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Pneumococcal Vaccination of the Elderly During Visits to Acute Care Providers: Who Are Vaccinated?

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Pneumococcal Vaccination of the Elderly During Visits to Acute Care Providers:
Who Are Vaccinated?

by

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A THESIS

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Abstract

Objectives: To understand factors associated with pneumococcal vaccination in the elderly during visits to acute care providers.

Methods: We included all elderly 65 years of age and older enrolled in a health insurance registry in a large Canadian city. Pneumococcal vaccination status was determined using a vaccination administrative database. Unvaccinated elderly were linked to ambulatory and inpatient care databases to determine acute care visits. Logistic regression was used to determine odds ratios for vaccination during a first visit to an acute care provider in 2009.

Results: Of 53,249 unvaccinated elderly, 23,574 presented to at least one acute care provider in 2009. Acute care visits were significantly associated with receipt of PPV (11.0% vs. 7.8%, risk adjusted odds ratio [OR]=1.53; 95% confidence interval [CI]=1.44,1.62), particularly ambulatory care visits during influenza season (OR=4.36; 95% CI=2.86,6.66) and inpatient visits with lengths of stay >14 days (OR=7.71, 95% CI=4.41,13.47).

Conclusions: Acute care visits hold potential to increase PPV coverage in the elderly and were associated with greater pneumococcal vaccine uptake during the annual influenza season and long hospital stays.

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Dedication

To my parents for being strong role models and my wife Jaycee for her tireless support.

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List of Symbols, Abbreviations and Nomenclature

AH	Alberta Health
AHS	Alberta Health Services
PPV-23 or PPV	23-valent Pneumococcal Polysaccharide Vaccine
PCV-7	7-valent Pneumococcal Conjugate Vaccine
PCV-13	13-valent Pneumococcal Conjugate Vaccine
CHREB	Conjoint Health Research Ethics Board
ACCS	Ambulatory Care Classification System
AHCIP	Alberta Health Care Insurance Plan
CI	confidence interval
RR	risk ratio
DAD	Discharge Abstract Database
ICD	International Classification of Diseases
PHN	personal health number
IQR	interquartile range
GP	general practitioner
PHANTIM	Primary Health Activity Network & Timely Information

Chapter One: Study Objective and Significance

1.1 Objective

The objective of this study was to use Alberta's population-based administrative data sources to determine the number of unvaccinated elderly 65 years of age and older accessing ambulatory and inpatient care services in Calgary from April 1, 2009 to March 31, 2010 and to describe the factors associated with PPV vaccination in these acute care settings.

1.2 Significance

The elderly 65 years of age and older are at risk of invasive pneumococcal disease (IPD), a bacterial infection that causes significant morbidity and mortality. This risk persists despite the introduction of a seven-valent pneumococcal conjugate vaccine for young children in the early 2000s that has resulted in a decrease in IPD among the elderly due to an indirect herd effect.

The pneumococcal polysaccharide vaccine is safe and effective in protecting against IPD in the elderly, and is recommended for all adults 65 years of age and older by the Public Health Agency of Canada. National consensus PPV vaccination targets are 80% for all persons 65 years of age and older and 95% for residents of long-term care facilities. However, actual coverage rates are typically in the 40% to 60% range. With a growing proportion of elderly predicted in coming years and drug-resistant pneumococcal strains emerging, there is an urgent need to increase uptake of pneumococcal vaccination in the elderly.

The elderly typically receive PPV in the community from a primary care practitioner or public health provider. However, community-based PPV vaccination efforts have been suboptimal in reaching coverage rate targets. In addition to community-based vaccination, elderly frequently access acute care services and these visits represent additional opportunities to increase PPV coverage rates. Therefore we conducted this study using a large population-based dataset to explore whether acute care visits could increase PPV vaccination.

PPV vaccination in acute care settings has been researched in the United States and internationally. However, to the best of our knowledge, there are no published Canadian studies on the association between acute care visits and pneumococcal vaccination rates in the elderly, including factors associated with vaccination. In addition, previous research has had limited generalizability to the general population 65 years and older due to reliance on medical records and retrospective assessment of PPV vaccination among IPD patients.

This study will further our understanding of PPV vaccination in acute care settings in Calgary. Knowledge of baseline PPV coverage rates may lend urgency to current vaccination efforts. Understanding the factors associated with PPV vaccination of elderly presenting to acute care will help target interventions to bring coverage rates closer to national targets. In the future, pneumococcal conjugate vaccines for the elderly may become available. However, as with PPV, these new vaccines will only be effective when adequate population coverage is achieved, an aim informed by this study.

Chapter Two: Background

2.1 Invasive Pneumococcal Disease

2.1.1 Disease Description

Streptococcus pneumoniae (pneumococcus) is a gram-positive, facultative anaerobic bacteria first recognized in the late 1800s as a major cause of pneumonia. There are 90 known serotypes of pneumococcus, each serotype corresponding to a distinct arrangement of complex polysaccharides encapsulating the bacterium. Though all serotypes can cause human disease, only a few serotypes produce the majority of pneumococcal infections.¹

Pneumococcal bacteria enter the human body through the nose and mouth and commonly colonize the upper respiratory tract in winter and early spring.² The bacteria are spread from person to person by inhaling infected droplets dispersed by sneezing or coughing. After colonization the bacteria may persist in an asymptomatic or carrier state, be cleared by the body's immune system, or more rarely proceed to cause symptomatic infection. Clinical progression is driven by multiple factors related to the host, microorganism, and medical therapy.³

Pneumococcal infections fall into two categories. Non-invasive infections are most common and less serious, taking the form of mucosal infections such as bronchitis, acute otitis media and sinusitis or pneumonia. Pneumococcus is the leading cause of non-invasive community-acquired pneumonia for persons in Canada 65 years and older.⁴

Invasive infections, known as invasive pneumococcal disease (IPD), occur when *S. pneumoniae* is isolated from a normally sterile body site that is typically free of bacteria such as

blood or spinal fluid. Most commonly, IPD cases occur in the form of bacteremia (*S. pneumoniae* in the blood), bacteremic pneumonia (lung infection with *S. pneumoniae* also in the blood) or pneumococcal meningitis (infection of the tissues and fluid surrounding the brain and spinal cord). More than 90% of IPD infections involve bacteremia with the remaining infections affecting the meninges. Invasion of other body sites such as the bones (osteomyelitis) and joints (septic arthritis) occurs more rarely.⁵

IPD is a serious illness requiring urgent medical care. Once in the blood or cerebrospinal fluid, pneumococcal bacteria can multiply and disseminate rapidly leading to sepsis, coma and death. Treatment involves empirical antibiotics after consideration of local resistance patterns, with more targeted therapy following laboratory testing for bacterial susceptibility.⁶

2.1.2 Risk Factors

Individuals with a weakened immune system or compromised integrity of the lower respiratory tract are at increased risk of IPD. Incidence rates of invasive pneumococcal disease are therefore highest in young children, the elderly and those with chronic health conditions or taking immunosuppressive medications.⁷ In developing countries the largest burden of disease is carried by young children while in the developed world, it is the elderly who are at greatest risk of morbidity and mortality from IPD.⁸

Medical conditions that increase the likelihood of IPD in all individuals but particularly in the elderly include pulmonary disease, cardiovascular disease, diabetes mellitus, chronic renal failure, chronic liver failure, malignant neoplasms including leukemia and lymphoma, multiple myeloma, HIV infection, anatomic or functional asplenia and sickle cell disease.⁹ Additional risk

factors associated with IPD infection include race, low socioeconomic status, preceding viral respiratory tract infections, overcrowding such as may occur in group care settings and behavioural risk factors such as smoking and alcoholism.^{10,11}

2.2 Epidemiology of IPD in the Elderly

2.2.1 North America

Reported incidence of IPD varies widely in epidemiological studies due to multiple factors including variable rates of obtaining blood cultures from patients with pneumonia, administration of antimicrobials prior to culturing the bacteria and variations in surveillance methods.³ However, general trends in epidemiological estimates can be observed.

Introduction of the seven-valent pneumococcal conjugate vaccine, PCV-7, for young children in the early 2000s has resulted in a decrease in incidence of IPD among the elderly due to the vaccine's effectiveness in reducing pneumococcal carriage and transmission in a population. In the United States from 1998 to 2003, Lexau et al. estimated a 53% to 62% reduction in mean incidence of IPD in elderly 65 years and older due to the seven vaccine serotypes found in PCV-7.¹² In Calgary, Alberta from 1998 to 2007 Kellner et al. found a 78% reduction in incidence of IPD due to PCV-7 serotypes in elderly 65 to 84 years of age.¹³ However, despite this public health achievement, IPD due to non-PCV-7 serotypes continues to have an impact on the elderly and there remains in North America an estimated 21 to 43 cases of IPD per 100,000 persons 65 years of age and older.¹⁴ These rates represent between 15,000 and 30,000 cases of bacteremia and meningitis annually among North American elderly.^{5,14}

Pneumococcal infections cause significant morbidity and mortality in North America. Of all age groups, mortality for IPD is highest in the elderly with nearly 1 in 5 cases over the age of 65 resulting in death with increasing age being associated with greater mortality.^{15,16} Though persons aged 65 and older in the United States account for roughly 30% of all IPD cases, they represent 55% of all IPD case fatality.⁵ Case fatality ranges from 16% for elderly 65 to 80 years of age to greater than 20% for elderly over the age of 80.^{17,18}

A population-based study in the United States from 1989 to 1998 estimated 38 deaths per 100,000 population in individuals over the age of 85 though a decreasing trend in mortality was noted over the 10-year period.¹⁹ This decrease in mortality rates has continued from 1990 to 2005, in part due to the introduction of PCV-7, with a 38 to 44 percent decrease in IPD mortality rates between the two periods 1990 to 1998 and 2001 to 2005.²⁰

Pneumococcus strains that are less susceptible to penicillin and other antimicrobials are becoming increasingly common.²¹ High-fatality rates and the emergence of drug-resistant pneumococcal strains demonstrate the importance of preventing pneumococcal infections through vaccination.

2.2.2 Canada

In Canada, IPD has been nationally notifiable since 2000 leading to more accurate reporting of incidence rates. IPD surveillance data is collected federally through the Canadian Notifiable Disease Surveillance System (CNDSS) and the Immunization Monitoring Program, ACTIVE (IMPACT) for pediatric cases. From 2005 to 2010, CNDSS reported rising incidence

rates of IPD in the elderly aged 60 years and older from 20.4 cases per 100,000 in 2005 to 23.2 cases per 100,000 in 2010 (Table 1).

Table 1. Reported incidence per 100,000 population of IPD in Canada for adults 60 years and older, 2005-2010

	Reported Cases of IPD	Incidence Rate per 100,000
2005	1173	20.4
2006	1132	19.1
2007	1271	20.7
2008	1369	21.5
2009	1475	22.4
2010	1573	23.2

Data from the Canadian Notifiable Disease Surveillance System²²

Though decreased IPD incidence rates in the elderly in the United States have been observed since the advent of PCV-7 for children in the early 2000s,²³ Canadian IPD incidence rates in the elderly have not shown a corresponding decrease. Possibilities for this finding include increased provincial and national surveillance and trends in testing and treatment protocols such as clinical thresholds for ordering blood cultures. However, other factors such as antimicrobial resistant strains may play a role. Use of PCV-7 has been shown to cause non-vaccine pneumococci replacement, altering the distribution of pneumococcal serotypes in the nasopharynx and potentially contributing to antibiotic resistance.²⁴

IPD-associated mortality for the elderly is similar in Canada and the United States. A review of pneumococcal bacteremia cases at two Canadian tertiary care centers found case

fatality to be greater than 30% for those older than 70 years, reaching as high as 43% in those older than 80 years, despite antimicrobial treatment and intensive care support.²⁵ The mean length of hospital stay for all adults was three weeks implying a similar or longer stay for the elderly. Given Canada's aging demographic, it is reasonable to anticipate that the public health impact of IPD may increase in coming years.²⁶

2.2.3 Alberta

In the province of Alberta, public health reporting of all invasive pneumococcal disease began in 1998. From 1998 to 2003, 1,774 cases of IPD were reported for all ages with a similar case rate in 2001 to 2003.⁹ The introduction of pneumococcal conjugate immunization for infants in Alberta in 2002 led to a prompt and large decline in the incidence of IPD in children <2 years of age. Correspondingly, there has also been a decline in the incidence of IPD in adults 65 years and older caused by the seven serotypes found in the children's conjugate vaccine.¹³

2.2.4 Calgary

The Calgary Area Streptococcus pneumoniae Epidemiology Research (CASPER) group began prospective population-based surveillance of IPD for all ages in Calgary beginning in 1998. From 2003 to 2007 incidence of IPD in seniors 65 to 84 years of age in Calgary was estimated at 24 cases per 100,000 person-years for all years combined, higher than the Canadian average.¹³

2.3 Pneumococcal Polysaccharide Vaccine

2.3.1 Efficacy

There are two types of pneumococcal vaccines authorized for use in Canada. A 7-valent conjugate vaccine (PCV-7) approved for children from 6 weeks to 9 years of age and a 23-valent polysaccharide vaccine (PPV-23) for adults at risk of pneumococcal disease including the elderly. PPV-23, hereafter termed PPV, contains capsular polysaccharides from each of 23 different types of pneumococci known to cause approximately 90% of pneumococcal bacteremia and meningitis.⁸

A single dose of PPV stimulates an antibody response to the 23 pneumococcal serotypes. Though evidence indicates it is doubtful PPV can provide protection against non-bacteremic pneumonia in the elderly,^{27,28} the vaccine has been demonstrated through meta-analyses to be effective against IPD in this age group.^{29,30} In healthy young adults with strong immune systems, serotype-specific protection against IPD can surpass 80% efficacy, while for the elderly efficacy declines with age and is typically in the range of 50% to 80%. In elderly with chronic medical conditions and suppressed immune systems, efficacy may be lower. The level of vaccine-induced pneumococcal antibody that correlates with protection against IPD has not been established nor has the duration of conferred immunity though antibody levels are believed to decline 5 to 10 years after vaccination.⁸ The vaccine is not effective against serotypes not represented in the vaccine.³¹

2.3.2 Safety

PPV is a safe vaccine with the most common vaccine-related adverse experiences being tiredness, muscle aches and chills which occur in approximately 1 in 5 adults. The incidence of vaccine-related systemic adverse experiences was less than 5% and included myalgia (2%), fatigue (1%) and headache (1%). Deaths or vaccine-related serious adverse experiences are exceedingly rare and have seldom been documented.³²

2.3.3 Cost-Effectiveness

Several studies have shown that PPV is a cost-effective intervention against IPD in the elderly.^{33,34} The Public Health Agency of Canada emphasizes that PPV for adults 65 years and older is, contrary to many other medical interventions, a cost-saving measure resulting in a net savings of seven dollars per life year saved. This can be compared to pneumococcal conjugate vaccination for children which is estimated to cost \$125,000 per life year saved and annual screening for cervical cancer which costs \$40,000 per life year saved.⁸ A cost-effectiveness study in Belgium demonstrated that vaccinating 1000 elderly people 65 years and older leads to greater than 9 life-years gained as well as a monetary benefit.³⁵ Other studies in the United States have demonstrated similar net savings from between \$141 to greater than \$6,000 per life-year gained.³⁶

2.3.4 Conjugate Vaccine Alternatives

The pneumococcal polysaccharide vaccine has been noted to have lower efficacy and shorter duration of protection against IPD compared to conjugate vaccines. In 2011, a 13-valent

pneumococcal conjugate vaccine (PCV-13), previously licensed by the Food and Drug Administration and endorsed by the Advisory Committee on Immunization Practices (ACIP) for children aged 6 weeks through 71 months, was licensed in the United States for adults 50 years and older.³⁷ PCV-13 was shown to have a similar safety profile to PPV-23. Although PPV is still the recommended vaccine by ACIP to protect against IPD in the elderly, PCV-13 is now available as an alternative.

Conjugate vaccines for the elderly have yet to be licensed for use in Canada but may be on the horizon. It is important to note, however, that conjugate vaccine are often more costly, require repeated doses and protect against a fewer number of serotypes.³⁸ Because a broader range of serotypes is implicated in IPD in the elderly compared to children, dependence on only a conjugate vaccine has the potential to leave elderly exposed to non-vaccine serotypes.^{39,40}

2.4 PPV Vaccination of the Elderly

2.4.1 Recommended Vaccination Coverage

Due to its proven efficacy, safety and cost-effectiveness, PPV has been widely recommended for all elderly to protect against IPD. Both the Advisory Committee on Immunization Practices in the United States and the Public Health Agency of Canada's National Advisory Committee on Immunization have recommended the vaccine since the late 1990s to protect against IPD for all persons 65 years and older.^{41,8}

Target PPV vaccination rates, also known as PPV vaccine coverage rates or PPV vaccination prevalence, have long been established in North America and are calculated as the number of individuals vaccinated divided by the number of individuals indicated to receive the

PPV vaccine. The United States' Health People 2020 target currently calls for 90% of all persons 65 years and older to be vaccinated with PPV.⁴² In Canada, the latest National Consensus Conference targets for PPV coverage are 80% for all persons 65 years of age and older and 95% for residents of long-term care facilities.⁴³

2.4.2 Gaps in Coverage

Unfortunately, despite public health's promotion of PPV for over a decade, uptake of PPV vaccination remains poor, consistently in the 40% to 60% range across North America. A study from the Center for Disease Control in the late 1990s found that all 50 states failed to reach a pneumococcal vaccination level greater than 60% among elderly aged 65 years and older.⁴⁴ A Florida state study found vaccine coverage rates as low as 30% in persons 65 years and older.⁴⁵ An analysis of neighborhood health clinics in Ohio found that 64% of elderly black men and women, aged 70 and older, were vaccinated with PPV.⁴⁶

Pneumococcal vaccination in the United States has improved somewhat since the late 1990s, with a national health study indicating PPV vaccination rates among individuals 65 years and older increased from 14% in 1989 to 60% in 2008.⁴⁷ Nevertheless, these improved coverage rates continue to lag behind national targets. A 2006 study of United States veterans more recently found vaccination rates continuing to fall short of Healthy People targets.⁴⁸ In a United Kingdom study, the same pattern was observed with even high risk individuals such as patients with splenic dysfunction, chronic heart disease, chronic respiratory disease, chronic renal disease and the immunosuppressed not being satisfactorily immunized.⁴⁹

In Canada, universal PPV vaccination programs for the elderly were introduced across the country in the late 1990s.⁵⁰ Since then, PPV vaccination rates have been similar to those in the United States, improving steadily over the years yet remaining suboptimal. In Canadian long-term care facilities, a 2001 study that 71% of residents were vaccinated with PPV.⁵¹ More recently, a 2006 national adult immunization survey found only 39% of elderly 65 years and older were vaccinated with PPV in the general population.⁵²

2.4.3 Factors Associated with Vaccination

The elderly typically receive PPV in the community from a primary care practitioner or public health provider. However, suboptimal PPV vaccination rates across North America indicate community-based vaccination efforts need to be enhanced or complemented. Improving vaccination programs requires an understanding of the diverse factors associated with receipt or lack of receipt of PPV vaccination in the elderly. These factors are often specific to each epidemiologic setting and may be divided into patient factors, health care provider factors and health system factors.

In a national study of 16,000 Medicare beneficiaries in the United States, the most common causes for not receiving PPV were not knowing vaccination was needed followed by lack of physician recommendation.⁵³ Awareness of PPV among the elderly is generally poor with one study indicating only 13% of high-risk elderly with consecutive admissions to an acute geriatric unit had heard of pneumococcal vaccine.⁵⁴ Physicians' low priority for PPV vaccination and difficulty in determining long-term care residents' vaccine history were cited as reasons for not receiving PPV in a Washington state nursing home.⁵⁵

Increased likelihood of receiving PPV has also been studied. In one survey of elderly in the United States from 1989 to 2008, characteristics independently associated with ever receiving PPV were higher age, female, non-Hispanic white race/ethnicity, not employed, higher education level, more physician visits in the past year, hospitalized within past year, having Medicare and other supplemental health insurance, and having a chronic medical condition.⁴⁷ In a study from Iowa, factors associated with PPV and influenza vaccination in the elderly were age 70 or greater, married, self-owned residence, working, increased number of high-risk medical conditions, current prescription medication and a physician visit in the last year.⁵⁶ In a third study from the United States, factors associated with PPV vaccination in high-risk elderly were health care providers' recommendations and patients' positive attitudes toward immunization.⁵⁷

The importance of epidemiologic context for determining factors associated with vaccination in the elderly explains why, for example, there is conflicting evidence regarding the role of ethnicity in obtaining PPV immunization. While some studies indicate a lack of ethnic disparity in PPV immunization among elderly patients in an urban care setting,⁵⁸ in other studies from different geographic areas, racial and ethnic minorities have been identified as having a significant difference in likelihood of PPV uptake.^{59,60}

A strong theme in the literature was the association between physician recommendation for PPV vaccination and receipt of the vaccine in the elderly 65 years of age and older. An international systematic review noted that recommendations by doctors play a central role in promoting pneumococcal vaccination.⁶¹ Ehresmann et al. highlight patient awareness of PPV and physician offering PPV as factors associated with PPV vaccination.⁶² Nowalk et al. report higher self-report PPV vaccination in patients whose physicians recommended the vaccine.⁶³ A

Canadian adult immunization coverage survey noted that while all immunizations are known to be positively linked to a medical recommendation, this is especially so in the case of pneumococcal immunization with 93% of individuals who had such a recommendation reporting they received pneumococcal immunization.⁵²

However, seeing a physician or public health professional in a community setting only has not been sufficient to elevate PPV coverage rates towards national targets. Hoover, Sambamoorthi and Crystal used National Health Interview Surveys in the United States to describe self-reported lifetime pneumococcal vaccination among >10,000 community dwelling elderly.⁶⁴ They inferred that about 13 million (45% of) community dwelling elderly were unvaccinated against pneumococcus including 11.4 million who saw a doctor at least once. Lack of a usual source of healthcare and lower frequency of physician visits were factors for not being vaccinated with PPV in a large self-report study from the United States.

2.5 Acute Care Visits and PPV Vaccination

Elderly may receive PPV in the community from a primary care practitioner or public health provider. However, current suboptimal PPV coverage rates indicate that community-based PPV vaccination efforts need to be enhanced or complemented. Interventions to improve PPV coverage in the community have demonstrated some success.^{65,66} Nevertheless, elderly are also known to frequently access acute care services and these acute care settings represent additional opportunities to vaccinate susceptible elderly. Acute care visits, defined as hospital stays or ambulatory care visits without admission to hospital such as a visit to an emergency department, may complement community-based PPV vaccination efforts.

A number of research studies have explored the relationship between acute care visits and PPV vaccination including factors associated with vaccination in these settings. All of these studies identified frequent missed opportunities to vaccinate the elderly with PPV during acute care visits.

2.5.1 United States Research

Kyaw et al. examined PPV vaccination of IPD patients using surveillance data from the Centers for Disease Control for six states in the United States.⁶⁷ They defined missed opportunities as one or more visits to a hospital, emergency room or main provider in the 2 years before infection among unvaccinated, adult IPD case-patients with a vaccine indication. They found that >80% of IPD patients had an indication to receive PPV but 52% were unvaccinated prior to admission for IPD. Of these unvaccinated adults, 92% had one or more opportunities for vaccination, 54% had been hospitalized and 58% had emergency room visits during the two years prior to their illness. Factors associated with being vaccinated during the 2-year period included elderly 65 years and older versus adults 18 to 49 years of age (OR=2.57, 95% CI=1.92,3.44), white race, presence of health insurance, at least one opportunity for vaccination (OR=8.32, 95% CI=3.54,19.55), at least one hospitalization (OR=1.74, 95% CI=1.37,2.21), and at least one emergency room visit (OR=1.44, 95% CI=1.13,1.83).

A study by Houck, Lowery and Praeli of Medicare pneumonia inpatients in twelve western United States showed that only 0.4% of susceptible individuals were given pneumococcal vaccination during hospitalization.⁶⁸ Though this study did not exclusively look at elderly with IPD, it noted that of the patients with no evidence of pneumococcal vaccination for

the four years prior to admission, 67% had a least one chronic condition associated with a possible increased risk for serious pneumococcal infection.

Greci, Katz and Jekel completed a retrospective chart review of all pneumonia patients, though not exclusively IPD patients, at a community hospital in the United States over a one-year period.⁶⁹ Out of 173 admissions, vaccine histories were documented in the hospital chart for less than 0.5% of patients. Though 97% of patients had indication for PPV, no vaccines were given in hospital.

Petersen, Saag, Wallace and Doebbeling conducted interviews of 787 urban and rural Iowa adults 65 years and older with one or more self-reported risk factors for IPD.⁵⁶ One half reported ever receiving PPV with factors associated with vaccination including age 70 or greater (OR=1.64, 95% CI=1.15,2.32), married, self-owned residence, working, increased number of risk factors, current prescription medication, and a physician visit in the last year (OR=2.53, 95% CI=1.52,4.19).

Splenectomy is a risk factor for bacteria sepsis and IPD and a strong indication for PPV vaccination. In a peri-splenectomy study by Kind et al. they found that 70% of patients 65 years and older had been vaccinated with PPV.⁷⁰

2.5.2 International Research

Parsons et al. conducted a retrospective cohort study of IPD patients in the United Kingdom at two teaching hospitals over an 8-year period.⁷¹ They found that only 8% of patients who had an indication for PPV vaccination were vaccinated despite a high prevalence of medical

comorbidities associated with risk of IPD. Only 1 patient was vaccinated out of 33 who were 65 years and older with no additional risk factors.

Two peri-splenectomy studies by Ejstrup, Hansen and Andreassen in Norway⁷² and Siddins et al. in Australia⁷³ examined in-hospital vaccination following spleen removal. Ejstrup et al. found that 62% unvaccinated adults had been vaccinated with PPV in association with splenectomy and Siddins et al. found that only 11% of adult patients who underwent incidental splenectomy were vaccinated in hospital.

2.5.3 Advantages of Current Study

Previous studies have lacked generalizability to the general population 65 years and older due to their reliance on medical records and retrospective assessment of PPV vaccination among IPD patients. These studies have also been performed outside of a Canadian context. These limitations and the advantages of our study are discussed below.

Research to date has used medical charts to assess PPV vaccination occurring in an acute care setting. Receipt of PPV is likely underestimated because vaccination is often not well documented in medical charts.⁷⁴ This study uses administrative data only, assessing vaccination status from public health records pre and post an acute care visit.

Previous studies have also focused on patients with IPD in an acute care setting, retrospectively assessing for missed opportunities to receive PPV. IPD patients may represent high-risk elderly with characteristics that differ from the general population 65 years of age and older. This large, population-based study captures all elderly in the city of Calgary regardless of

risk profile, therefore describing vaccination coverage and characteristics for all elderly in Calgary.

Lastly, to the best of our understanding, there has been no published research looking at population-based associations between acute care visits and pneumococcal vaccination in the elderly. There has also been no Canadian research examining factors associated with PPV vaccination in acute care settings. Lastly, the PPV coverage rate calculated from this study is the first known estimate of cumulative PPV coverage for urban Calgary elderly ≥ 65 years.¹³

2.6 Summary and Overview of the Study

There is an urgent need to increase uptake of pneumococcal vaccination in the elderly to protect against invasive pneumococcal disease. Specifically, IPD continues to cause a high burden of disease in the elderly, a growing proportion of elderly are predicted in coming years, drug-resistant pneumococcal strains are emerging and pneumococcal conjugate vaccines are on the horizon but, like the current pneumococcal polysaccharide vaccine, will only be effective with adequate population coverage. PPV is known to be safe, efficacious and cost-effective in protecting the elderly against IPD.

In addition to community-based vaccination, elderly frequently access acute care services and these visits represent additional opportunities to increase PPV coverage rates towards national targets. Therefore we conducted this study using a unique, large population-based dataset to explore whether acute care visits could increase PPV coverage rates. Our research has a methodological advantage over previous studies by not relying on medical records and

capturing all elderly regardless of risk profile therefore lending to generalizability to the general population 65 years and older.

The purpose of this study is to use Alberta's population-based administrative data sources to determine the number of unvaccinated elderly 65 years of age and older accessing acute care services in Calgary and to describe the factors associated with PPV vaccination in these acute care settings. The study hypotheses were that many elderly access acute care, opportunities for PPV vaccination in these acute care settings are being missed and factors associated with vaccination can be identified. Understanding the factors associated with PPV vaccination for all elderly presenting to acute care will help target interventions to bring coverage rates close to national targets.

Chapter Three: Methods

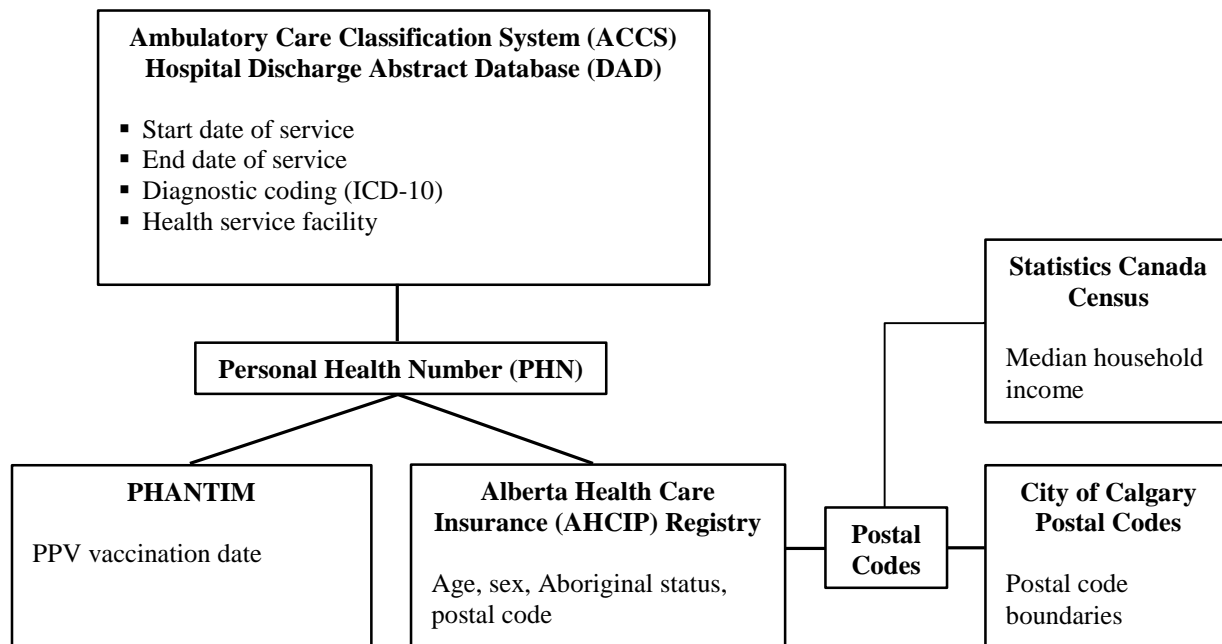
3.1 Study Design and Period

We used a retrospective cohort design to assess PPV vaccination among elderly 65 years and older before and after visiting acute care providers in the city of Calgary during the fiscal year 2009 (April 1, 2009 to March 31, 2010). The design linked Alberta's health care insurance registry, ambulatory care database and hospital discharge abstract database for fiscal year 2009 (April 1, 2009 to March 31, 2010) with public health vaccination data for the city of Calgary (January 1, 1998 to March 31, 2012) via unique personal health numbers.

3.2 Data Sources and Linkages

The data sources, their elements and linkages are shown in Figure 1. The Alberta Health Care Insurance Plan (AHCIP) registry, Ambulatory Care Classification System (ACCS), Hospital Discharge Abstract Database (DAD) and PHANTIM public health vaccination database were linked by personal health number. Median household income derived from the 2006 Statistics Canada census and geographic postal code boundaries for the city of Calgary were linked to the AHCIP registry using postal codes. The following is a description of these data sources, the data elements accessed and the database linkages.

Figure 1. Data Sources, Elements and Linkage



3.2.1 Alberta Health Care Insurance Plan Registry

The Alberta Health Care Insurance Plan Registry maintained by Alberta Health contains demographic information including personal health number (PHN), age, sex, aboriginal status and postal code for all residents enrolled in the provincial health insurance plan. Canada has a government-financed universal health care insurance system resulting in a low opt-out rate for the provincial insurance plan (<1%).

The AHCIP registry was used to identify all elderly 65 years and older enrolled in the provincial health insurance plan on April 1, 2009. This population was linked to the Ambulatory Care Classification System (ACCS), Hospital Discharge Abstract Database (DAD) and PHANTIM public health vaccination databases by PHN.

3.2.2 PHANTIM Public Health Immunization Database

The Primary Health Activity Network & Timely Information (PHANTIM) public health immunization database maintained by Alberta Health Services' Calgary Zone public health contains vaccination data for the city of Calgary and the surrounding towns of Cochrane and Airdrie. PHANTIM was used to identify the date of PPV vaccination for each individual.

Recording of PPV vaccination in Alberta began in 1998, the first year a single lifetime dose of pneumococcal polysaccharide vaccine became publicly funded. All health care providers, including primary, acute care and public health practitioners, are required to report PPV vaccine used. Prior PPV vaccination outside Alberta is recorded in PHANTIM when reported by physicians and patients. PPV received prior to 1998 was coded as occurring in 1998 if reported by a patient or provider.

As a publicly-funded resource, supply of PPV to community and acute care providers in Calgary is tightly controlled by public health and contingent on accurate reporting of vaccine use. All administered doses of PPV must be reported to public health including client identification and date of vaccination. As a result, public health vaccination records for the city of Calgary are considered complete and representative of PPV usage from a face validity perspective, though actual validation of the PHANTIM database has yet to be performed through precise data collection.

3.2.3 Ambulatory Care Classification System

The Ambulatory Care Classification System (ACCS) maintained by Alberta Health Services contains information for all patient visits to government-funded facilities in Alberta

including all encounters at emergency departments, outpatient clinics operated from acute care facilities and day procedure facilities. Diagnostic imaging services are included if they are the only service provided while clinical laboratory procedures are excluded. The ambulatory care database does not include patient visits to family physicians in the community. Administrative, demographic and clinical data for ACCS is extracted from patient charts by coders using a uniform protocol. Data elements obtained from ACCS included the start and end date of service, diagnostic codes (up to 10 using the International Classification of Diseases ICD-10 coding) and the health service facility visited.

3.2.4 Discharge Abstract Database

The Alberta Discharge Abstract Database (DAD) maintained by Alberta Health Services contains information on all inpatient stays at acute care facilities in Alberta from admission until patient separation (discharge or death). Administrative, demographic and clinical data for ACCS is extracted from patient charts by coders using a uniform protocol. Data elements obtained from DAD included the start and end date of service, diagnostic codes (up to 10 using ICD-10 coding) and the health service facility visited.

3.2.5 Statistics Canada Census

The 2006 Statistics Canada national census²⁶ collects median household income by dissemination area, the smallest standard geographic unit in Canada. The postal code conversion file was used to link multiple dissemination areas in the census data to postal codes in the administrative data using a single link indicator. The single link indicator identifies the

geographic area with the majority of dwellings assigned to a particular postal code. Median household income by postal code was then linked to individuals in the AHCIP registry by postal code.

3.2.6 City of Calgary Postal Codes

The geographic boundaries of the city of Calgary by postal code were used to identify the study population of all elderly 65 years and older living in the city of Calgary on April 1, 2009.

3.3 Study Population

3.3.1 Inclusion Criteria

The study population was all adults in the AHCIP registry who were 65 years of age and older on April 1, 2009 and living in the city of Calgary as determined by metropolitan postal code boundaries. Unvaccinated or susceptible elderly, our population of interest, were members of the study population who had not received PPV from 1998, the first year of public funding for the vaccine, to 2008. Vaccinated elderly, the complement of the unvaccinated group, were also analyzed as a separate population.

3.3.2 Exclusion Criteria

Three percent of the study population was excluded due to patient death or migration out of Alberta during the study period of fiscal year 2009 (April 1, 2009 to March 31, 2010). Contraindication to PPV was not a criterion for exclusion as the only absolute contraindication to vaccination is an anaphylactic reaction to a previous dose.⁴

3.4 Study Variables

3.4.1 Dependent Variable

The outcome variable was vaccination (yes, no) with the pneumococcal polysaccharide vaccine (PPV) from April 1, 2009 to March 31, 2010 as recorded in PHANTIM. A single lifetime dose of pneumococcal polysaccharide vaccine became publicly funded in Alberta in 1998 and is indicated for all individuals 65 years of age and older.¹³ PPV vaccination is administered by Alberta Health Services for the city of Calgary, Alberta, a metropolitan center with a population of 1.2 million. The study population from the AHCIP registry, all elderly 65 years and older in the city of Calgary on April 1, 2009, was linked to public health vaccination records to determine elderly 65 years of age and older with and without PPV vaccination on April 1, 2009 (i.e. no documented PPV for the period 1998 to 2008).

Both the vaccinated and unvaccinated elderly on April 1, 2009 were then stratified into individuals with at least one visit compared to no visits to an acute care provider in 2009 (April 1, 2009 to March 31, 2010). Unvaccinated elderly on April 1, 2009 were assessed to see if they received PPV anytime in 2009 (April 1, 2009 to March 31, 2010).

3.4.2 Independent Variables

The main exposure variable was visits to an acute care provider during the fiscal year 2009 (April 1, 2009 to March 31, 2010) obtained from the ACCS and DAD databases. In addition, we stratified our analysis of the relationship between acute care visits and PPV vaccination by the demographic variables age, sex, and aboriginal status obtained from the AHCIP registry as well as household median income obtained from the Statistics Canada

national census. Using data elements from the ACCS and DAD databases we also obtained data on the occurrence of the first visit to acute care, number of Charlson comorbidities,⁷⁵ mental health diagnosis, health service facility visited and length of inpatient stay (DAD only). These independent variables were used to explore factors associated with PPV vaccination in an acute care setting.

3.4.2.1 Acute Care Visits

Acute care visits were classified into ambulatory care only with no admission to hospital and inpatient care requiring a hospital stay (with or without ambulatory care). If the time between the end date of one visit and start date of the subsequent one or more visits was less than twenty-four hours, the entire sequence of visits, termed an episode of care, was considered as one visit. This was done to ensure that one episode of care, such as ambulatory care followed by a change to an inpatient care bed or inter-facility transfer, was not counted as multiple visits. Each episode of care was considered as a single opportunity to receive PPV.

Elderly who were unvaccinated with PPV were stratified into individuals with no visits versus ≥ 1 visits to an acute care provider in 2009. Unvaccinated elderly in both the no visits and ≥ 1 visits groups were then stratified into those that received and did not receive PPV in 2009.

Those who received PPV and had at least one visit to an acute care provider in 2009 were further stratified by the timing of vaccine administration relative to the patient's first visit in 2009. Recommendations to receive PPV can be made in an acute care setting without immediate administration of the vaccine when insufficient vaccine supply or clinical priorities necessitate a post-visit referral to primary care or public health in the community to complete vaccination. In

Calgary, a 10-minute PPV vaccination appointment with community public health has wait times consistently less than 2 weeks and sensitivity analysis for window periods of 7, 14 and 28 days showed no disproportionate effects on PPV vaccination rate estimates (4.4% vaccinated during 1st visit or within 7-days post-visit, 1.7% vaccinated between 8 and 14 days post-visit, 3.6% vaccinated between 15 and 28 days post-visit) (Table 2). Therefore we attributed PPV administered during a visit, or within a 14-day window period, to a PPV recommendation made in acute care and equivalent to receiving the vaccine in the acute care setting. Visits that began during but ended after fiscal year 2009 were followed for the 14-day window period to determine if PPV vaccination had occurred.

Table 2. Sensitivity analysis (7, 14, 28 day window periods) for attribution of receipt of pneumococcal polysaccharide vaccine (PPV) to the first visit to an acute care provider in 2009

Window Period	Vaccinated in 2009 n = 2,592 (%)
Prior to 1 st visit	581 (22.4)
During 1 st visit or within 7-days post-visit	114 (4.4)
Between 8 and 14 days post-visit	45 (1.7)
Between 15 and 28 days post-visit	94 (3.6)
Greater than 28 days post-visit	1758 (67.9)

3.4.2.2 Age Group

Elderly 65 years and older were divided into three age groups (65-74 years, 75-84 years and 85 years of age and older) based on their age in the AHCIP registry as of April 1, 2009, the beginning of the study period. Actual age was used to calculate median age and its interquartile range.

3.4.2.3 Sex

We used the variable sex (male, female) from the ACHIP registry on April 1, 2009, the start of the study period.

3.4.2.4 Aboriginal Status

Aboriginal status (yes, no) on April 1, 2009, the start of the study period, was obtained from the ACHIP registry. This variable includes any AHCIP registrant with a reported Band number and/or First Nations group number.

3.4.2.5 Household Median Income

Household median income was obtained from the 2006 Statistics Canada national census and categorized into quartiles according to the total study population of all Calgary elderly 65 years and older (Q1: \$0 - \$51,546, Q2: \$51,566 - \$69,763, Q3: \$69,781 - \$90,813 and Q4: > \$90,828).

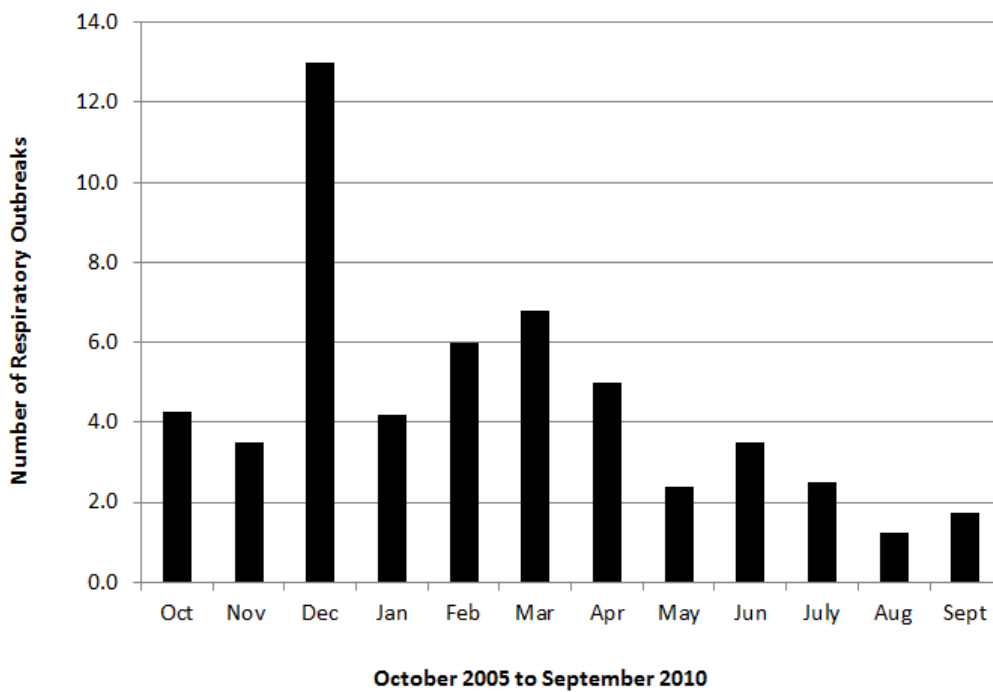
3.4.2.6 Occurrence of Patient's First Visit to Acute Care

The date of a patient's first visit to acute care after April 1, 2009, the start of the study period, was obtained from the ACCS and DAD databases. Occurrences of first visits to acute care were classified into visits that did not occur during the typical seasonal influenza season (April 2009 to September 2009) and visits that occurred during the typical seasonal influenza season (October 2009 to March 2010). The exact timing of the influenza season can vary slightly

each year but typically occurs from October to March with a smaller number of influenza cases falling outside this period.

Public health influenza surveillance in Calgary tracks respiratory outbreaks including but not limited to influenza A (including H1N1), influenza B, parainfluenza, respiratory syncytial virus and human metapneumovirus. The five-year trend in respiratory outbreaks is shown in Figure 2, and roughly demonstrates the higher incidence of respiratory outbreaks during the annual influenza season of October to March. Though April 2008 also had a reasonably high number of respiratory outbreaks, we used the typical influenza season of October to March to stratify patients' first visit to acute care.

Figure 2. Number of respiratory outbreaks (influenza A and B, parainfluenza, RSV, hMPV, other) in Calgary from 2005-2010



3.4.2.7 Charlson Comorbidities

ICD-10 diagnostic codes from the ACCS and DAD databases were used to count the number of Charlson comorbidities for each individual (Appendix A). The Charlson comorbidity index⁷⁵ predicts the ten-year mortality for a patient with a range of comorbid conditions such as congestive heart failure, cancer and kidney disease and is often used for risk adjustment in administrative data analysis. All elderly 65 years and older are indicated to receive PPV in Alberta, so our use of Charlson comorbidities was as an additional independent variable to help understand the reasons associated with PPV vaccination during a first visit to an acute care provider.

The Charlson index includes nine chronic conditions known as risk factors for IPD in adults including individuals 65 years and older (congestive heart failure, chronic pulmonary disease, diabetes with and without complications, renal disease, any malignancy including lymphoma and leukemia, moderate or severe liver disease, metastatic solid tumor, AIDS/HIV).¹¹ We searched the main or “most responsible” diagnosis code field and all secondary diagnostic code fields on a patient’s first visit for a match with any of the 17 Charlson comorbidities. The number of Charlson comorbidities was stratified into 3 categories (none, 1, >1).

3.4.2.8 Mental Health Diagnosis

ICD-10 diagnostic codes from the ACCS and DAD databases were used to determine if an individual had a mental, behavioral or neurodevelopmental health diagnosis (Appendix B). We hypothesized that a mental health diagnosis could present challenges in obtaining consent to administer the vaccine. The main or “most responsible” diagnosis code field and all secondary

diagnostic code fields for a patient's first visit were searched for a match with one or more of the ICD-10 codes F01 to F99 and mental health diagnosis was then dichotomized (yes, no).

3.4.2.9 Health Service Facility

The location of a patient's first visit to an acute care provider in 2009 was obtained from the ACCS and DAD databases. The Foothills Medical Centre, Peter Lougheed Centre and Rockyview General Hospital are the three large tertiary care centres in Calgary. The health service facility location for a patient's first visit was categorized as not occurring or occurring at one of these three tertiary care centres (non-tertiary care versus tertiary care).

3.4.2.10 Length of stay

A patient's length of stay in hospital is the time from admission to discharge from hospital or death. Length of stay for a first visit to an acute care provider in 2009 was obtained from the DAD database. Fourteen days represented approximately the 75th percentile of length of stay and was used to classify length of stay into short versus long stays (≤ 14 days vs. > 14 days).

3.5 Ethical Approval

The study was approved by the Conjoint Health Research Ethics Boards of the University of Calgary.

3.6 Data Analysis

For all statistical tests, $p < 0.05$ was considered significant. Univariate and multivariate data analyses were performed using Stata/SE version 11.0 software (StataCorp LP, College Station Texas, 2009).

3.6.1 Descriptive Statistics

Descriptive statistics were used to describe population characteristics (age, sex, aboriginal status and household median income) and rates of PPV vaccination. All variables were categorical and age was also described using the median and interquartile range. The vaccination rate, also known as vaccine coverage, is the percentage of individuals who received PPV divided by the total number of individuals indicated to receive the vaccine. Chi-squared tests (χ^2) were used to determine any statistically significant differences between the vaccinated and unvaccinated groups.

3.6.2 Multivariate Analysis

Two logistic regression models were built to assess the relationship between PPV vaccination of the elderly and visits to acute care. The first model was used to calculate odds ratios for PPV vaccination of the elderly in 2009. The second model was used to calculate odds ratios for PPV vaccination (i.e. factors associated with PPV vaccination) during the first visit to an acute care provider in 2009.

3.6.2.1 Model 1: Association of PPV with Acute Care Visits

We used logistic regression was used to build a model of the odds of PPV vaccination in 2009 among elderly 65 years of age and older with and without visits to acute care. The dependent variable was PPV vaccination (no, yes) and the independent variables were ≥ 1 visits to an acute care provider in 2009 (no, yes), age (65-74, 75-84, 85+), sex (male, female), aboriginal status (no, yes) and household median income quartiles (Q1 to Q4). Age, sex, aboriginal status and household median income were adjusted for as potential confounders of the relationship between acute care visits and PPV vaccination.

3.6.2.2 Model 2: Factors Associated with PPV During a First Visit

We fitted a second logistic regression model to understand the factors associated with PPV vaccination during a first visit to an acute care provider. The dependent variable was PPV vaccination (no, yes) and the independent variables were age (65-74, 75-84, 85+), sex (male, female), aboriginal status (no, yes), household median income (quartiles), occurrence of first visit (during vs. not during influenza season), Charlson comorbidities (none, 1, >1), mental health diagnosis (no, yes), health service facility (tertiary vs. non-tertiary care) and inpatient length of stay (≤ 14 days vs. >14 days). Charlson comorbidities measuring health status and potential risk factors for healthcare services use include myocardial infarction, congestive heart failure, peripheral vascular disease, cerebrovascular disease, dementia, chronic pulmonary disease, peptic ulcer disease, renal disease, hemiplegia or paraplegia, cancer, liver disease, diabetes and AIDS (Appendix A). Mental health was considered as a potential barrier to vaccination consent. We followed a step-wise approach beginning with age and sex as

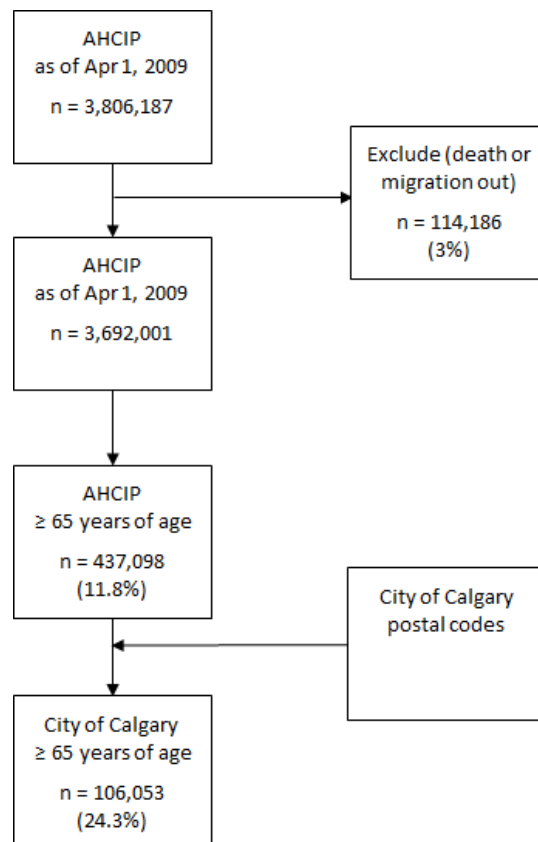
independent variables. Additional variables were introduced in stages and retained if the resulting model was significantly different using the likelihood ratio test.

Chapter Four: Results

4.1 Study Population

There were a total of 3,692,001 registrants in the AHCIP registry after excluding 3% (n = 114,186) of the population due to death or migration out during the study period April 1, 2009 to March 31, 2010. Registrants age 65 years and older on April 1, 2009 represented 11.8% (n = 437,098) of the AHCIP registrants. Using city of Calgary postal codes, 24.3% (n = 106,053) of these elderly resided in Calgary. The final study population was 106,053 individuals 65 years of age and older in the city of Calgary as of April 1, 2009 (Figure 4).

Figure 3. Derivation of study population of elderly 65 years and older in the city of Calgary as of April 1, 2009



4.2 Baseline Vaccination Rates

Stratification of the study population of 106,053 elderly 65 years and older into those with and without PPV vaccination prior to 2009 is shown in Figure 4.

The prevalence of PPV vaccination, also known as the vaccination rate or coverage rate, for the study population on April 1, 2009 was 49.8%. This represents 52,804 elderly who were vaccinated with PPV prior to 2009.

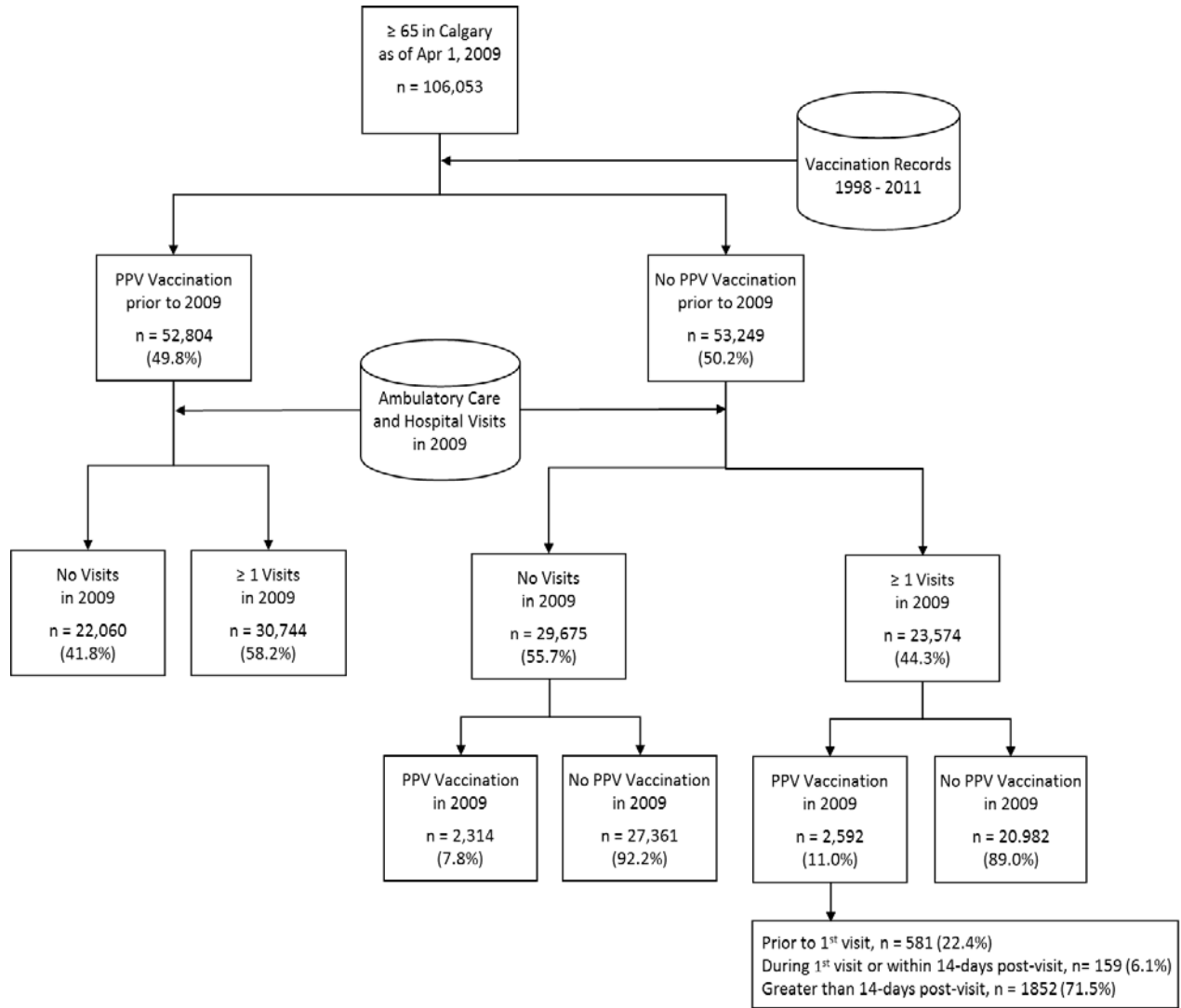
Unvaccinated or susceptible elderly, our population of interest, were members of the study population who had not received PPV from 1998, the first year of public funding for the vaccine, to 2008. There were 50.2% (n = 53,249) of elderly who were unvaccinated with PPV on April 1, 2009.

Baseline vaccination rates for both the vaccinated and unvaccinated elderly are presented in Table 3. Both groups had a higher proportion of younger elderly ($P < 0.001$), females ($P < 0.001$) and non-Aboriginals ($P < 0.001$). Compared to elderly vaccinated with PPV prior to 2009, unvaccinated elderly were younger ($P < 0.001$) and less likely to be female ($P < 0.001$).

Vaccination rates were higher in older age groups ($P < 0.001$), beginning at 36.9% for elderly 65-74 years of age and reaching 68.5% for elderly over the age of 85, the highest risk age group for acquiring IPD. The median age of the vaccinated group was 77 years of age and for the unvaccinated was 70 years of age. A higher percentage of females vs. males (52.0% vs. 47.0%, $P < 0.001$) and non-Aboriginals vs. Aboriginals (49.8% vs. 40.2%, $P < 0.001$) were vaccinated prior to 2009.

A reverse socioeconomic gradient was noted as vaccination rates were lower for higher household income quartiles ($P < 0.001$). Stratification of PPV vaccination rates by age and household median income demonstrated that this reverse socioeconomic gradient was only present for elderly 85 years and older. Vaccination rates increased by income quartile for age 65 to 74 but decreased by income quartiles for age 85 and older (Table 4).

Figure 4. Pneumococcal polysaccharide vaccine (PPV) vaccination prior to and during 2009 among Calgary elderly 65 years of age and older with and without visits to an acute care provider



**Table 3. Pneumococcal polysaccharide vaccine (PPV) vaccination rates on April 1, 2009
among Calgary elderly 65 years of age and older**

	Vaccinated n (%)	Not Vaccinated n (%)	Total Population n (%)	Vaccination Rate [%, (95% CI)]
Overall	52,804	53,249	106,053	49.8 (49.4-50.1)
Age on April 1, 2009				
65-74	21,056 (39.9)	35,983 (67.6)	57,039 (53.8)	36.9 (36.5-37.3)
75-84	22,906 (43.4)	13,199 (24.8)	36,105 (34.0)	63.4 (62.9-63.9)
85+	8,842 (16.7)	4,067 (7.6)	12,909 (12.2)	68.5 (67.7-69.3)
Median (IQR)	77 (11)	70 (10)	75 (12)	
Sex				
Male	22,071 (41.8)	24,887 (46.7)	46,958 (44.3)	47.0 (46.5-47.4)
Female	30,733 (58.2)	28,362 (53.3)	59,095 (55.7)	52.0 (51.6-52.4)
Aboriginal				
No	52,662 (99.7)	53,038 (99.6)	105,700 (99.7)	49.8 (49.5-50.1)
Yes	142 (0.3)	211 (0.4)	353 (0.3)	40.2 (35.1-45.5)
Household income				
Q1 (\$0 - \$51,546)	13,595 (25.8)	12,804 (24.1)	26,399 (24.9)	51.5 (50.9-52.1)
Q2 (\$51,566 – \$69,763)	13,226 (25.0)	13,201 (24.8)	26,427 (24.9)	50.0 (49.4-50.7)
Q3 (\$69,781 – \$90,813)	12,953 (24.5)	13,462 (25.3)	26,415 (24.9)	49.0 (48.4-49.6)
Q4 (>\$90,828)	13,030 (24.7)	13,782 (25.9)	26,812 (25.3)	48.6 (48.0-49.2)

Table 4. Pneumococcal polysaccharide vaccine (PPV) vaccination rates on April 1, 2009 among Calgary elderly 65 years of age and older, stratified by household median income and age

	Vaccinated n (%)	Not Vaccinated n (%)	Total Population n (%)	Vaccination Rate %
All elderly 65+				
Q1 (\$0 - \$51,546)	13,595 (25.8)	12,804 (24.1)	26,399 (24.9)	51.5
Q2 (\$51,566 – \$69,763)	13,226 (25.0)	13,201 (24.8)	26,427 (24.9)	50.0
Q3 (\$69,781 – \$90,813)	12,953 (24.5)	13,462 (25.3)	26,415 (24.9)	49.0
Q4 (>\$90,828)	13,030 (24.7)	13,782 (25.9)	26,812 (25.3)	48.6
Age 65-74				
Q1 (\$0 - \$51,546)	4,587 (21.8)	8,075 (22.4)	12,662 (22.2)	36.2
Q2 (\$51,566 – \$69,763)	5,006 (23.8)	8,617 (23.9)	13,623 (23.9)	36.7
Q3 (\$69,781 – \$90,813)	5,390 (25.6)	9,414 (26.2)	14,804 (26.0)	36.4
Q4 (>\$90,828)	6,073 (28.8)	9,877 (27.4)	15,950 (28.0)	38.1
Age 75-84				
Q1 (\$0 - \$51,546)	6,062 (26.5)	3,480 (26.4)	9,542 (26.4)	63.5
Q2 (\$51,566 – \$69,763)	5,853 (25.6)	3,525 (26.7)	9,378 (26.0)	62.4
Q3 (\$69,781 – \$90,813)	5,669 (24.7)	3,153 (23.9)	8,822 (24.4)	64.3
Q4 (>\$90,828)	5,322 (23.2)	3,041 (23.0)	8,363 (23.2)	63.6
Age 85+				
Q1 (\$0 - \$51,546)	2,946 (33.3)	1,249 (30.7)	4,195 (32.5)	70.2
Q2 (\$51,566 – \$69,763)	2,367 (26.8)	1,059 (26.0)	3,426 (26.5)	69.1
Q3 (\$69,781 – \$90,813)	1,894 (21.4)	895 (22.0)	2,789 (21.6)	67.9
Q4 (>\$90,828)	1,635 (18.5)	864 (21.2)	2,499 (19.4)	65.4

4.3 Visits to Acute Care Providers in 2009 Among Unvaccinated Elderly

Over half of the study population (n=106,053) had at least one visit to an acute care provider in 2009 (n = 54,318) with the remainder having no visits to an acute care provider (n = 51,735) (Figure 4).

Compared to elderly vaccinated with PPV prior to the start of the study period (April 1, 2009), elderly unvaccinated with PPV at the start of the study period were less likely to have one or more visits to an acute care provider in 2009 (58.2% vs. 44.3%, $P<0.001$). Nevertheless, of the 53,249 elderly who were unvaccinated with PPV prior to the start of the study period, 44.3% (n = 23,574) had at least one visit to an acute care provider in 2009 (Table 5). Compared to unvaccinated elderly with no visits to an acute care provider, unvaccinated elderly who accessed acute care were older ($P<0.001$), more likely to be female ($P<0.001$), more likely to be Aboriginal ($P<0.043$) and had a lower household median income ($P<0.001$).

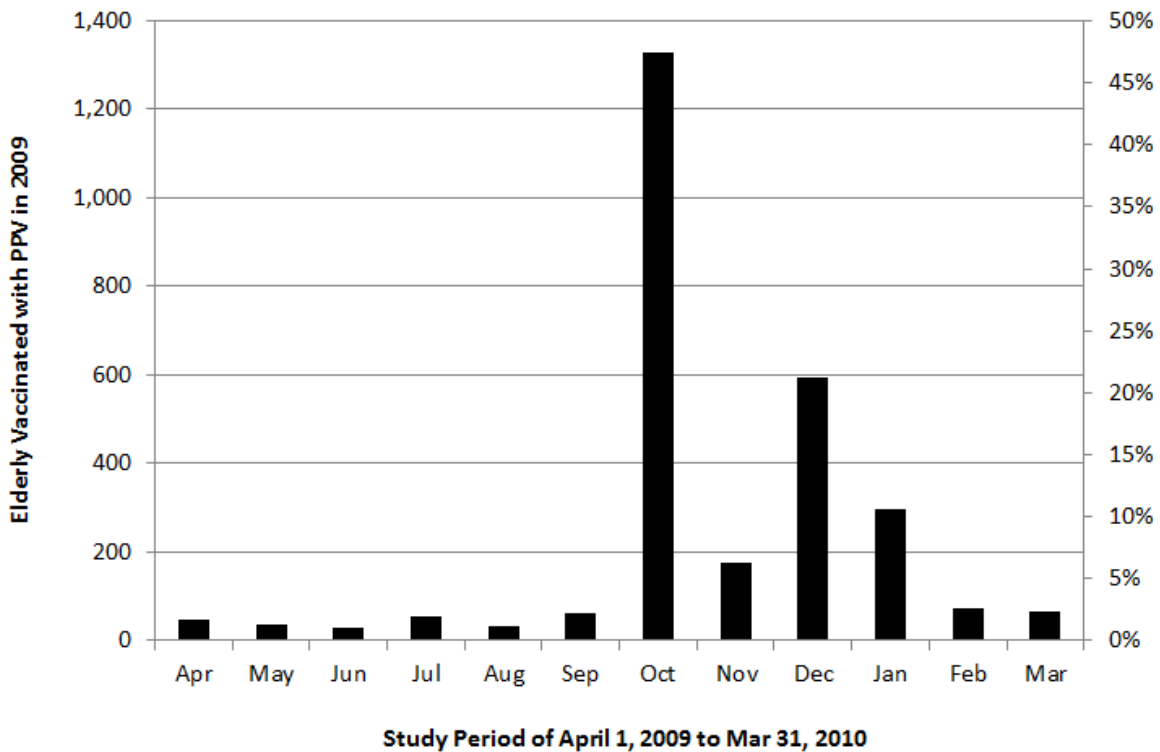
Table 5. Visits to acute care providers in 2009 among Calgary elderly 65 years of age and older who were unvaccinated with PPV

	No Acute Care Visits n = 29,675 (%)	≥1 Acute Care Visits n = 23,574 (%)	P-Value
Overall	29,675	23,574	
Age on April 1, 2009			<0.001
65-74	20,858 (70.3)	15,125 (64.2)	
75-84	6,738 (22.7)	6,461 (27.4)	
85+	2,079 (7.0)	1,988 (8.4)	
Median (IQR)	70 (11)	71 (11)	
Sex			<0.001
Male	14,074 (47.4)	10,813 (45.9)	
Female	15,601 (52.6)	12,761 (54.1)	
Aboriginal			0.043
No	29,572 (99.7)	23,466 (99.5)	
Yes	103 (0.3)	108 (0.5)	
Household income			<0.001
Q1 (\$0 - \$51,546)	6,920 (23.3)	5,884 (25.0)	
Q2 (\$51,566 – \$69,763)	7,323 (24.7)	5,878 (24.9)	
Q3 (\$69,781 – \$90,813)	7,664 (25.8)	5,798 (24.6)	
Q4 (>\$90,828)	7,768 (26.2)	6,014 (25.5)	

4.4 Seasonal Distribution of PPV Vaccination

There were 2,592 elderly 65 years and older who were vaccinated with PPV during the study period (April 1, 2009 to March 31, 2010) (Figure 5). The majority of vaccine (90.5%; n = 2,346), was administered during the seasonal influenza season which runs from October to March of each year. Most PPV was administered in October (47.5%; n = 1,231), followed by December (21.2%, n = 549), January (10.6%, n = 274) and November (6.3%, n = 162).

Figure 5. Pneumococcal polysaccharide vaccine (PPV) vaccinations during 2009 among Calgary elderly 65 years of age and older



4.5 Association of PPV Vaccination with Acute Care Visits in 2009

Of the 53,249 unvaccinated elderly in this study, 23,574 individuals presented to at least one acute care provider in 2009. The PPV vaccination rate for the no visit group was 7.8% compared to 11.0% for elderly that accessed acute care. This association between ambulatory or inpatient visits to an acute care provider in 2009 and higher likelihood of PPV vaccination was found to be statistically significant (adjusted odds ratio [OR]=1.53; 95% confidence interval [95% CI]=1.44,1.62). Nevertheless, 89.0% of elderly remained unvaccinated at the end of 2009 (Table 6).

Despite age being a major risk factor for IPD, there was a lower odds ratio for PPV vaccination in 2009 in the 75-84 age group (OR=0.48; 95% CI=0.44,0.52) and 85 and older age group (OR=0.63; 95% CI=0.55,0.71) compared to the 65-74 age group.

Elderly were more likely to be vaccinated in 2009 with increasing household income (1st quartile OR=1.14; 95% CI=1.04,1.25 compared to 4th quartile OR=1.44; 95% CI=1.32,1.56).

Table 6. Association between visits to acute care in 2009 and pneumococcal (PPV) vaccination among previously unvaccinated Calgary elderly 65 years of age and older

	Vaccinated [n (%)]			Odds Ratio ^a (95% CI)
	No Visits n = 29,675	Visits n = 23,574	Total n = 53,249	
Acute care visits in 2009				
No visits			2,314 (7.8)	Reference
Visits			2,592 (11.0)	1.53 (1.44,1.62)
Age on April 1, 2009				
65-74	1,965 (6.6)	1,919 (8.1)	3,884 (10.8)	Reference
75-84	261 (0.9)	475 (2.0)	736 (5.6)	0.48 (0.44,0.52)
85+	88 (0.3)	198 (0.8)	286 (7.0)	0.63 (0.55,0.71)
Sex				
Male	1,144 (3.9)	1,228 (5.2)	2,372 (9.5)	Reference
Female	1,170 (3.9)	1,364 (5.8)	2,534 (8.9)	0.97 (0.92,1.03)
Aboriginal				
No	2,309 (7.8)	2,582 (10.95)	4,891 (9.2)	Reference
Yes	5 (0.02)	10 (0.05)	15 (7.1)	0.75 (0.44,1.27)
Household income				
Q1 (\$0 - \$51,546)	436 (1.5)	529 (1.8)	965 (7.5)	Reference
Q2 (\$51,566 – \$69,763)	511 (1.7)	617 (2.1)	1,128 (8.5)	1.14 (1.04,1.25)
Q3 (\$69,781 – \$90,813)	636 (2.1)	682 (2.2)	1,318 (9.8)	1.30 (1.19,1.42)
Q4 (>\$90,828)	731 (2.5)	764 (2.6)	1,495 (10.8)	1.44 (1.32,1.56)

^a Age, sex, aboriginal and household median income adjusted odds ratio

4.6 Factors Associated with PPV During a First Visit

The majority of the 23,574 acute care visits by unvaccinated elderly were for ambulatory care only without a hospital stay (90.3%) with the remainder (9.7%) also having an admission to hospital (Table 7). Elderly who were admitted to hospital were older (median age 75 vs. 71) with lower socioeconomic status (median household income 28.6% vs. 24.6% in Q1 and 22.0% vs. 25.9% in Q4).

Only 6.1% (n=159) of the 23,574 unvaccinated elderly who presented to at least one acute care provider in 2009 received PPV in association with their first visit (Table 8). The majority (n=94) received PPV during a first visit to ambulatory care only compared to the remainder (n=65) who received PPV during a first visit that included inpatient care.

For elderly with a first visit to ambulatory care in 2009 without admission to hospital, individuals 75-84 years of age were less likely to receive PPV (OR=0.47; 95% CI=0.26,0.85) compared to elderly 65-74 years of age. Elderly receiving ambulatory care at one of Calgary's three tertiary care centers were more likely to receive PPV (OR=1.81; 95% CI=1.04,3.14) than those attending non-tertiary care facilities. Finally, there was a strong association between receipt of PPV at a first ambulatory care visit during the fall influenza season (October to March) (OR=4.36; 95% CI=2.86,6.66) compared to the remainder of the year.

For elderly with a first visit to acute care in 2009 involving admission to hospital, females were less likely than males to receive PPV (OR=0.52; 95% CI=0.32,0.84). Notably, a median length of inpatient stay greater than 14 days was strongly associated with PPV vaccination (OR=7.71; 95% CI=4.41,13.47).

Table 7. First visits to acute care providers in 2009 among Calgary elderly 65 years of age and older

	First Visit to Acute Care in 2009		
	≥1 Acute Care Visits n = 23,574 (%)	Ambulatory Care Only n = 21,280 (%)	Inpatient Care n = 2,294 (%)
Overall	23,574	21,280	2,294
Age on April 1, 2009			
65-74	15,125 (64.2)	13,988 (65.7)	1,137 (49.6)
75-84	6,461 (27.4)	5,705 (26.8)	756 (33.0)
85+	1,988 (8.4)	1,587 (7.5)	401 (17.4)
Median (IQR)	71 (11)	71 (10)	75 (13)
Sex			
Male	10,813 (45.9)	9,754 (45.8)	1,059 (46.2)
Female	12,761 (54.1)	11,526 (54.2)	1,235 (53.8)
Aboriginal			
No	23,466 (99.5)	21,182 (99.5)	2,284 (99.6)
Yes	108 (0.5)	98 (0.5)	10 (0.4)
Household income			
Q1 (\$0 - \$51,546)	5,884 (25.0)	5,228 (24.6)	656 (28.6)
Q2 (\$51,566 – \$69,763)	5,878 (24.9)	5,242 (24.6)	636 (27.7)
Q3 (\$69,781 – \$90,813)	5,798 (24.6)	5,300 (24.9)	498 (21.7)
Q4 (>\$90,828)	6,014 (25.5)	5,510 (25.9)	504 (22.0)

Table 8. Factors associated with pneumococcal (PPV) vaccination among Calgary elderly who visited acute care in 2009

	Ambulatory Care Only ^a			Inpatient Care ^a		
	Vaccinated n = 94 (%)	Odds Ratio (95% CI) n = 20,748		Vaccinated n = 65 (%)	Odds Ratio (95% CI) n = 2,252	
		Model 1 ^b	Model 2 ^c		Model 1 ^b	Model 2 ^c
Age on April 1, 2009						
65-74	73 (77.7)	Reference		22 (33.8)	Reference	
75-84	13 (13.8)	0.47 (0.26,0.85)	0.47 (0.26,0.85)	25 (38.5)	1.31 (0.74,2.29)	1.39 (0.79,2.43)
85+	8 (8.5)	1.07 (0.51,2.22)	1.05 (0.51,2.18)	18 (27.7)	1.23 (0.65,2.33)	1.40 (0.75,2.60)
Sex						
Male	47 (50.0)	Reference		37 (57.0)	Reference	
Female	47 (50.0)	0.92 (0.61,1.37)	0.88 (0.59,1.32)	28 (43.0)	0.53 (0.32,0.86)	0.52 (0.32,0.84)
Household income						
Q1 (\$0 - \$51,546)	21 (22.3)	Reference		23 (35.4)	Reference	
Q2 (\$51,566 – \$69,763)	23 (24.5)	1.11 (0.62,2.00)	-	15 (23.1)	0.71 (0.38,1.33)	-
Q3 (\$69,781 – \$90,813)	27 (28.7)	1.29 (0.73,2.27)	-	14 (21.5)	0.81 (0.43,1.54)	-
Q4 (>\$90,828)	23 (24.5)	1.07 (0.59,1.93)	-	13 (20.0)	0.77 (0.40,1.48)	-
Occurrence of first visit						
Not flu season (Apr–Sep)	33 (35.1)	Reference		42 (64.6)	Reference	
Flu season (Oct–Mar)	61 (64.9)	4.68 (3.05,7.18)	4.36 (2.86,6.66)	23 (35.4)	1.68 (1.02,2.75)	-

	Ambulatory Care Only ^a			Inpatient Care ^a		
	Vaccinated n = 94 (%)	Odds Ratio (95% CI) n = 20,748		Vaccinated n = 65 (%)	Odds Ratio (95% CI) n = 2,252	
		Model 1 ^b	Model 2 ^c		Model 1 ^b	Model 2 ^c
Charlson comorbidities						
None	65 (69.2)	Reference		15 (23.1)	Reference	
1	24 (25.5)	1.76 (1.09,2.82)	-	22 (33.8)	0.74 (0.38,1.45)	-
>1	5 (5.3)	1.94 (0.78,4.86)	-	28 (43.1)	0.90 (0.46,1.75)	-
Mental health diagnosis						
No	93 (98.9)	Reference		40 (61.5)	Reference	
Yes	1 (1.1)	0.40 (0.05,2.99)	-	25 (38.5)	1.59 (0.93,2.73)	-
Health service facility						
Non-tertiary care	79 (84.0)	Reference		59 (90.8)	Reference	
Tertiary care	15 (16.0)	1.78 (1.03,3.09)	1.81 (1.04,3.14)	6 (9.2)	1.11 (0.41,3.00)	-
Length of stay						
≤ 14 days	-	-	-	17 (26.2)	Reference	
> 14 days	-	-	-	48 (73.8)	7.15 (4.00,12.79)	7.71 (4.41,13.47)

^a First visit in 2009; ^b Full model; ^c Fitted model with statistically significant variables

Chapter Five: Discussion

5.1 Summary

This study used Alberta's large, population-based administrative data sources to determine the number of unvaccinated elderly 65 years of age and older accessing ambulatory and inpatient care services in Calgary from April 1, 2009 to March 31, 2010 and to describe the factors associated with PPV vaccination in these acute care settings.

Key findings include:

- a) Pneumococcal vaccine uptake in the elderly (49.8%) is suboptimal compared to national consensus targets (>80% for all persons 65 years and older). To the best of our knowledge, this is the first estimate of cumulative PPV coverage for urban Calgary elderly 65 years and older.
- b) A large number of susceptible Calgary elderly accessed acute care in 2009 but the majority did not receive PPV by year-end.
- c) After adjustment for age, sex, aboriginal status and household income, acute care visits were significantly associated with receipt of PPV. We understand this to be the first study to associate acute care visits with PPV vaccination using population-level data.
- d) After adjustment for age, sex, household income, Charlson comorbidities, mental health diagnosis and health service facility, ambulatory care visits during influenza season were significantly associated with receipt of PPV during influenza season.

- e) After adjustment for age, sex, household income, occurrence of first visit, Charlson comorbidities, mental health diagnosis and health service facility, inpatient visits were significantly associated with receipt of PPV for long lengths of stay >14 days.

5.2 PPV Coverage Rates

The pneumococcal polysaccharide vaccine is recommended by the U.S. Advisory Committee on Immunization Practices in the United States and the Public Health Agency of Canada's National Advisory Committee on Immunization for all persons 65 years and older to protect against morbidity and mortality caused by IPD. Using large, population-based administrative data sources we found baseline PPV coverage rates in Calgary were suboptimal compared to national consensus targets.

Calgary's baseline PPV coverage rate of 49.8% for urban-dwelling elderly 65 years and older is consistent with PPV coverage rates of 40% to 60% found in other North American studies.^{47,44,52} In the United States vaccination rates are consistently lower than target vaccination rates of 90% for all persons 65 years and older set by the United States' Health People 2020 initiative.⁴² The same was confirmed in Calgary, with the city's coverage rate being suboptimal compared to the 80% target for elderly 65 years and older set by the most recent National Consensus conference in Canada.⁴³ Half of all elderly 65 years and older in Calgary are therefore unvaccinated with PPV and at risk of invasive pneumococcal disease. Despite primary care and public health vaccination efforts in the community, since the introduction of PPV in Alberta in 1998 many elderly remain susceptible to IPD-related morbidity and mortality.

Baseline vaccination rates were higher for elderly over the age of 75, females, non-aboriginals and those with lower household median income. Previous research has found lower PPV vaccine coverage for males and ethnic minorities,^{47,59} however the reverse socioeconomic gradient at baseline was an unexpected finding. We suspect this finding is due to advancing age being associated with both increased cumulative opportunity to receive PPV vaccine and residence in lower income communities, as supported by age and household median income stratification. For example, the PPV vaccination rate was 38.1% for age 65-74 and high median income and 70.2% for age 85 years and older and low median income.

Vaccination rates in 2009 were lower for elderly over the age of 75 and individuals with lower household median income (Table 2). Since this population represented the remaining unvaccinated elderly at the start of 2009, this finding clearly indicates that these two populations do not have the same characteristics. The difference may be due to characteristics of the remaining unvaccinated elderly that make them harder to reach with PPV. For example, remaining unvaccinated elderly 75 years of age and older may have a higher prevalence of vaccine refusal or assumed prior receipt of PPV. Similarly, remaining unvaccinated elderly with lower household income may have a higher prevalence of misinformation or lack of awareness about the vaccine. These findings suggest that public health interventions will need to be increasingly innovative to reach the remaining unvaccinated elderly and achieve national coverage rate targets.

We understand the PPV coverage rate calculated from this study to be the first estimate of cumulative PPV vaccination for urban Calgary elderly 65 years and older.¹³ A key step in continually improving performance of a vaccination program is measuring and monitoring

outcomes such as vaccine coverage.⁷⁶ Due to its derivation solely from administrative data sources, the PPV vaccine coverage rate from this study has the potential to be updated periodically as a performance measure for Calgary's PPV vaccine program.

5.3 Acute Care Visits and PPV Vaccination

5.3.1 Elderly Accessing Acute Care

We confirmed our first study hypothesis that unvaccinated elderly frequently access acute care services as almost one half ($n = 23,574$) of our susceptible study population had at least one visit to an acute care provider in 2009. These visits represent frequent points of contact with healthcare providers beyond regular community-based care and are therefore additional opportunities for elderly to receive PPV. If all unvaccinated elderly who accessed acute care services in 2009 were vaccinated with PPV, coverage rates would rise from 49.8% to 72.0%. Assuming an incidence of 68 cases of IPD per 100,000 unvaccinated persons 65 years of age and older and 50% effectiveness of PPV in this population,²⁹ this rise in coverage rate would result in 8 lives saved in Calgary during the study period.

Unvaccinated elderly who access acute care are also known to be at higher risk of IPD compared to those who do not access acute care. We found that unvaccinated elderly presenting to acute care were older than those without acute care visits and therefore at greater risk of IPD. Additionally, elderly with visits to acute care have been shown in the literature to frequently have high-risk medical conditions for IPD.⁷⁷ Klein and Adachi found that 56% of adults over two winter periods had one or more high-risk conditions for IPD on admission to hospital, such as chronic heart, lung or kidney disease.⁷⁸ Parsons et al. found that at least one risk factor for IPD

was present in 59% of IPD patients admitted to hospital.⁷¹ Martin, Brauner and Plouffe found that adults presenting to emergency departments have more risk factors for invasive pneumococcal disease, are less likely to receive regular physician care and are more likely to be of lower socioeconomic status.⁷⁹ A large U.S. study of Medicare pneumonia inpatients across 12 western states showed that 66% of unvaccinated elderly had at least one chronic condition associated with increased risk for IPD.⁶⁸ Susceptible elderly presenting to acute care therefore represent a subset of the target vaccine population who would especially benefit from PPV protection.

5.3.2 Missed Opportunities for PPV Vaccination

We also confirmed our second hypothesis that there are frequent missed opportunities to vaccinate susceptible elderly who present to acute care. The majority (89%) of our large cohort of susceptible elderly did not receive PPV by year-end despite accessing acute care services at least once. This finding is consistent with previous research that has demonstrated frequent missed opportunities to vaccinate with PPV in acute care settings. Kyaw et al. showed that one or more missed opportunities were documented in nearly all unvaccinated adult IPD patients with a vaccine indication in hospital.⁶⁷ Greci, Katz and Jekel found that no PPV vaccine was given in hospital among adult patients hospitalized for pneumonia.⁶⁹ Parsons et al. report that only 8% of adults with IPD were vaccinated in hospital despite an indication that 76% receive the vaccine according to UK pneumococcal vaccination guidelines.⁷¹ In Calgary, there are also frequently missed opportunities to vaccinate elderly with PPV when they come in contact with the acute care system.

5.3.3 Association between Acute Care Visits and PPV Vaccination

Even though only 6.1% of unvaccinated elderly received PPV in association with their first visit to an acute care provider, visits to acute care were overall significantly associated with receipt of PPV after adjusting for age, sex, aboriginal status and household income. We believe this to be the first study to draw a baseline population-based association between acute care visits and PPV vaccination in the elderly. In particular, we found that acute care visits were significantly associated with receipt of PPV during influenza season and inpatient visits with long hospital stays. This suggests that targeted acute care interventions have the potential to reach a greater proportion of unvaccinated elderly and increase population coverage towards national targets.

5.4 Ambulatory Care and PPV Vaccination

The finding of a strong association between receipt of PPV at a first ambulatory care visit during the fall influenza season is likely due to the concurrent offering of PPV alongside annual influenza vaccination. This longstanding relationship between PPV and influenza vaccine offerings is due to many factors including both microorganisms having differential impact during the winter and early spring,⁷⁹ a common set of risk factors for infection,⁸⁰ influenza being a risk factor for subsequent pneumococcal infection⁸¹ and the efficiency of offering pneumococcal vaccine during annual influenza campaigns.⁸²

Goebel and Mufson found that 82% of pneumococcal vaccine was administered in the fall and winter and 45% of PPV recipients received it together with the influenza vaccine.⁸³ We

similarly found that 90.5% of PPV in Calgary was administered during the seasonal influenza season which runs from October to March of each year and pneumococcal vaccine is regularly offered at annual public health mass influenza clinics in the city. Previous public health messaging encouraging administration of PPV in conjunction with the seasonal influenza vaccine has likely had a positive effect as patients and providers are aware that PPV should be given during this time of the year. However, further strengthening of this messaging is warranted as many elderly remain unvaccinated following an ambulatory care visit during the annual influenza season.

A high volume of unvaccinated elderly in Calgary (about 50%) had at least one ambulatory care visit during the non-influenza season (April to September) and interventions to improve PPV coverage, such as standing orders and patient and provider education and reminders, have been shown to be effective at any time during the year. Rimple et al., Tobacman and Rodriguez et al. used educational surveys to boost pneumococcal coverage rates by creating awareness among patients and providers.^{84,85,86} Terrell-Perica demonstrated the effectiveness of a pneumococcal patient reminder letter.⁸⁷ Jacobson et al. describe a one-page low-literacy patient education tool for elderly 65 years and older or those with IPD risk factors that was implemented during the summer at an ambulatory care clinic operating within a tertiary care hospital.⁸⁸ Patients in the intervention group were four times more likely to have discussed pneumococcal vaccination with their clinic physician and were five times more likely to receive the vaccine. Slobodkin et al. demonstrated the effectiveness of standing orders in increasing pneumococcal vaccination at a busy emergency department throughout the year.⁸⁹

Though Calgary's current strategy of promoting PPV vaccination during the influenza season has been successful, to further increase PPV uptake among susceptible elderly, public health should broaden its focus and consider interventions and messaging encouraging PPV vaccination throughout the year. The majority of acute care visits are for ambulatory care without a hospital stay and interventions targeted at these year-round visits hold potential to increase PPV coverage.

Lastly, elderly accessing ambulatory care at one of Calgary's three tertiary care centers were more likely to receive PPV compared to elderly attending non-tertiary care facilities. This may be due in part to the three tertiary care hospitals in Calgary having ready access to PPV through the on-site hospital pharmacies. Access to PPV is more variable at non-tertiary care facilities requiring a post-visit referral to primary care or public health for vaccination in the community.

5.5 Inpatient Care and PPV Vaccination

Though a smaller number of elderly were admitted to hospital at least once in 2009 (n = 2,252), proportionately more individuals were vaccinated compared to ambulatory care visits alone. Unlike ambulatory care visits, influenza season was not a predictor of vaccination during hospital stays. One potential reason may be that hospital providers are not aware of the availability of PPV vaccine at Calgary tertiary care facilities.

Long lengths of stay during a hospital admission were strongly associated with PPV vaccination, yet there was no association between vaccination and number of Charlson comorbidities even though the Charlson index includes nine chronic conditions known as risk

factors for IPD (Appendix A).⁷⁵ We speculate that other factors such as patient admission and discharge processes, behavioral risk factors for IPD such as smoking and alcohol use or increased length of opportunity for vaccination may lead to increased PPV vaccination during long stays. For example, females were less likely to receive PPV during a first inpatient stay in 2009. We consider that higher male prevalence of behavioral risk factors for IPD, such as smoking and alcohol use, may heighten acute care providers' awareness of the need for PPV and lead to more frequent recommendation of the vaccine to men.

We know of no PPV vaccination policies or standing orders at hospitals in Calgary that may have influenced our study results. During our study period, mandatory reporting of IPD cases to public health were followed up using a standard protocol advising the attending physician to administer PPV if the individual was unvaccinated and 65 years or older. The number of unvaccinated IPD cases during our study period was small and this public health intervention was unrelated to length of inpatient stay.

Since longer inpatient stays are undesirable for elderly 65 years and older for multiple reasons, including impact on quality of life and the possibility of additional nosocomial infections, it is important to consider how to raise PPV coverage rates independent of time spent in hospital. Previous interventions to improve inpatient PPV vaccination have been successful regardless of length of stay and, similar to in ambulatory care settings, include standing orders, and patient and provider education and reminders. Middleton et al. discuss a standing order program that increased PPV vaccination rates by 30.5% in a tertiary care hospital and 15.3% in a community hospital with both interventions costing less than \$10,000 per quality-adjusted life-year gained.⁹⁰ Thomas et al. used a nurse coordinator intervention to improve PPV vaccination

upon discharge from a medial teaching unit from zero of 38 eligible patients to 27 of 54 eligible patients.⁹¹ Clancy, Gelfman and Poses implemented a computerized pre-discharge reminder to increase PPV coverage to 45% from 3% at a university teaching hospital.⁹² All of these interventions were independent of length of stay. Similar interventions targeted towards admission and discharge processes may help reach unvaccinated elderly without long stays in hospital.

Lastly, given the higher proportion of females 65 years and older and their lower likelihood of receiving PPV during a first inpatient stay in 2009, PPV interventions in Calgary should also consider how to reach elderly females during short admissions. Inpatient geriatric units that care for a predominately female population are an example of potential locations to launch a PPV vaccination initiative.

5.6 Study Limitations

This study has several limitations. Using available data sources, our study focused only on acute care visits and did not address the significant amount of PPV vaccination that occurs in the community through visits to public health or primary care providers. We were unable to describe the association between visits and PPV vaccination for these opportunities and could not comment on the effect of community-based PPV vaccination on our finding of an association between acute care visits and receipt of PPV. Nevertheless, a large number of unvaccinated elderly presented to acute care and these visits represent additional opportunities to complement community-based PPV vaccination.

In the absence of medical records, we were unable to evaluate indications for PPV. The only absolute contraindication to PPV is an anaphylactic reaction to a previous dose, so all unvaccinated elderly 65 years and older are indicated to receive a single lifetime dose.⁴ Without patient charts we used the convention of a 14-day window to attribute vaccination to an acute care visit. This attribution window may have resulted in an underestimation or overestimation of actual vaccination associated with acute care visits. Underestimation could have occurred if a recommendation to receive PPV was made in acute care but the patient received PPV in the community after the 14-day window. Overestimation could have occurred if no recommendation to receive PPV was made in acute care but the patient received PPV independently in the community during the 14-day window. Our sensitivity analysis revealed no significant difference in outcomes with larger post-visit window sizes however misclassification bias remains a disadvantage in this study design.

The public health vaccination database included PPV administered in Alberta from 1998, the first year of universal funding for the vaccine, to 2008. However, some elderly may have received PPV vaccination prior to 1998 based on case-by-case risk assessment for IPD. Though the elderly population typically has a lower incidence of relocation, some individuals may have also migrated to Calgary since 1998 and were previously vaccinated with PPV outside of the city. Both instances would lead to misclassification of vaccinated elderly as unvaccinated. We reason that numbers in both cases are likely small relative to a universal vaccination program. Moreover, known documentation of prior PPV vaccination reported by physicians and patients is immediately recorded in the vaccination database and PPV received prior to 1998 was coded as occurring in 1998 if reported by a patient or provider.

During our study period, April 1, 2009 to March 31, 2010, pandemic (H1N1) influenza impacted Alberta in two phases.⁹³ Wave 1 lasted from April 19 to July 25, 2009 and wave 2 from October 11 to December 5, 2009. Influenza mass immunization clinics opened as usual just after Thanksgiving in 2009 with PPV initially offered until October 31st. Influenza clinics were then shut down for 1 week and, when reopened, PPV was not offered in order to target priority groups to receive the H1N1 and seasonal influenza vaccine. PPV vaccination at public health mass influenza clinics was resumed mid-December 2009. Elderly who did not receive PPV during this 6-week period from early November to mid-December may or may not have been part of the cohort that accessed acute care in 2009. Non-differential misclassification bias would result in an underestimation of our finding of an association between acute care visits and PPV vaccination and the odds ratio estimate during a typical year may be higher.

Failure to administer PPV in acute care settings is a multifaceted issue⁹⁴ related to patient factors (e.g. lack of awareness, misinformation, vaccine refusal)^{95,96} provider factors (e.g. competing priorities, attitudes towards immunization, provider recommendation, ability to identify the elderly who are unvaccinated),^{97,98,99} and health system factors (e.g. existence of immunization programs or standing orders, reminder systems, provider compensation).^{100,101,102} An assessment of these factors was beyond the scope of this study. Future research can provide insight into reasons for missed PPV vaccination opportunities in Calgary.

5.7 Knowledge Translation

Knowledge translation was a consideration throughout this research project. Public health's communicable disease unit in Calgary coordinates and monitors PPV vaccination in the

city, maintains the Phantim database and tracks IPD cases as a provincially notifiable disease. This unit was engaged in the development of the study design to clarify the current gap between evidence and practice for PPV vaccination of the elderly in Calgary and ensure the results of this study could be applied to Calgary's local context.

The results of this research study have been communicated to Calgary's communicable disease unit. The study's outcomes are currently being used to inform a PPV vaccination initiative for the elderly at an emergency department within a new tertiary care facility in Calgary. Further work is required to assess barriers to knowledge use, tailor and implement interventions and evaluate and monitor sustained knowledge use.

Chapter Six: Conclusion

To the best of our knowledge this is the first large, population-based Canadian study addressing associations between acute care visits and pneumococcal vaccination in the elderly, including factors associated with vaccination. Other localities in Alberta may similarly leverage their population-based administrative data sources to identify acute care PPV vaccination opportunities for the elderly.

We found that acute care visits were associated with greater PPV uptake in the elderly during influenza season and long hospital stays. However, most unvaccinated elderly continue to access acute care services in Calgary without receiving PPV. Though most PPV is administered by primary care and public health in the community, community-driven vaccination efforts have been unable to raise population coverage rates towards national consensus targets. Given the large number of unvaccinated elderly that access acute care each year in Calgary, our findings suggest there is an opportunity to increase population coverage rates for the elderly by launching PPV vaccination initiatives in acute care settings.

Future research may provide further insight into how to target these interventions.

Suggested areas of focus include:

- a) Determination of patient, provider and health system barriers associated with PPV uptake in acute care settings in Calgary.
- b) Trial of an intervention to increase PPV vaccination in acute care settings in Calgary.

There is a strong evidence-base around acute care interventions to improve PPV

- vaccine coverage in these settings and commonly cited interventions include patient and provider education, point-of-care and advance reminders, and standing orders.
- c) Evaluation of IPD-related morbidity and mortality associated with elderly in our study who accessed acute care but did not receive PPV vaccine. Though there is strong evidence underlying the cost-effectiveness of PPV vaccination, local context would provide a catalyst for intervention.
 - d) Analysis of the association between GP visits and PPV vaccination using a similar study design with the use of physician claims data in place of acute care databases. Combining results with this study would more fully characterize PPV vaccine delivery in Calgary and may inform community-based or whole population-level interventions.

There is an urgent need to increase uptake of pneumococcal vaccination in the elderly to protect against invasive pneumococcal disease. Specifically, IPD continues to cause a high burden of disease in the elderly, a growing proportion of elderly are predicted in coming years and drug-resistant pneumococcal strains are emerging. It is hoped that this study and the suggested future research will contribute to interventions to increase PPV coverage rates and further protect the health of the elderly.

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Appendix A. ICD-10 Charlson Comorbidities

Comorbidities	ICD-10 Codes
Myocardial infarction	I21.x, I22.x, I25.2
Congestive heart failure	I09.9, I11.0, I13.0, I13.2, I25.5, I42.0, I42.5-I42.9, I43.x, I50.x, P29.0
Peripheral vascular disease	I70.x, I71.x, I73.1, I73.8, I73.9, I77.1, I79.0, I79.2, K55.1, K55.8, K55.9, Z95.8, Z95.9
Cerebrovascular disease	G45.x, G46.x, H34.0, I60.x--I69.x
Dementia	F00.x--F03.x, F05.1, G30.x, G31.1
Chronic pulmonary disease	I27.8, I27.9, J40.x--J47.x, J60.x--J67.x, J68.4, J70.1, J70.3
Rheumatic disease	M05.x, M06.x, M31.5, M32.x--M34.x, M35.1, M35.3, M36.0
Peptic ulcer disease	K25.x--K28.x
Mild liver disease	B18.x, K70.0--K70.3, K70.9, K71.3--K71.5, K71.7, K73.x, K74.x, K76.0, K76.2--K76.4, K76.8, K76.9, Z94.4
Diabetes without chronic complication	E10.0, E10.1, E10.6, E10.8, E10.9, E11.0, E11.1, E11.6, E11.8, E11.9, E12.0, E12.1, E12.6, E12.8, E12.9, E13.0, E13.1, E13.6, E13.8, E13.9, E14.0, E14.1, E14.6, E14.8, E14.9
Diabetes with chronic complication	E10.2--E10.5, E10.7, E11.2, E11.5, E11.7, E12.2--E12.5, E12.7, E13.2--E13.5, E13.7, E14.2--E14.5, E14.7
Hemiplegia or paraplegia	G04.1, G11.4, G80.1, G80.2, G81.x, G82.x, G83.0--G83.4, G83.9
Renal disease	I12.0, I13.1, N03.2--N03.7, N05.2--N05.7, N18.x, N19.x, N25.0, Z49.0--Z49.2, Z94.0, Z99.2
Any malignancy, including lymphoma and leukemia, except malignant neoplasm of skin	C00.x--C26.x, C30.x--C34.x, C37.x--C41.x, C43.x, C45.x--C58.x, C60.x--C76.x, C81.x--C85.x, C88.x, C90.x--C97.x
Moderate or severe liver disease	I85.0, I85.9, I86.4, I98.2, K70.4, K71.1, K72.1, K72.9, K76.5, K76.6, K76.7
Metastatic solid tumor	C77.x--C80.x
AIDS/HIV	B20.x--B22.x, B24.x

Appendix B. ICD-10 Mental, Behavioral and Neurodevelopmental Disorders

Disorders	ICD-10 Coding
Mental disorders due to known physiological conditions	F01-F09
Mental and behavioral disorders due to psychoactive substance use	F10-F19
Schizophrenia, schizotypal, delusional, and other non-mood psychotic disorders	F20-F29
Mood [affective] disorders	F30-F39
Anxiety, dissociative, stress-related, somatoform and other nonpsychotic mental disorders	F40-F48
Behavioral syndromes associated with physiological disturbances and physical factors	F50-F59
Disorders of adult personality and behavior	F60-F69
Intellectual disabilities	F70-F79
Pervasive and specific developmental disorders	F80-F89
Behavioral and emotional disorders with onset usually occurring in childhood and adolescence	F90-F98
Unspecified mental disorder	F99-F99