and pregnancy/child birth using principal diagnosis codes (*International Classification of Disease* (ICD), *9th* and *10th revisions*), same day readmissions, admissions with in-hospital death, paediatric admissions, admissions with a hospital stay lasting 30 days or more, and admissions from hospitals in Northern Quebec (Appendix 6.1). These represent patient subgroups that likely differ with regards to the patterns of use and need of primary health care services.

6.7 Methods

6.7.1 Data Source

The Régie de l'Assurance Maladie du Québec (RAMQ) pays for health services provided by hospitals and physicians for all persons registered with Quebec's universal health insurance program. We linked data from RAMQ databases using a unique lifetime identifier encrypted from the personal health insurance number: 1) a registered person file, which contains patient demographics; 2) a physician claims file, which contains physician services performed in hospital, office or clinic; 3) a hospital file, which includes information about each hospital admission; and 4) a physician information file, which contains information on the enrolling primary care physician, including practice type and characteristics, number of patients and services provided, and income source. RAMQ databases also contain information on the specialty of the billing physician.

6.7.2 Patients

Patients were selected into the original cohort study if a primary care physician enrolled them as a 'vulnerable patient' between November 2002 and January 2005. Since 2002, primary care physicians enrol 'vulnerable patients' into their practice by billing a fee code if a patient is 70 years old or above or has one or more specified chronic health conditions (Appendix 6.2). (33) This fee code is available to primary care providers in both new and traditional PC practices.

6.7.3 Main Outcomes

We considered the time to a hospital readmission as our primary outcome. This was calculated by counting the number of days that elapsed since the patient was discharged ($t = 0$) from hospital to the day that a patient was readmitted or censored at 90 days. For secondary outcomes, we examined the time to an ED visit and the time to death up to 90 days after discharge. We further distinguished ED visits not associated with readmission, which include all ED visits for which there is no admission on the same day or the following day. We created this outcome measure to separate out hospital encounters that were handled in the emergency department and did not necessitate hospital admission, which we believed may better reflect less urgent care that could have been prevented by appropriate ambulatory care.

6.7.4 Covariates

All covariates were measured at the index admission. We included patient age, sex, and major diagnostic categories, and the time since enrolment by a primary care physician. We used Pampalon's material deprivation index based on the 2006 census dissemination areas as a measure of neighbourhood socio-economic status, and a categorical variable developed by the Quebec National Institute of Public Health to represent the patient's residential geographic location as a function of the proximity to an urban center and to a tertiary or secondary referral hospital. (34-36) We controlled for the number of previous admissions, the time since previous use of inpatient care, the patient morbidity level and relative intensity of hospital resource use. Patient morbidity level is one of three Resource Utilization Bands (moderate, high or very high), calculated using the Johns Hopkins ACG Case-Mix System and based on diagnostic codes for both inpatient and outpatient utilization in the calendar year preceding the index admission. Relative Intensity Weights (RIW) reflect the relative use of hospital resources, adjusted for age, comorbidities and complexity level. (37) In some specifications, we also included physician characteristics (age, sex, years in practice, the total number of patients, and income source, e.g., short-term care establishment, salary, emergency services) and indicator variables for each hospital as covariates (Appendix 6.3).

6.7.5 Statistical Analysis

We first derived a propensity score from a logistic regression of FMG enrolment at index admission on predictors, with flexible modeling using restricted cubic splines (Appendix 6.3). We derived stabilized inverse-probability-weights (IPW) from propensity scores to balance covariates across exposure groups, with standardized differences greater than 10% considered meaningful. We constructed separate sets of weights to investigate effect heterogeneity by morbidity level. Finally, we estimated cumulative incidence functions (also referred to as rates within a specified time interval to alleviate the text) and time-dependent hazard ratios from a flexible parametric survival model weighted by IPW. (38) When competing risks either by death and/or readmission were present, we use the same modelling techniques adapted for survival data in the presence of competing risks, which can generate both sub-distribution and cause-specific measures of association. (39) We used the clustered bootstrap to obtain 95% confidence intervals (CIs) and indicator variables or single imputation for missing data on covariates. We used Stata MP 14 for all analyses.

6.8 Results

The 2002-09 Quebec claims data used in our analysis included 351 113 elderly or chronically ill patients hospitalized for any cause, representing 749 537 hospital discharges. Of those, we excluded 128 881 admissions (17.2%) from 106 176 patients (reasons documented in Appendix 6.1). We included a total of 620 656 discharges for any cause (312 377 patients). The stabilized IPWs chosen had a mean close to 1, small standard errors and a reasonable range (see Appendix 6.4). (40, 41) Table 6.1 presents unweighted and weighted patient characteristics at index admission. Before weighting, we observed small differences in patient demographics, overall burden of morbidity, and length of stay during index admission across primary care models. Notably, a higher proportion of patients enrolled in traditional PC were in the lowest material deprivation quintile (least privileged) and lived in a university region. After weighting, there were no standardized differences on measured covariates greater than 10% (Appendix 6.5).

Table 6.1 Characteristics of hospitalized elderly or chronically ill patients at index admission, Quebec (Canada) 2002-2009 (unweighted and weighted)

N = 620 656 discharges	Unweighted		Weighted	
Characteristics	**Team-based PC**	**Usual PC**	**Team-based PC**	**Usual PC**
Sex, %				
Female	52.7	52.7	52.1	52.7
Age (years)				
Mean	73.3	73.8	73.3	73.7
Morbidity (RUB), %				
Moderate	17.8	16.9	17.2	17.1
High	28.6	27.9	28.1	28.0
Very high	53.6	55.2	54.8	54.9
Hospitalization cost*				
Mean	$5,656	$5,603	$5,621	$5,616
Length of hospital stay (days)				
Mean	7.2	7.5	7.5	7.5
Years since enrolled with PCP				
Mean	2.5	2.2	2.2	2.2
Year of index admission, %				
2002-2003	8.9	15.8	14.3	14.6
2004	17.8	20.1	18.7	19.6
2005	19.9	20.6	19.8	20.4
2006	17.9	18.6	18.8	18.5
2007	17.3	18.4	19.3	18.2
2008	14.5	5.3	7.4	7.1
2009	3.8	1.2	1.8	1.7
Material deprivation quintile, %				
Q1 (low)	10.4	14.0	13.4	13.4
Q2	16.0	16.2	16.1	16.2
Q3	20.7	19.4	19.1	19.6
Q4	23.5	21.0	21.5	21.4
Q5 (high)	21.8	22.7	23.4	22.6
Missing	7.6	6.8	6.5	6.9
Geographical region, %				
Urban/university	22.8	36.0	32.9	33.7
Suburban	42.3	38.5	39.4	39.1
Intermediate	28.2	19.6	21.3	21.1
Rural	6.5	5.5	6.2	5.8
Missing	0.2	0.3	0.3	0.3

*Costs in current Canadian dollars are based on resource intensity weights for an admission multiplied by its unit cost per fiscal year.
** Covariates and two-way interactions adjusted for are listed in Appendix 6.3. Standardized differences between groups after weighting are shown in Appendix 6.4.

Table 6.2 shows the unadjusted rates of readmission, ED visit and mortality within 15, 30 and 90 days of hospital discharge in the study sample and averaged over the study period.

Table 6.2 Cumulative incidence functions of post-discharge outcomes among hospitalized elderly or chronically ill patients hospitalized, Quebec (Canada) 2002-2009

Time since discharge	Cumulative incidence / 1 000 discharges (95% CI)			
	Readmission	**Post-discharge ED**	**Post-discharge ED not associated with readmission**	**Mortality**
15 days	81.0 (80.3 to 81.8)	136.2 (135.3 to 137.1)	110.1 (109.3 to 110.9)	10.5 (10.3 to 10.8)
30 days	137.4 (136.5 to 138.4)	205.7 (204.6 to 206.9)	165.7 (164.7 to 166.8)	16.1 (15.8 to 16.4)
90 days	254.7 (253.3 to 256.1)	328.9 (327.5 to 330.3)	266.2 (264.9 to 267.5)	26.3 (25.9 to 26.7)

*All discharges (N=620 656) were included in the analysis.

We observed no meaningful or statistically significant differences between team-based and traditional PC models for readmissions after adjusting for covariates (Table 6.3). Patients enrolled in multidisciplinary team-based PC practices had a lower adjusted cumulative incidence of ED visits, ED visits not associated with readmission and of death at 15 days after discharge and beyond (Table 6.3).

Table 6.3 Adjusted difference in cumulative incidence of post-discharge outcomes by PC delivery models among hospitalized elderly or chronically ill patients

Time since discharge	Adjusted difference in cumulative incidence / 1 000 discharges (95% CI)			
	Readmission	**Post-discharge ED**	**Post-discharge ED not associated with readmission**	**Mortality**
15 days	0.7 (-1.7 to 3.0)	-1.9 (-6.4 to -0.7)	-4.4 (-7.0 to -1.9)	-2.9 (-4.6 to -1.3)
30 days	1.2 (-2.1 to 4.5)	-4.2 (-8.2 to -0.2)	-7.5 (-10.8 to -4.2)	-3.8 (-5.9 to -1.7)
90 days	5.5 (0.8 to 10.3)	-5.3 (-10.1 to -0.4)	-10.7 (-14.9 to -6.5)	-5.0 (-7.9 to -2.2)

*All discharges (N=620 656) were included in the analysis. Covariates and two-way interactions adjusted for are listed in Appendix 6.3.
A negative number favors team-based primary care models.

Table 6.4 shows cause-specific adjusted hazard ratios (HR) estimated from marginal structural survival models for the relationship between enrolment in a multidisciplinary team-based PC model at index admission and readmission or ED

visits. Relative to patients enrolled in traditional PC practices, those in team-based PC had similar 30-day rates of readmission, 3% lower rates of ED visits and 5% lower rates of ED visits not associated with readmission. The HRs typically moved slightly towards the null value between the 30th and the 90th day after discharge, except for readmission rates which were 4% higher in patients enrolled in team-based PC (Table 6.4) by the end of the follow-up period.

Table 6.4 Adjusted cause-specific hazard ratios for the association between enrolment in multidisciplinary team-based PC at index admission and post-discharge outcomes

| Time since discharge | Adjusted hazard ratio (95% CI) | | | |
	Readmission	Post-discharge ED	Post-discharge ED not associated with readmission	Mortality
15 days	1.01 (0.96 to 1.04)	0.98 (0.94 to 1.01)	0.95 (0.91 to 0.98)	0.96 (0.92 to 0.99)
30 days	1.01 (0.96 to 1.04)	0.97 (0.93 to 1.00)	0.95 (0.91 to 0.98)	0.95 (0.92 to 0.98)
90 days	1.04 (1.00 to 1.07)	0.99 (0.95 to 1.02)	0.97 (0.92 to 1.00)	0.97 (0.93 to 1.00)

*All discharges (N=620 656) were included in the analysis. Covariates and two-way interactions adjusted for are listed in Appendix 6.3.

Figure 6.1 displays adjusted differences in 30-day cumulative incidence post-discharge outcomes by subgroup of patient morbidity level. Among patients in the lowest morbidity level (moderate morbidity), we found no significant differences on any of the post-discharge outcomes. Among patients classified in the high morbidity subgroup, slightly fewer patients enrolled in team-based PC died or returned to the ED within 30 days, and approximately 5 more patients per 1 000 discharges were readmitted if they were enrolled in team-based PC. Small differences in mortality rates were also observed among patients in the highest morbidity subgroup, and we found that approximately 10 fewer patients (per 1000 discharges) enrolled in team-based PC practices returned to the ED if their morbidity level was very high (Figure 6.1).

Figure 6.1 Adjusted* difference in 30-day cumulative incidence of post-discharge outcomes between team-based and non-team-based PC delivery models, by morbidity level
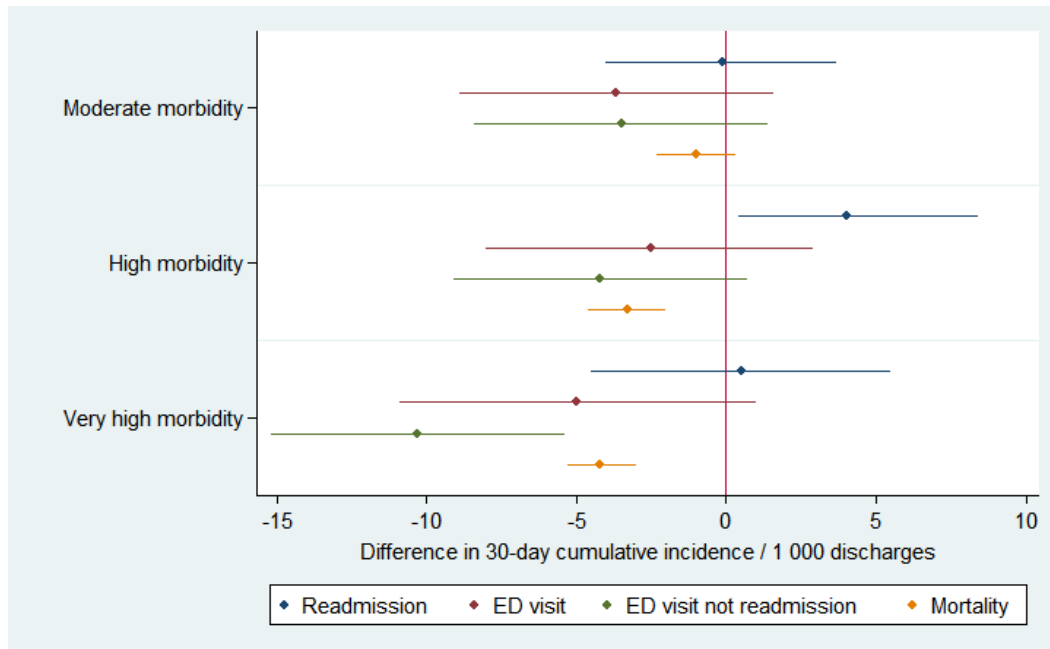
Notes: Horizontal lines represent clustered 95% CIs. Vertical line represents null association.
*Covariates and two-way interactions adjusted for are listed in Appendix 6.3.
A negative number favors team-based primary care models.

6.9 Discussion

In our study, approximately 1 in 4 elderly or chronically ill patients hospitalized for any cause returned to the hospital within 30 days of discharge (including readmission and ED visits). Patients enrolled in team-based PC practices had 5% lower rates of 30-day ED visit not associated with readmission, and significantly fewer patients died in the early period after hospital discharge compared to patients enrolled in traditional PC practices. The strength of these associations diluted beyond 30 days after discharge. We did not find that newer team-based PC delivery models were associated with lower rates of readmission within 30-days. In fact, rates of readmission were on average higher by 4% among patients enrolled in team-based practices over the complete 90 days of follow-up after discharge. These results varied somewhat by patient morbidity subgroup. Notably, the lower 30-day rates of ED visits and mortality associated with enrollment in team-based PC were predominantly observed among patients within the highest morbidity subgroup.

For the elderly or the chronically ill, the post-discharge period is a time of vulnerability due to age or due to the complexity of care, which often involves multiple chronic conditions and multiple care providers. Our findings that the

general population of elderly or chronically patients is at high risk of both readmission and post-discharge ED visits (1, 42) highlight the need to address potential failures and barriers in the coordination of care of elderly or chronically ill patients, which may include an overstressed primary care system, lack of electronic medical records spanning across settings, lack of financial incentives and poor integration of care across settings. (43)

Several factors or mechanisms may influence rates of readmission, ED visits, and mortality, including patient- (e.g. severity of illness), physician- and community-level factors that are not captured in administrative health databases. Unmeasured differences in case-mix across PC delivery models that are being compared in this study may have biased our analytical results, i.e. FMG practices may enrol patients with less functional limitations or with lower severity, which in turn would make them appear to perform better based on mortality rates and other post-discharge outcome measures. To minimize the risk of residual confounding, we effectively balanced measured covariates which we believe to be reasonable proxies for patient health status and severity at index admission, and we modeled covariates, time-dependent effects and interactions flexibly (e.g. restricted cubic splines). Further, physician participation and patient enrolment in PC models depends largely on physician preferences and characteristics (e.g. physicians who joined FMGs have less years of practice), which may in turn affect the way patients are managed in an outpatient setting. (44) The use of IPW based on measured physician and patient characteristics at index admission may have accounted for this selection bias to some degree, but not completely.

In the absence of unmeasured confounding, that team-based PC practices are associated with lower mortality rates but not with readmission rates may suggest that FMG practices keep their sickest patients alive longer, which in turn increases their likelihood of being readmitted. (45) This hypothesis is consistent with lower mortality rates that occurred predominantly among patients within higher morbidity subgroups, and with higher rates of readmission among FMG patients which occur later in the follow-up period rather than earlier. However, in this study, the sub-distribution cumulative incidence functions and the cause-specific hazard ratios

were qualitatively similar, suggesting that competing events (such as mortality) played a minor role in driving associations with readmissions and other post-discharge care encounters. (46, 47)

That lower rates of post-discharge ED visits and mortality associated with newer team-based PC practices occurred primarily in the highest of the health care system users may suggest that nurses and physicians practicing in a FMG achieve better results on the coordination of care for the highest users. In a parallel study, we report that rates of post-discharge follow-up by a primary care physician were higher among very highly morbid patients enrolled in a FMG, which is consistent with the above hypothesis. (48) Nurses practicing within primary care teams likely play a role in providing follow-up services in the post-discharge period, but this information is not captured in Quebec administrative health databases. Although early evaluations of Quebec primary care reforms highlighted important variations in how interdisciplinary collaboration was implemented in FMGs, (49) the roles and tasks of nurses in the design of the FMG program include systematic follow-up and case management for patients with complex medical needs. Future research should investigate the role played by primary care nurses for recently discharged patients. In addition, because post-discharge follow-up by nurses was not specifically addressed in the FMG policy, this may represent a potential intervention point to further impact patient outcomes and cost of care.

Finally, this is the first study to examine patterns of readmissions and other post-discharge events in the context of system-level efforts to transform primary care delivery. Results from other studies that examined practice-level (or *bottom-up*) innovations implemented locally and with greater intensity may provide insight into future policy targets to scale up Canadian reforms. In the US, many of the primary care practices studied thus far that undertook transformation for enhanced care coordination within the Patient Centered Medical Home framework were found to have significantly lower readmission rates. (50-54) These often included case management, multidisciplinary teams, and post-discharge follow-up. Accordingly, strategies for care coordination examined in recent systematic reviews and meta-analyses of randomized controlled trials also found that involving more individuals

in post-discharge care delivery (e.g. multidisciplinary teams or care managers) as well as supporting patient capacity for self-care led to significant reductions in hospital admissions or readmissions. (25, 55) A compilation of studies also found that post-discharge follow-up was associated with reductions in readmission rates, (56-61) including one conducted by our research team highlighting particularly important reductions if follow-up was provided in a timely manner in a primary care setting. (62) Consistent with our results, the evidence on newer team-based PC models in Canada have pointed to small improvements in health utilization measures (not specifically in the post-discharge period), mainly on lower rates of hospitalizations and ED visits among elderly or chronically ill patients, and some improvements in processes of care. (63-67)

6.10 Limitations and Strengths

As discussed above, the causal interpretation of our results is tempered by potential sources of bias, most notably by unmeasured confounding due to severity of illness and functional limitations of patients and by selection bias due to physician preferences and practice behaviors. Our study has several methodological strengths. We used information from more than 600 000 admissions that occurred from 2002 to 2009. The large database of patients used in this study likely reflects the population of elderly or chronically ill patients in Quebec who visited a primary care physician, which greatly improves the generalizability of our findings. We also used methods to address various biases, including selection and collider-stratification bias with IPW, and model misspecification using flexible modelling of covariates and time-dependent effects.

6.11 Conclusion

Our results suggest that existing team-based PC delivery models in Quebec are associated with better patient outcomes in the post-discharge period, notably for ED visits and mortality. This applies to the elderly or chronically ill patients, and these associations were found primarily for patients with very high morbidity. We did not observe differences in 30-day rates of readmission; however, rates of readmission seemed to be slightly higher among patients enrolled in team-based PC

practices beyond the 30-day timeframe, which may or may not be due to patients surviving longer in this group. The lack of any association between enrollment in team-based PC delivery models and readmission, and the lack of any differences for elderly or chronically ill patients in the lower spectrum of medical complexity suggest that more targeted or intensive efforts than what are currently deployed towards improving the care transition may be needed to yield further improvements in post-discharge outcomes among this patient population.

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APPENDICES

Appendix 6.1 Number of hospital admissions excluded with reasons

C.f. Appendix 5.1

Appendix 6.2 RAMQ definition of vulnerable patients by age or health condition in 2003

C.f. Appendix 5.2

Appendix 6.3 Statistical models

C.f. Appendix 5.5

Appendix 6.4 Description of inverse probability weights[*]

C.f. Appendix 5.6

Appendix 6.5 Standardized differences

C.f. Appendix 5.7

CHAPTER 7: CONCLUSION

7.1 Summary of Research

The goal of this thesis was to shed light on whether and how primary health care may contribute to improving health system performance in the period following hospital discharge, in particular in reducing hospital readmissions among elderly or chronically ill patients. The three manuscripts included in this thesis generated new knowledge relevant to policy in the context of primary health care reforms in Quebec and beyond, including: (i) on the opportunity area of outpatient physician follow-up as a strategy to effectively reduce hospital readmissions, and (ii) on how innovations in primary health care delivery implemented province-wide are associated with process and outcome measures of quality of care in the post-discharge period.

In addition to providing evidence of a large preventive effect of timely post-discharge outpatient follow-up, the results from the first manuscript contribute to a better understanding of how the timing, the type of setting (primary care or specialty care) and the target population modify this effect. Reductions in the risk of readmission were larger if follow-up was provided at least within 3 weeks of hospital discharge, and follow-up provided by a primary care physician was associated with larger reductions. This information may be useful to decision- and policy-makers interested in designing guidelines for the optimal delivery of outpatient follow-up to improve patient care and contain costs.

For the same population of elderly or chronically ill patients, the second and third manuscripts demonstrated that the 5-year population-averaged rates of post-discharge events (process and outcome measures of quality) in Quebec varied by whether patients were enrolled in new models of primary care delivery (i.e. FMG) or in traditional primary care practices. In the second manuscript, physician outpatient follow-up rates were similar among patients enrolled with an FMG and

in traditional practices. The overall results masked lower rates of follow-up with a medical specialist overall and higher rates of follow-up with a primary care physician for patients with high or very high morbidity. This description is consistent with the hypothesis that nurses practicing in FMGs provide a portion of the needed care to ensure a smooth transition from hospital to home, and potentially offset some of the physician follow-up services; however, reliable data on services provided by nurses are needed to test this hypothesis.

In the third manuscript, the results demonstrated slightly lower rates of return to the hospital within 30 days of discharge (readmission or ED visits) among patients enrolled in FMG practices; the lower rates were primarily observed for ED visits not associated with readmission and in patients with a very high morbidity burden. Interestingly, early post-discharge mortality was also lower among patients enrolled in FMGs, which is a desirable performance attribute provided that complete risk-adjustment was achieved. Patients surviving longer, however, are at a greater risk of readmission and ED visits, which needs to be kept in mind when comparing these outcomes across exposure groups. Given that post-discharge adverse events are common, costly and burdensome to patients, the results from the three manuscripts included in this thesis highlight room for improvement as well as actionable areas for research and for policy toward improving performance evaluation, patient care and health system costs associated with the inadequate management of care transitions.

7.2 Implications for Health Services Research

This research contributes to the advancement of the science and practice of health services research in a number of ways. I have demonstrated: 1) for the first time in the field that the implementation of time-specific propensity scores can handle the complex time-relationships of the exposure and of covariates appropriately; 2) that, when appropriate, inverse probability weights and marginal structural models may represent useful tools to address (to varying degrees) the various challenges in the analysis of large administrative health databases, including measured confounding, selection bias, collider-stratification bias, and non-collapsibility; 3) that the novel

application of flexible modelling of non-linear relationships using splines in the context of the care transition may improve our ability to make inference about quality of care, notably by including the time-dependency of the baseline hazard, of the exposure and of covariates to allow for smooth predictions in survival analysis and reduce the likelihood of model misspecification (thereby improving risk-adjustment); and finally 4) the novel application and illustration of flexible parametric survival models adapted to account for competing risks in this context may serve as a template for health services researchers to provide a valid and transparent profile of time-to-event process and outcome performance measures.

7.3 Implications for Practice and Policy

The findings presented in this thesis demonstrate that timely post-discharge follow-up represents one important strategy to prevent patients from re-entering the hospital system. The three-week critical time window to yield greatest reductions in the risk of readmission at the population level can also support best practice recommendations and/or serve as a basis of target for future policies. The timing effect, however, will also depend on the presence of other components of an ideal transition in care, for instance on the timeliness and accuracy of information transfer between the inpatient and the outpatient setting; other such components should be given full consideration in designing guidelines and policies. In addition, the large effect of outpatient follow-up when provided by a primary care physician rather than by a medical specialist serves to reinforce the role of primary health care in achieving better coordination of care. As such, post-discharge outpatient follow-up by a primary care physician may represent an area of opportunity for policies that enable this role.

The estimated absolute reductions in risk of readmission attributable to outpatient follow-up were larger with increasing morbidity level. Despite this, I encourage health decision-makers to keep in mind that efforts at preventing readmission targeting only patients with very high morbidity (or high-risk patients) may not necessarily yield greater reductions than a population-wide approach. Given that outpatient follow-up is feasibly implementable on a large scale and is highly

unlikely to cause harm, this raises the question as to whether a population-wide approach represents a more cost-effective strategy to prevent readmissions and improve quality of post-discharge care for the general elderly or chronically ill population.

Lastly, the associations found between new models of primary health care delivery and process and outcome measures in the period after discharge suggest that more targeted or intensive efforts than what are currently deployed towards improving the care transition are needed to achieve better performance in comparison to traditional practice organizations. Nevertheless, as the ability to draw inference about performance relies strongly on the capacity to risk-adjust, I encourage policy-makers in Quebec and elsewhere to work toward developing information technology capacity and easier access to data to enable researchers to account for additional sources of confounding (e.g. services provided by nurses, patient health status and functional limitations) and to elucidate the mechanisms underlying observed relationships.

7.4 Future Directions

This work highlights several future directions for health services research, in particular in the area of care transitions. First, the novel application of time-specific propensity scores, which appeared well-suited to study the timely effect of outpatient follow-up, could be further validated against assumptions of unmeasured confounding and other types of biases in a simulation study. Further, other health professionals (e.g. nurses and care coordinators) may contribute to some extent to ensuring a smooth transition from hospital to home. This information is typically not recorded in administrative health databases, and future work that could link these databases with electronic health records containing this type of information is needed. For valid health system performance measurement, the ability to link administrative health data with richer sources of information about patient health and functional limitations and patient care also represents an important goal for policy-makers and for researchers.

Particularly, future studies should assess the performance of team-based models of primary care delivery on timely outpatient follow-up with reliable information on the services provided by nurses practicing in primary care teams. Until such information is available, simulation techniques can help to understand the influence that improving timely post-discharge follow-up (e.g. with follow-up by nurse practicing in primary care) may have in the context of primary care transformations. In a working paper, I implement a novel approach to mediation analysis (stochastic mediation contrasts) to assess whether and to what extent targeted policy interventions aimed at improving timely post-discharge follow-up would influence the association between multidisciplinary team-based primary care practices and rates of post-discharge outcomes.

7.5 Conclusion

This work highlights the importance of the care transition as an area for research, policy and practice to work together to affect change. The competence of the health system to address failures in care transitions may lie in part in ensuring that primary health care delivery and organization aligns with the essential components of an ideal transition in care. In this regard, the evidence accumulated suggests that it is important to consider timely outpatient follow-up as a competence to be further developed. Existing innovations in team-based primary health care delivery models may also possess the necessary competence, although additional efforts are needed to determine whether this is actually the case, in particular in understanding the work that non-physician team members are providing in the post-discharge period. In this research, causal inference and flexible modelling methods represented useful tools to address analytical challenges and biases that conventional methods cannot address, and investigators may consider applying these techniques when appropriate to address their research question.

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