Modeling the Impact of Needle Exchange Programs Accounting for both HIV and HCV Infections and HIV/CV Co-Infections

by

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Abstract

Purpose: The aim of this study is to model the impact of needle exchange interventions on human immunodeficiency virus (HIV) and hepatitis C virus (HCV).

Methods: In order to model the impact of needle exchange interventions, behavioural effects (sexual and drug use) were translated into estimates of the number of HIV and HCV cases averted by the programs through a mathematical model. Behavioural effects data on 63 clients had been collected previously by two Health Units in Ontario. The secondary data were analyzed to estimate the number of HIV and HCV cases averted while accounting for co-infection. A Bernoulli process model was used to estimate the number of averted cases for the condom distribution and counselling aspects of the needle exchange intervention. A modification of the Bernoulli process model was used for needle exchange interventions to account for drug use behaviours. Furthermore, this model estimated the number of cases averted while also accounting for the clients' partner's co-infection status. Once the number of HIV and HCV cases averted was determined, a cost analysis was conducted to estimate the net medical savings of the interventions. Costs were converted to 2011 Canadian dollars.

Results: Of the 63 clients, 21.40 HIV and 5.18 HCV cases were directly averted by the needle exchange intervention when HIV/HCV co-infection status of the partner was not taken into account. When the clients' partners' co-infection status was taken into account, lesser numbers were directly averted by the needle exchange intervention. The discounted medical savings averted were $6,950,028 and $6,741,331 when co-infection was and was not accounted for, respectively, for the 63 individuals.

Conclusion: The study demonstrated a different modeling method to account for HIV and HCV cases averted in the context of needle exchange. This study provides a foundation for future large scale cost-effectiveness studies.

Acknowledgement

I would like to thank my two supervisors, Prof. Ana Johnson and Prof. Beatriz Alvarado for being patient with me as I try to continue my thesis throughout law school. While we may sometimes have different views, I am grateful for their guidance and support for everything they have done. Their wisdom and experience have been helpful through my journey. I am also grateful to the Ontario Government and the Department of Public Health Sciences for their financial support for completing my degree.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

HIV	Human Immunodeficiency Virus
AIDS	Acquired Immunodeficiency Syndrome
HCV	Hepatitis C Virus
MSM	Men who have Sex with Men
IDU	Injection Drug User
CA Dollars	Canadian Dollars
STI	Sexually Transmitted Infection

Chapter 1:

Introduction

1.1 Background

Human immunodeficiency virus (HIV), a retrovirus, is known to attack immune cells to cause acquired immunodeficiency syndrome (AIDS), a condition in humans in which progressive failure of the immune system allows life-threatening opportunistic infections and cancers to eventually kill the host.[1-3] Approximately 68,000 Canadians are currently affected by HIV/AIDS with an estimated 2,300-4,300 new cases of HIV reported in 2009.[4] There is no cure for HIV, and treatment usually consists of highly active antiretroviral therapy amounting in the direct costs of medical treatment for HIV/AIDS to be estimated at $257,984 (2011 CA dollars) per case over a lifetime.[5] The annual cost of medical treatment in Canada is estimated at $768,120,000 for HIV for all the cases.[6] Recent data indicate that HIV prevalence is increasing in Aboriginal People and female populations and remains underdiagnosed in Men who have Sex with Men (MSM) and injection drug users (IDUs).[7] In 2008, the Public Health Agency of Canada estimated that 19% of infected MSM and 25% of infected IDUs were unaware of their HIV infection.[8] Due to the way HIV is transmitted, and because of its profound impact on the immune system, it is often accompanied by co-infections such as hepatitis C virus (HCV).[9-23]

Hepatitis C is a chronic liver disease caused by the hepatitis C virus (HCV).[24] In 2009, an estimated 250,000 people in Canada were infected with HCV.[24] According to the Public Health Agency of Canada, there were 11,357 new cases of hepatitis C among Canadians with 63.6% (7,223 cases) among men in 2009.[25] Currently, being an injection drug user (IDU) is the

dominant risk factor for HCV transmission in Canada and is implicated in 70-80% of recent HCV cases.[26] As of 2008, the number of Canadians co-infected with HIV and HCV is about 13,000.[27, 28] Current treatment usually involves a combination of pegylated interferon and ribavirin to remove the virus from the body with liver transplant as an alternative to critical conditions.[29] Poret *et al.* estimated the average cost of treating an individual in the first year following diagnosis of HCV to be approximately $13,737 (2011 CAN dollars) in direct medical costs while a 2005 paper predicted Canada's annual economic burden of HCV to be 135 million dollars by 2015.[30,31]

There is a large risk of co-infection between HIV and HCV especially among drug injection users.[19, 23, 27, 32-37] The prevalence of HIV among HCV incidence is currently at 50-90% among IDUs within 5 years.[27, 36, 37] While not entirely clear, there is evidence that there is some attributable effect of HIV on HCV and HCV on HIV because when on disease is present, the prevalence of the other is also higher.[27, 36, 37]

1.2 Ontario's Public Health Programs

In Ontario, there are 36 public health units that administer health promotion and disease prevention programs including programs for STI prevention.[38] According to the Ministry of Health and Long-Term Care, a public health unit "is an official health agency established by a group of urban and rural municipalities to provide a more efficient community health program, carried out by full time, specially qualified staff".[38] In Ontario, public health units are required, under the Mandatory Health Programs and Service Guidelines to reduce the incidence of and complications from all STIs, including HIV/AIDS.[39] Current public health unit programs focus on the prevention, diagnosis, and treatment of STIs and are organized regionally.[40] While public health units are instructed to use specific interventions (i.e., needle exchange interventions,

condom distributions, health clinics) for achieving this goal, questions remain regarding these methods' actual cost-effectiveness at stopping the spread of disease.[41] Public health units need accurate information on the costs and effectiveness of interventions to limit STI and HCV transmission so that they can make sound resource allocation decisions.[42, 43]

1.3 Purpose

The purpose of this project was to model the impact of needle exchange interventions on human immunodeficiency virus (HIV) and hepatitis C virus (HCV). This thesis will present a modelling exercise of measuring the impact of needle exchange programs. The primary goal of a needle exchange intervention is reducing the number of contaminated needles that targets preventing HIV and HCV. Hence, other STIs will not be considered in the model for co-infection. The needle exchange interventions that are being examined have two main components that will affect HIV and/or HCV transmission rate based on changes in sexual and drug behaviour: (1) providing condoms and counselling which will only affect HIV cases averted due to sexual behaviour changes, and (2) providing clean needles and counselling which will affect both HIV and HCV cases averted due to drug use behaviour changes.

1.4 Objectives

To examine the needle exchange's impact on reducing HIV and HCV infections, as well as HIV infections attributable to HCV and HCV infections attributable to HIV.

(1) This study used mathematical models to calculate the number of preventable cases of:

- HIV, due to changes in sexual behaviour (number of partners, condom use, and sexual acts) resulting from the condom distribution and counselling components of the needle exchange intervention;

- HIV, due to changes in drug risk behaviour (number of partners sharing needles, number of drug injections with cleaned and unclean needles) resulting from the needle exchange component of the needle exchange intervention;
- HCV, due to changes in drug risk behaviour (number of partners sharing needles, number of drug injections with cleaned and unclean needles) resulting from the needle exchange component of the needle exchange intervention;
- HIV from drug risk behaviour attributable to HCV and HCV from drug risk behaviour attributable to HIV.

(2) This study estimated medical care costs saved due to the needle exchange intervention with regards to HIV and HCV cases averted.

Chapter 2:

Literature Review:

2.1 Needle Exchange Programs

Needle exchange programs (NEPs) reduce the risk of HIV and HCV by increasing access to sterile needles and syringes, removing dirty needles that are in circulation and educating injecting drug users about the risks of sharing contaminated needles.[44] The reasoning for providing sterile needles is that by reducing risky drug behaviours like needle sharing there is a probability of reducing transmission of HIV and HCV.[44] Furthermore, by increasing the safe disposal of used needles, the used needles are not being shared in the community.[44] Next, NEPs help injection drug users in obtaining drug information, treatment, and primary health care.[44]

According to the Ontario Harm Reduction Distribution Program (OHRDP), from a cost perspective, NEPs reduce the health risks to the injector, which "can be costly to heal if the individual ends up in the emergency department with an illness that could have been prevented by having access to clean sterile equipment".[45] OHRDP also claims that "providing the needed equipment for safe injection, injectors have contact with health service staff which can contribute to a stabilization or improvement in their general health and social functioning".[45] Within Ontario, all 36 of the health units are licensed to use needle exchange programs.

The first needle exchange program in the world was offered 1984 located in Amsterdam, the Netherlands.[46] The idea was that these programs were not meant for curing the addiction but for reducing the harm injection drug users do to themselves and their community.[46] The first needle exchange program in Canada opened in Vancouver in 1989 followed by Toronto and Montreal shortly after. [47]

Strike *et al.* reported over 3.2 million clean syringes distributed in Toronto to about 41, 000 drug injection users in 2006.[44] Some reasons needle exchange programs are good public policy are (1) the program reduce transmission of HIV and HCV among injection drug users (IDUs), (2) the program reduces unsafe drug use and sexual behaviours associates with the transmission of HIV and HCV, (3) the program reduces the number of used needles discarded in the community, (4) the program does not encourage initiation of injection drug use, (5) the program does not increase the duration or the frequency of injection drug use, (6) the program does not decrease the motivation to reduce drug use, (7) it is more cost-effective to pay the operational costs of the needle exchange programs than pay the lifetime costs of providing treatments to injection drug users, (8) and needle exchange programs are usually the only contact between injection drug users who do not receive medical treatment and health service providers.[44, 48-55]

While there is some debate regarding negative side effects of needle exchange programs, past studies have not found evidence of greater injection frequency, increased illicit drug use, a rise in syringe lending to other IDUs, recruitment of new IDUs, greater numbers of discarded used needles, less motivation to change (i.e., reduce) drug use, or increased transition from noninjecting drug use to IDU.[56-65] A study by Ksobiech found that return rates of used needles worldwide is about 90% due to needle exchange programs.[66] This high return rate means there is a lower probability of dirty needles circulating in the community which results in a higher likelihood that drug injection users are using clean, sterile needles.[66] Needle exchange programs have been associated with decreased levels of needle sharing and decreased risky injecting behaviours.[44, 67]

2.2 Prevention Effectiveness: Evidence and Limitations

A literature search was conducted among reviews for evidence of needle exchange programs reducing the incidence of HIV and/or HCV (see figure 1). The search strategy located studies using CINAHL, Embase, Cochrane, and MEDLINE). For inclusion criteria, the studies had to (1) have data concerning IDUs who use needle exchange programs, (2) have data on needle exchange usage information on IDUs, (3) include effectiveness of needle exchange programs taking into account HIV or HCV (4) be review articles and published no earlier than the year 1990. Articles earlier than 1990 and not in English are excluded. The key words used included 'needle exchange program and HIV' or 'needle exchange programs and HCV'. Thirty one articles included needle exchange programs and HIV while 137 articles were found for needle exchange programs and HCV. Combined, there were 163 articles (excluding duplicates) and when limited by exclusion criteria, 146 articles remained. A summary of the studies is presented in Table 1. Other reviews indicate that needle exchange programs reduce HIV and HCV transmission, especially for injection drug users (IDUs).[67-69]

From the literature review, the longitudinal review studies all show that NEP decrease the harm, prevalence, or indirect protective effect on HIV or HCV.[49, 51, 70] The general direction the studies from the literature review show are either the prevalence of HIV or HCV decreased when using needle exchange programmes or that the adjusted odds ratio decreased for transmitting HIV or HCV when using needle exchange programmes.[48-55, 70-84] The literature was not able to find out which type of settings worked best.[85] While the review study by Jones *et al*. did find that the needle exchange programmes did reduce HCV, they were unable to determine which type of settings and approach worked best for the needle exchange programme.[85]

Some limitations are that most reviews focused on the impact of HIV in measuring the effectiveness of the interventions, rather than HCV so we do not have as much knowledge on HCV as HIV.[68, 69] Wodak *et al.* published the first international review examining the evidence of needle exchange programs in the reduction of HIV infection among injection drug users.[69] While the review found significant evidence of reduced HIV infection from needle exchange programs, the review lacks information regarding HCV.[69] Furthermore, the reviews did not account for co-infection of HIV and HCV.[67] While there has been some studies that have explored the co-infection between HIV and syphilis, no study has incorporated the co-infection between HIV and HCV. [62, 63] These studies have incorporated multiplicative factors to the probability of transmission to account for the co-infection between HIV and syphilis.[62, 63] No previous work has shown an increased probability of transmission for the co-infection between HIV and HCV. Past literature has indicated the prevalence of HIV among HCV incidence is currently at 50-90% among IDUs within 5 years.[27, 36, 37] In sum, evidence from the reviews of intervention studies show that needle exchange interventions significantly reduce the risk of HIV and HCV.[67-69] There is a large risk of co-infection between HIV and HCV especially among drug injection users that should be explored.[19, 23, 27, 32-37]

Figure 1. Flow Chart of Literature Search of Evidence of Needle Exchange Programs

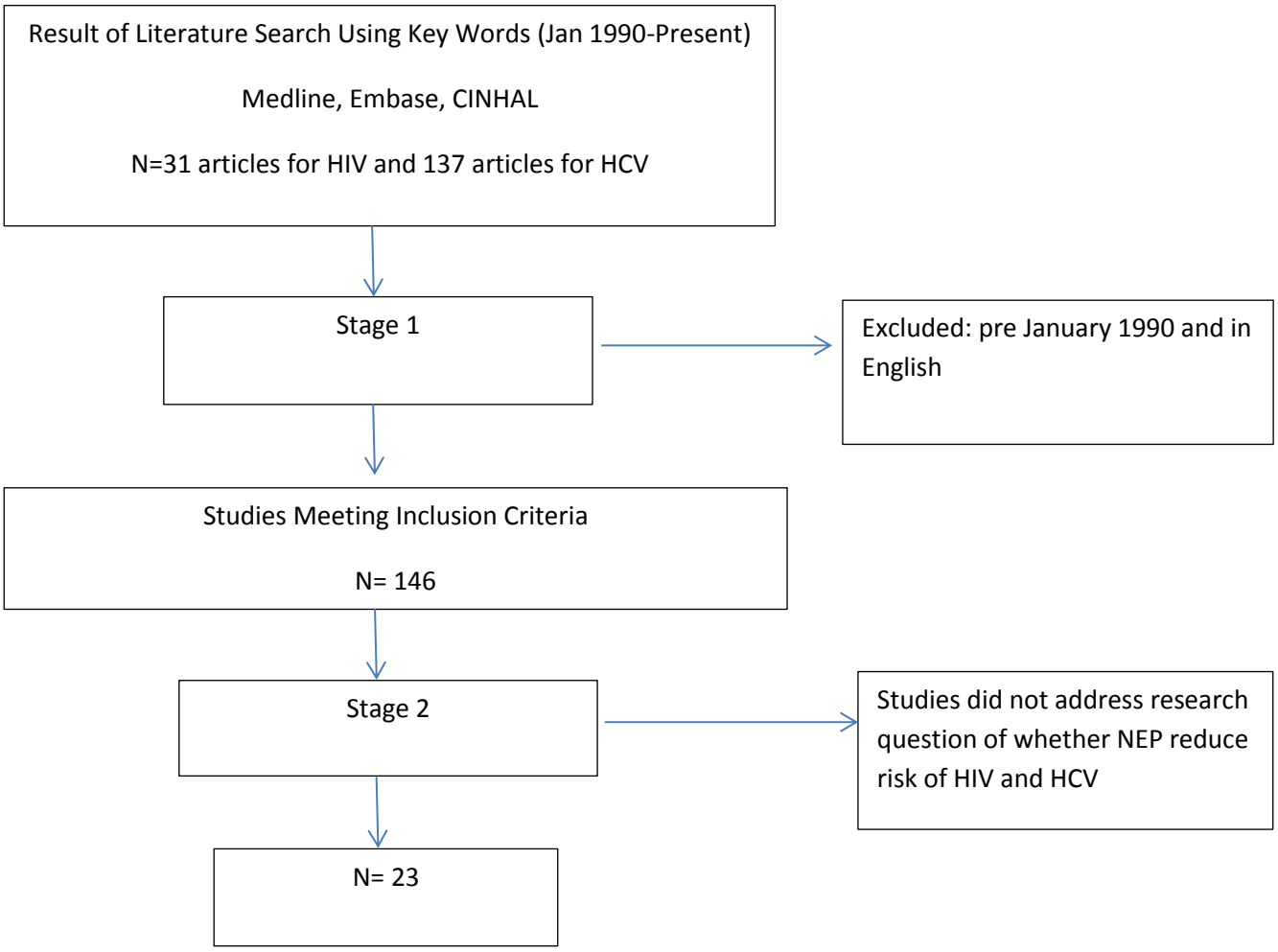


Table 1. Summary of Review and Meta-Analysis Search for Impact of Needle Exchange Interventions among Drug Injection Users for Reducing Human Immunodeficiency Virus (HIV) and Hepatitis C Virus (HCV)

Author	Study Design & Size	Article	Purpose	Results	Conclusion
Bayoumi & Zaric[71]	Simulation model of a dynamic compartmental model to simulate the population of Vancouver, British Columbia (n=3 000 to 20 000)	The cost-effectiveness of Vancouver's supervised injection facility.	To estimate the impact of the facility on survival, rates of HIV and hepatitis C virus infection in Canada's only supervised injection facility	The facility was associated with an incremental net savings of almost $14 million and 920 life-years gained over 10 years	Vancouver's supervised injection site is associated with improved health and cost savings, even with conservative estimates of efficacy.
Des Jarlais *et al.*[72]	Review of cross sectional study (n=72 for 1990-1991 and n = 412 for 2000-2001)	Reductions in hepatitis C virus and HIV infections among injecting drug users in New York City, 1990-2001	To assess the trends in HIV and HCV among IDUs from 1990 to 2001 in New York City while including the effects of the needle exchange program that was established in this time period	HIV prevalence declined from 54 to 13%. HCV prevalence declined from 80 to 59% among HIV-seronegative individuals, and from 90 to 63% overall	The Needle exchange program was temporally associated with the decrease in HIV and HCV prevalence in New York City
Dolan *et al.*[48]	Review of pilot exploratory study N = 1345	Prison-based syringe exchange programmes: a review of international research and development	6 evaluations of prison syringe exchange interventions among drug users in prisoners.	Reports of drug use decreased or remained stable over time. Reports of syringe sharing declined dramatically. No new cases of HIV, hepatitis B or hepatitis C transmission were reported. The evaluations found no reports of serious unintended negative events, such as initiation of injection or of the use of needles as weapons.	Indicated that prison syringe exchange programmes are feasible and do provide benefit in the reduction of risk behaviour and the transmission of blood-borne infection without any unintended negative consequences
Emmanuelli & Deseclos[49]	Longitudinal study Sample size not applicable	Harm reduction interventions, behaviours and associated health outcomes in France, 1996-2003	To track the effect of the French harm reduction programme targeted at intravenous drug users (IDUs) and associated health outcomes	HIV prevalence among IDUs decreased from 40% to 20% and HCV prevalence remained high (60-70%)	Harm reduction have positive effect on reducing HIV.
Gibson *et al.* [50]	Review of prospective cohort study (n = 259)	Two- to sixfold decreased odds of HIV risk behavior associated with use of syringe exchange.	Compared the HIV risk behavior of exchange clients with that of nonclients in a needle exchange program	Both univariate and multivariate analyses revealed a more than twofold decreased odds of HIV risk behavior associated with use of the exchange. In a second multivariate analysis, which examined the interaction of exchange use with access to other sources of syringes, the odds of HIV risk behavior were decreased more than sixfold for IDUs without other sources	Use of the exchange had a substantial protective effect against HIV risk behavior and may have been especially critical for IDUs without other sources of syringes
Golberg	Longitudinal Study	Trends in HCV	We set out to ascertain if the anti-	Among Edinburgh's	Needle exchange

et al. [51]	Sample size not applicable	prevalence among injecting drug users in Glasgow and Edinburgh during the era of needle/syringe exchange.	HCV prevalence among injectors from Edinburgh had declined with the era of needle syringe exchange program	injectors, significant ($p < 0.0001$) decreases in anti-HCV prevalence from 69% (1989/90) to 13% (1997) and from 80% (1989/90) to 54% (1997) were seen in those aged < 25 y and > or = 25 y, respectively. Among Glasgow's injectors, a significant ($p < 0.0001$) decrease in prevalence from 91% (1990) to 43% (1997) was seen only among those aged < 25 y.	program is associated with the decrease in prevalence
Hagan *et al.* [73]	Review of case control study N = 38 and 26 for Hepatitis B and C respectively	Reduced risk of hepatitis B and hepatitis C among injection drug users in the Tacoma syringe exchange program	To examine the association between syringe exchange use and hepatitis B and C in injection drug users	After adjustment for demographic characteristics and duration of injecting drugs, nonuse of the exchange was associated with a sixfold greater risk of hepatitis B (odds ratio [OR] = 5.5; 95% confidence interval [CI] = 1.5, 20.4) and a sevenfold greater risk of hepatitis C (OR = 7.3; 95% CI = 1.6, 32.8)	The results suggest that use of the exchange led to a significant reduction in hepatitis B and hepatitis C in the county and may have also prevented a substantial proportion of human immunodeficiency virus infections in injection drug users
Hagan *et al.* [74]	Review of prospective cohort N = 187 and 460 for Hepatitis C and B respectively	Syringe exchange an d risk of infection with hepatitis B and C viruses.	To assess whether participation in a syringe exchange program was associated with incidence of hepatitis B virus (HBV) and hepatitis C virus (HCV) infection	Need exchange had no protection against HCV infection (sporadic users, RR = 2.6, 95% CI 0.8-8.5; regular users, RR = 1.3, 95% CI 0.8-2.2; vs. RR = 1.0 for nonusers	No evidence to conclude the needle exchange program had a protective effect against HCV
Hagan *et al.* [75]	Review of prospective cohort N = 2208	Changes in injection risk behavior associated with participation in the Seattle needle-exchange program	To understand in greater detail the lack of an association between exchange use and risk of hepatitis B or C virus transmission	Lower likelihood of injection with a used syringe (AOR = 0.7, 95% confidence limit 0.5, 0.9). There was no association between exchange use and cooker or cotton sharing (AOR = 0.8, 95% confidence limit 0.6, 1.1) or betweenexchange use and use of a common syringe to divide drugs (AOR = 0.9)	Risk reduction measures adopted by users may not be sufficient to prevent transmission of all blood-borne viruses, including hepatitis C virus.
Heimer *et al.*[52]	Ecological Study Sample size varied from 48 to 398	Needle exchange decreases the prevalence of HIV-1 proviral DNA in returned syringes in New Haven, Connecticut.	To report on the deployment of the syringe tracking and testing system in the New Haven needle exchange program	Prevalence decreased rapidly to less than 45% during the first 3 months of the program and remained at this level for the following 10 months	The needle exchange program in New Haven has decreased the percentage of syringes testing positive for HIV-1 proviral DNA among needle exchange clients while simultaneously serving as an entry

					point for drug treatment
Holtzman *et al.* [70]	Longitudinal Study N = 4663	The influence of needle exchange programs on injection risk behaviors and infection with hepatitis C virus among young injection drug users in select cities in the United States, 1994-2004	To assess whether participation in needle exchange programs (NEPs) influenced incident hepatitis C virus (HCV) infection through effects on injection risk behaviors among young injection drug users (IDUs) in the United States	Multivariate results showed no significant relationship between NEP use and HCV seroconversion. Controlling for sociodemographic characteristics, IDUs reporting NEP use were significantly less likely to share needles (aOR=0.77, 95% CI=0.67-0.88).	Results suggest an indirect protective effect of NEP use on HCV infection by reducing risk behavior
Hurley *et al.* [53]	Ecological Study N = 52	Effectiveness of needle-exchange programmes for prevention of HIV infection	Used an ecological study design to compare changes over time in HIV seroprevalence in injecting drug users worldwide, for cities with and without NEPs	Seroprevalence increased by 5.9% per year in the 52 cities without NEPs, and decreased by 5.8% per year in the 29 cities with NEPs. The average annual change in seroprevalence was 11% lower in cities with NEPs (95% CI -17.6 to -3.9, p = 0.004)	Needle exchange programmes is strongly associated with the decrease in HIV seroprevalence despite the possibility of confounding. Strongly support needle exchange programs are effective
Jones *et al.* .[76]	Systematic Review 11 studies	Optimal provision of needle and syringe programmes for injecting drug users: A systematic review	This systematic review sought to determine which approaches to the organisation and delivery of NSPs are effective for reducing HCV	Based on 11 studies there was no evidence of an impact of different NSP settings or syringe dispensation policies on drug injecting behaviours, but mobile van sites and vending machines appeared to attract younger IDUs and IDUs with higher risk profiles	Difficult to draw conclusions on 'what works best' within the range of harm reduction services available to IDUs
Kwon *et al.* [54]	Simulation model N = estimated population size of IDU in Australia (215, 000)	The impact of needle and syringe programs on HIV and HCV transmissions in injecting drug users in Australia: a model-based analysis	Estimate how changes in sterile syringe distribution through needle-syringe programs (NSPs) may affect HIV and hepatitis C virus (HCV) incidence among injecting drug users (IDUs) in Australia	HIV is effectively controlled through NSP distribution of sterile syringes {with the effective reproduction ratio below 1 [0.66 median, interquartile range (0.63-0.70)] under current syringe distribution}. In contrast, HCV incidence is expected to remain high and its control is not feasible in the foreseeable future. estimate that if syringe distribution or coverage doubled, then annual incidence is likely to reduce by 50%. However, if it was decreased to one third of the current level, then approximately 3 times the incidence could be expected	Research highlights the large benefits of NSPs, puts forward a quantitative relationship between incidence and syringe distribution, and indicates that increased coverage could result in significant reductions in viral transmissions among IDUs
Lamden	Retrospective cross sectional study	Hepatitis B and hepatitis C virus	To evaluate the effect of both needle exchange and hepatitis B	No independent protective effect for	Hepatitis C is highly prevalent among

et al. [77]	N = 773	infections: risk factors among drug users in Northwest England	vaccination on the prevalence of hepatitis B and hepatitis C infections.	either anti-HBc or anti-HCV acquisition was found after the introduction of a needle-exchange scheme	Merseyside drug users and is likely to prove difficult to control because of rapid acquisition early in the injecting career
MacDonald *et al.*[55]	Ecological Study N = 99 cities and 778 years of data	Effectiveness of needle and syringe programs for prevention HIV transmission	To examine the effectiveness of needle and syringe programmes (NSPs) in preventing HIV transmission among injecting drug users	HIV prevalence decreased by 18.6% per annum in cities that introduced NSPs, and increased by 8.1% in cities that had never introduced NSPs (mean difference −24.7% [95% CI: −43.8, 0.5%], P = 0.06). The mean difference was –33% when comparison was weighted to one over the variance of the regression estimator (29% decreasein cities with NSPs and 5% increase in cities without NSPs,P < 0.001). When analysis was restricted to cities with first HIV seroprevalence less than 10%, the average annual change in seroprevalence was 18% lower in cities with NSPs (P = 0.03).	Study provides additional evidence that NSPs reduce transmission of HIV infection
MacDonald *et al.* [78]	Cross sectional study N = 979 clients in 1995, 1463 in 1996 and 1699 in 1997	Hepatitis C virus antibody prevalence among injecting drug users at selected needle and syringe programs in Australia, 1995-1997	To describe point prevalence of HCV antibody and relevant risk behaviour among people who inject drugs and who attended selected needle and syringe programs throughout Australia in 1995, 1996 and 1997.	HCV prevalence declined significantly from 63% in 1995 to 51% in 1996 and 50% in 1997 (P < 0.001). Among respondents who reported injecting for less than three years, prevalence declined from 22% in 1995 to 13% in 1996 and 1997 (P < 0.001). Reported use of needles and syringes after someone else in the previous month declined from 31% in 1995 and 28% in 1996 to 15% in 1997 (P < 0.001).	Significant decrease in HCV prevalence with the needle exchange intervention
Mannsson *et al.* [79]	Cohort incidence study N = 698	Continued transmission of hepatitis B and C viruses, but no transmission of human immunodeficiency virus among intravenous drug users participating in a syringe/needle exchange program	To examine the virological efficacy of a syringe/needle exchange program was evaluated in a cohort incidence study	Adequate follow-up was possible in 515 (74%) and showed no new cases of HIV infection during a median of 31 months. Multiple logistic regression analysis showed hepatitis seroconversion to correlate with frequent syringe/needle exchanges (OR 1.31; CI 1.02-1.7).	The absence of HIV spread was probably partly due to the low prevalence of HIV-infected IVDUs in the city. Despite free syringes and needles, HCV continued to spread at high rates

Neaigus *et al.* [80]	Ecological Study N = 326	Greater drug injecting risk for HIV, HBV, and HCV infection in a city where syringe exchange and pharmacy syringe distribution are illegal	This study compares the parenteral risk for HIV and hepatitis B (HBV) and C (HCV) infection among IDUs in Newark, NJ, USA, where syringe distribution programs were illegal during the period when data were collected, and New York City (NYC) where they were legal	IDUs in Newark (n = 214) vs. NYC (n = 312) were more likely to test seropositive for HIV (26% vs. 5%; AOR = 3.2; 95% CI = 1.6, 6.1), antibody to the HBV core antigen (70% vs. 27%; AOR = 4.4; 95% CI = 2.8, 6.9), and antibody to HCV (82% vs. 53%; AOR = 3.0; 95% CI = 1.8, 4.9), were less likely to obtain syringes from syringe exchange programs or pharmacies (AOR = 0.004; 95% CI = 0.001, 0.01), and were more likely to obtain syringes from street sellers (AOR = 74.0; 95% CI = 29.9, 183.2), to inject with another IDU's used syringe (AOR = 2.3; 95% CI = 1.1, 5.0), to reuse syringes (AOR = 2.99; 95% CI = 1.63, 5.50), and to not always inject once only with a new, sterile syringe that had been sealed in a wrapper (AOR = 5.4; 95% CI = 2.9, 10.3).	In localities where sterile syringe distribution is illegal, IDUs are more likely to obtain syringes from unsafe sources and to engage in injecting risk behaviors.
Taylor *et al.* [81]	Review of cross sectional study N = 1949	Prevalence of hepatitis C virus infection among injecting drug users in Glasgow 1990-1996: are current harm reduction strategies working?	To determine the prevalence of HCV antibodies among injecting drug users and to gauge the effectiveness of needle/syringe exchange in preventing the transmission of HCV infection	Respondents who began injecting after the introduction of needle/syringe exchange in the city were significantly less likely to test HCV antibody positive than those who commenced injecting prior to the advent of needle/syringe exchange, after adjusting for length of injecting career	The prevalence of HCV among injectors in Glasgow has decreased during the era of needle/syringe exchange
Turner *et al.* [82]	Meta-analysis study N = 2986	The impact of needle and syringe provision and opiate substitution therapy on the incidence of hepatitis C virus in injecting drug users: pooling of UK evidence	To investigate whether opiate substitution therapy and needle and syringe programmes can reduce hepatitis C virus transmission among injecting drug users	A pooled meta-analysis. Needle exchange coverage was associated with reduction in HCV rates (adjusted OR 0.48 and 95% CI 0.25-0.93). Also found strong evidence of opiate substitution therapy to reduce HCV rates. Combined therapy and needle exchange coverage reduced odds of HCV infection by nearly 80% (adjusted OR 0.21 and 95%CI 0.08-	Strong evidence that uptake of opiate substitution therapy and high coverage of needle and syringe programmes can substantially reduce the risk of hepatitis C virus transmission among injecting drug users

				0.52)	
Van Den Berg *et al.* [83]	Review of prospective cohort N = 714	Full participation in harm reduction programmes is associated with decreased risk for human immunodeficiency virus and hepatitis C virus: evidence from the Amsterdam Cohort Studies among drug users.	To investigate the impact of harm-reduction programmes on HIV and hepatitis C virus (HCV) incidence among ever-injecting drug users (DU) from the Amsterdam Cohort Studies (ACS)	Methadone dose or NEP use alone were not associated significantly with HIV or HCV seroconversion. However, with combination of these variables and after correction for possibly confounding variables, we found that full participation in a harm reduction programme (HRP) was associated with a lower risk of HIV and HCV infection in ever-injecting drug users (DU), compared to no participation [incidence rate ratio 0.43 (95% CI 0.21-0.87) and 0.36 (95% CI 0.13-1.03), respectively].	Full participation in harm reduction prgorammes was associated with a lower incidence of HCV and HIV infection in ever-injecting DU, indicating that combined prevention measures--but not the use of NEP or methadone alone
Wu *et al.* [84]	Prospective community randomized trial N = 1675	Evaluation of a needle social marketing strategy to control HIV among injecting drug users in China	To evaluate the effectiveness of a needle social marketing strategy to reduce needle sharing and hepatitis C Virus (HCV)/HIV transmission among injecting drug users (IDU) in China	Needle sharing behaviours were similar in the two groups at baseline (68.4 vs. 67.8%), and dropped significantly to 35.3% in the intervention community and remained relatively stable in the control community (62.3%; P < 0.001)	Needle social marketing can reduce risky injecting behaviour and HIV/HCV transmission among injecting drug users in China and should be expanded

2.3 Economic Literature: Evidence and Limitations

A literature search was conducted for cost-effectiveness of needle exchange programs for HIV and HCV (see figure 2). The search strategy located studies using CINAHL, Embase, and MEDLINE. For inclusion criteria, the studies had to (1) have data concerning IDUs who use needle exchange programs, (2) include data on effectiveness of needle exchange taking into account HIV and HCV infections, (3) be in English and published no earlier than 1990. Exclusion criteria consisted of studies that were (1) not in English, (2) published earlier than, and (3) did not address the research question. The key words used included needle exchange

programs and cost-effectiveness and cost benefit analysis. 26 articles were found to match the key words. After inclusion criteria, 9 articles remained (see Table 2).

Figure 2. Flow Chart of Literature Search for Cost Effectiveness of Needle Exchange Programs

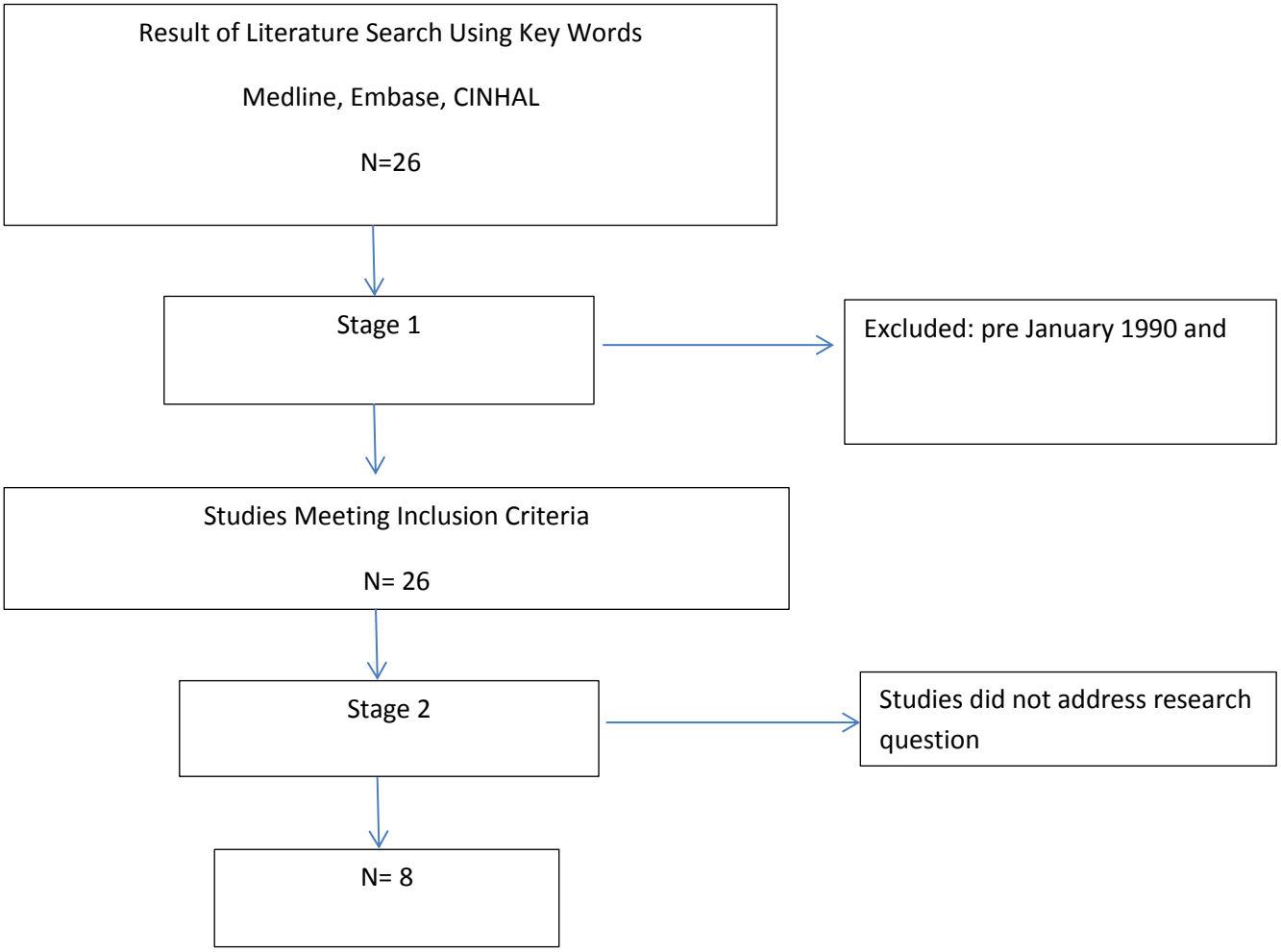


Table 2. Summary of the Literature on the Cost-Effectiveness of Needle Exchange Programs (Taking into Account Human Immunodeficiency Virus [HIV] and Hepatitis C Virus [HCV] Infections)

Author	Study Design & Size	Article	Purpose	Results	Conclusion
Andresen & Boyd[86]	Mathematical modelling	A cost-benefit and cost-effectiveness analysis of Vancouver's supervised injection facility	To conduct a cost-effectiveness and cost-benefit analysis of a supervised injection facility in Vancouver using secondary data gathered and analysed in 2008	Vancouver's SIF, Insite, on average, prevents 35 new cases of HIV and almost 3 deaths each year. This provides a societal benefit in excess of $6 million per year after the programme costs are taken into account, translating into an average benefit-cost ratio of 5.12:1.	Vancouver's SIF appears to be an effective and efficient use of public health care resources, based on a modelling study of only two specific and measurable benefits-HIV infection and overdose death
Bayoumi &		The cost-	To estimate the	The incremental net savings was	Vancouver's supervised injection site is associated

Zaric[87]		effectiveness of Vancouver's supervised injection facility.	impact of the facility on survival, rates of HIV and hepatitis C virus infection, referral to methadone maintenance treatment and associated costs	more than $18 million and the number of life-years gained was 1175.	with improved health and cost savings, even with conservative estimates of efficacy
Cohen et al.[88]		Structural interventions to prevent HIV/sexually transmitted disease: are they cost-effective for women in the southern United States?	To explores whether structural interventions may be a cost-effective way to prevent HIV in this population	The cost per HIV intervention averted was about $9 000 per case compared to most other prevention programs costing more than $10 000 per case.	Structural interventions hold the greatest promise in reducing HIV transmission among low-prevalence populations with needle exchange intervention being one of the most cost-effective options.
Jacobs et al.[89]		Cost effectiveness of Streetworks' needle exchange program of Edmonton.	To conduct a cost-effectiveness analysis of the Edmonton Streetworks needle exchange program	$9,500 (Canadian) per HIV infection delayed for one year	The discounted cost per case averted is less than the cost of a case of AIDS. Continuing the program is a dominant strategy.
Laufer[90]		Cost-effectiveness of syringe exchange as an HIV prevention strategy.	To analyze the cost-effectiveness of New York State-approved syringe exchange programs (SEPs) and estimate the cost-saving potential of these programs	A cost-effectiveness ratio of $20,947 per HIV infection averted was calculated based on an estimated 87 HIV infections averted across the seven programs and total program costs of $1.82 million (all amounts given in US dollars)	This research demonstrates that syringe exchange is a cost-effective and cost-saving strategy for reducing HIV transmission
Pinkerton[91]		Is Vancouver Canada's supervised injection facility cost-saving?	To determine whether Vancouver's Insite supervised injection facility and syringe exchange programs are cost-saving	If Insite were closed, the annual number of incident HIV infections among Vancouver IDU would be expected to increase from 179.3 to 262.8. These 83.5 preventable infections are associated with $17.6 million (Canadian) in life-time HIV-related medical care costs, greatly exceeding Insite's operating costs, which are approximately $3 million per year.	The associated savings in averted HIV-related medical care costs are more than sufficient to offset Insite's operating costs
Pollock et al.[92]		Cost-effectiveness of harm reduction in preventing hepatitis C among injection drug users	To explore the potential of syringe exchange programs (SEPs) to reduce HCV incidence and prevalence	SEP is predicted to have little impact on HCV incidence and prevalence within realistic populations of IDUs.	Short-term incidence analysis substantially overstates SEP effectiveness and cost-effectiveness in preventing HCV
Zhang et al.[34]		Needle and syringe programs in Yunnan, China yield health and financial return	data from Yunnan province, the province most affected by HIV in China, to (1) estimate the population benefits in terms of infections prevented due to the programs; (2) calculate the cost-effectiveness of NSPs	It is estimated that NSPs in Yunnan have averted approximately 16-20% (5,200-7,500 infections) of the expected HIV cases since 2002 and led to gains of 1,300-1,900 DALYs. The total $1.04 million spending on NSPs from 2002 to 2008 has resulted in an estimated cost-saving over this period of $1.38-$1.97 million due to the prevention of HIV and the associated costs of care and management.	NSPs are not only cost-effective but cost-saving in Yunnan

The literature found that needle exchange programmes are cost effective and cost saving.[34, 93-96] The bulk of the reviews were done using mathematical modelling and the general trend show that needle exchange programs required about $9000 to $21 000 to prevent a new case of HIV.[88, 90, 95] The study by Cohen *et al*. attempted to show that structural interventions are the most cost effective resulting in using only about $9000 to prevent 1 case of HIV while studies from Laufer showed that about $21 000 was required to prevent 1 case of HIV.[88, 90] Regardless of the difference presented between the studies, even at the high cost of about $21000, the price is still less expensive compared to the $257,984 (2011 CA dollars) for 1 HIV case over lifetime.[5]

However, a significant portion of the current literature focuses on the financial burden of only HIV prevention in needle exchange interventions, neglecting the economic impact of preventing HCV, thereby underestimating the impact of needle exchange programs on both infections.[34, 93-96] Only a handful of studies to date have attempted to measure the economic impact of preventing HCV in needle exchange intervention.[33, 35, 97] One HIV study that attempted to measure the economic impact of HCV is a cost-effectiveness analysis evaluating needle exchange programs in Yunan, China by Zhang *et a.l*[34] The HIV study estimated that the needle exchange programs were able to avert about 5200-7200 HIV infections during the 2002-2008 time period.[34] The study spent $1.04 million on the programs and the estimated cost-savings over the period was estimated to be $1.38-$1.97 million due to prevention of HIV and associated cost of care and management.[34] However, Zhang *et al.* acknowledged that they only concentrated on HIV and stated the actual savings would be significantly higher because HCV has a 55-80% prevalence among Chinese IDUs and the program would also limit HCV cases.[34]

An Australian report from 2000-2009 on the cost-effectiveness of needle exchange programs reported $1.28 billion (2009 AU dollars) or $1.31 billion (2011 CA dollars) in health care cost savings in the time period.[35] The initial funding for the programs was $243 million (2009 AU dollars) or $250 million (2011 CA dollars) and an estimated 32,050 new cases of HIV and 96,667 new cases of HCV were directly averted due to the programs.[35] However, all these studies base their calculation of HIV and HCV in isolation of each other.[33, 35, 97] The studies usually use a mathematical equation (such a Dynamic simulation and Bernoulli models) to calculate the number of HIV averted cases without considering the infection status of HCV.[33, 35, 97] The studies do not take into account HCV co-infection.[98, 99] Recent data show co-infection rates of HIV among HCV positive injection users to be significantly higher than the general population.[27, 36, 37] No studies have attempted to model the effect of HIV and HCV prevention that take into account co-infection. Advantages of including HCV co-infection is that a stronger accuracy of cases averted because while not entirely clear, there is evidence that there is some attributable effect of HIV on HCV and HCV on HIV.[27, 36, 37]

2.4 Rationale

There is a large burden on IDUs in Canada regarding HIV and HCV because of the health and medical burden they pose.[26, 69] The medical costs of treating HIV and HCV are significantly higher compared to the costs of implementing prevention interventions such as needle exchange programs.[6] A scan of the literature on the economics of needle exchange programs has shown that such interventions are cost-effective.[33-35, 93-97] However, no studies have taken into consideration HCV or HCV co-infection when calculating the economic benefits of these interventions. When conducting a cost-effectiveness analysis, the inclusion of savings associated

with preventing other diseases is particularly relevant among the population of injection drug users (IDUs), since they are at an increased risk of HCV.[27, 36, 37]

Hence, this study explored how co-infection affects health outcome of HIV and HCV in evaluating the cost-effectiveness of needle exchange programs through modelling. Furthermore, the feasibility of conducting these types of modeling in a large scale can be a better estimate of the effects and costs of NEP in Canada.

Chapter 3:

Methods

3.1 Existing Parent Study

3.1.1 Background

This study is part of a parent project entitled, "A Pilot Project to Evaluate the Cost-Effectiveness of Public Health Interventions to Reduce AIDS/HIV and Sexually Transmitted Infections (STIs)" (Principal Investigator: Dr. Ana Johnson) funded by Ontario HIV Treatment Network. The parent study was a pilot study designed to measure the feasibility of evaluating the cost-effectiveness of the three interventions (condom distribution, HIV and STI counselling and testing, and needle exchange) in two health units in Ontario (taking into account HIV, HCV, chlamydia, hepatitis B, syphilis, and gonorrhoea). Both behavioural data and cost data were collected. This thesis focused on the cost-effectiveness of only one type of intervention, the needle exchange interventions in the two health units taking into account HIV and HCV only. In addition, this thesis took into account HIV and HCV co-infection, whereas the parent study considered the different infections separately. Data for the needle exchange intervention were collected from two health units in two cities in South Western Ontario: Health Units A and B (population about 500,000 and 100,000 respectively).

3.1.2 Description of Interventions

Health Unit A's needle exchange intervention entailed the use of a mobile van, a fixed site, and a coalition of agencies and pharmacies. The intervention offered unlimited needle exchanges, health assessments, information and education, addiction counselling, sexual assault

counselling, and referral. Specific services include condom distribution for sex trade and personal use, Hepatitis A and B vaccination, influenza vaccine clinics, urine testing and treatment for chlamydia and gonorrhoea, anonymous HIV testing, pregnancy testing and referrals, screening and counselling for Hepatitis A, B, C. Other services included syphilis and tuberculosis, prenatal follow-up, and support for high risk women. The needle exchange program collaborates with an Aboriginal community health centre to provide on-site needle exchange outreach from the mobile van. A confidential record is kept of the number of needles a client exchanges/receives per visit. A client may exchange/receive as many an unlimited number of needles at each visit.

Health Unit B's needle exchange intervention provides unlimited needles, biohazard containers, alcohol swabs, tourniquets, condoms, health information/resources, and referrals as part of the needle exchange program. A confidential record is kept of the number of needles a client exchanges/receives per visit. Both NEPs are similar in nature as they both give out free condoms, provide counselling, and offer new, clean needles to drug injection users.

3.1.2 Data Collection Methodology

In the parent study, data were collected on sexual behavioural and drug use behaviour from a convenience sample of clients (16 years and older) from two cities from September 2005 to January 2007 (15 months). The time frame (the period each client participated in the study or time between Time 1 and 2 survey) for each individual client was 3 months. Data were collected in a needle exchange facility (drop-in centre or a mobile van). The method of recruitment was through health unit staff. The clients recruited were not new clients. The clients recruited were repeat users of the intervention because there was a greater level of trust between the clients and

the staff members. The parent study provided the sexual and drug behaviour data from the needle exchange clients. A face-to-face interview was conducted to obtain participants' information regarding their sexual and drug user behaviour in the past month (recall period 1 month). After clients were interviewed, a reminder card containing an unique identifier was given to each client for a follow-up survey three months later. Compensation gift certificates for bus, grocery, or coffee were given to each client to participate in the study. Each client received $20 worth of certificates for completing the baseline survey and an additional $25 worth of certificates for completing the follow-up survey. A total of 120 clients from 14,030 clients in the needle exchange interventions from Health Unit A and B (12,297 and 1733 respectively) in South Western Ontario were recruited, 60 from each unit. Of the initial 120 clients recruited to participate in the study, 63 clients returned for the follow-up survey.

Furthermore, in the parent study, data on intervention costs were collected for each of the interventions provided by the health units from the health care system's perspective (see Appendix IV). This data was provided by the health units themselves collected by staff workers through one on one interviews, phone interviews, or self-surveys in the interventions from the parent study.

3.1.3 Survey Data

The sexual behaviour survey included questions on the number of vaginal, anal, and oral sex acts in the previous month and number of times condoms were used during sexual intercourse in the previous month. The drug use behaviour questions were asked to determine whether or not the client shared their syringes, and the frequency they used cleaned and uncleaned syringes. Furthermore, information on demographics such as age, gender, ethnicity,

socioeconomic status, education, and whether the client participated in other interventions were collected to determine whether the service population varied significantly between those who completed the Time 2 survey and those who did not. In previous work done by George Huang (in EPID 499 project at Queen's University), the demographics of the sample population in the needle exchange interventions were analyzed to determine if there were significant differences among the patient groups who completed Time 2 and those who did not. The largest difference was the group that completed Time 2 were on average older and more educated than the group that did not complete the Time 2. A summary of these results can be found in Appendix II and Appendix III.

3.2 Study Design and Methods

3.2.1 Economic Evaluation

1**.** To satisfy Objective 1, this study translated sexual and drug behaviour outcomes into health outcomes.

2. For Objective 2, this study calculated medical care costs averted, based on the number of infections averted from Objective 1 and conducted a sensitivity analyses to assess the robustness of the results given the uncertainty surrounding various parameters.[100, 101, 102, 103]

A structural plan was needed prior to taking analytic steps. The structural plan consists of specifying the perspective of the analysis, establishing the analytic time horizon and the discount rate for costs and consequences. The present analysis adopted a health care system perspective as recommended by the Panel on Cost-Effectiveness in Health and Medicine. [100, 104, 105] The perspective of the study concerns who pays for and who benefits from the intervention.

The health care perspective does not include costs from the patient's perspective (e.g., travel, productivity loss).[100] The analytic time horizon of this study was 25 years.

Inflation can be defined as a rise in the general level of prices of goods and services in an economy over a period of time. On the other hand, discounting is a technique used in economics to convert future costs and consequences to their present value.[106] Independent from inflation, the underlying assumption is that economic resources are more highly valued in the present than in the future. The equation for calculating prevent value = future value / $(1+\text{discount rate})^{\text{time (years)}}$.[106] For example, assume that a patient needs to undergo a liver transplant 25 years from now due to chronic HCV infection, which has a one time cost of $250,000. The $250,000 is not paid now, but 25 years in the future. Hence, the future costs of $250,000 needs to be converted to present day value at a certain discount rate. Or equivalently, which amount of money today will grow to $250,000 in 25 years at a certain interest rate. Current literature recommends a discount rate of 3%.[104, 105] Present value = $\$250{,}000/ (1+0.03)^{25} = \$119{,}401.39$. Thus, the medical cost of performing a liver transplant 25 years from now at $250,000 will cost $119,401.38 today if a discount rate of 3% is used. For this study, future medical costs of treatment will be discounted to present day value (2011 dollars). Conversion of foreign currency to Canadian currency will be done by the currency exchange rates set by the Bank of Canada set on the closing month of January in 2011 dollars (i.e., 1 US dollar is equivalent to $1.0028 Canadian).[107] For currency in the past, the past value was converted to the present value with inflation rate set at 3%. If the past currency was foreign, the currency exchange took place after the past value was to 2011 value first.

3.2.2 Estimation of Effects

The number of HIV and HCV infections averted was calculated using a Bernoulli Process Model, which compared the sexual and drug behaviours of individuals before and after the intervention.[108] According to Pinkerton and Abramson, the model treats each sexual intercourse or drug injection with a shared partner as "an independent stochastic trial (like flipping a coin) that is associated with a small probability of HIV".[109] The model permits effectiveness evaluations of prevention programs targeting sexual and drug risk behaviours by using self-reported behaviours and the associated risk of transmission.[109, 110] The Bernoulli model is validated and is known to be reliable for estimating the number of HIV cases averted.[109-113]

Specifically, the number of HIV and HCV infections independently averted was calculated by estimating the expected probability of HIV and HCV infection pre-test (Time 1) and post-test (Time 2) for each participant. The difference in these expected probabilities, when summed across all participants and compared to the corresponding estimate for the comparison group, yielded the expected number of infections averted by the intervention.[113-115]

This total number of infections averted was assumed to be directly linked to the behavioural change instigated by the intervention (see Figure 1 below for flow chat). Although this type of model has been widely used to model the effectiveness of HIV prevention interventions on the number of HIV cases averted, such modeling has not been used to model the effect on HCV.[109, 110]

3.2.3 Data

The data needed for the mathematical models were obtained from the parent study and from the literature. Sexual and drug use behaviour data were obtained from the parent study and

correspond to parameters K, N, M, T in the Bernoulli Formula (See equation I or appendix II).[109, 110] Estimates were extracted from the literature for certain key parameters for HIV and HCV, as described below.

(1) For HIV, per act transmission probabilities were obtained from the literature.[101]

(2) HIV prevalence was obtained from Health Units and similar to that of literature.[109-113]

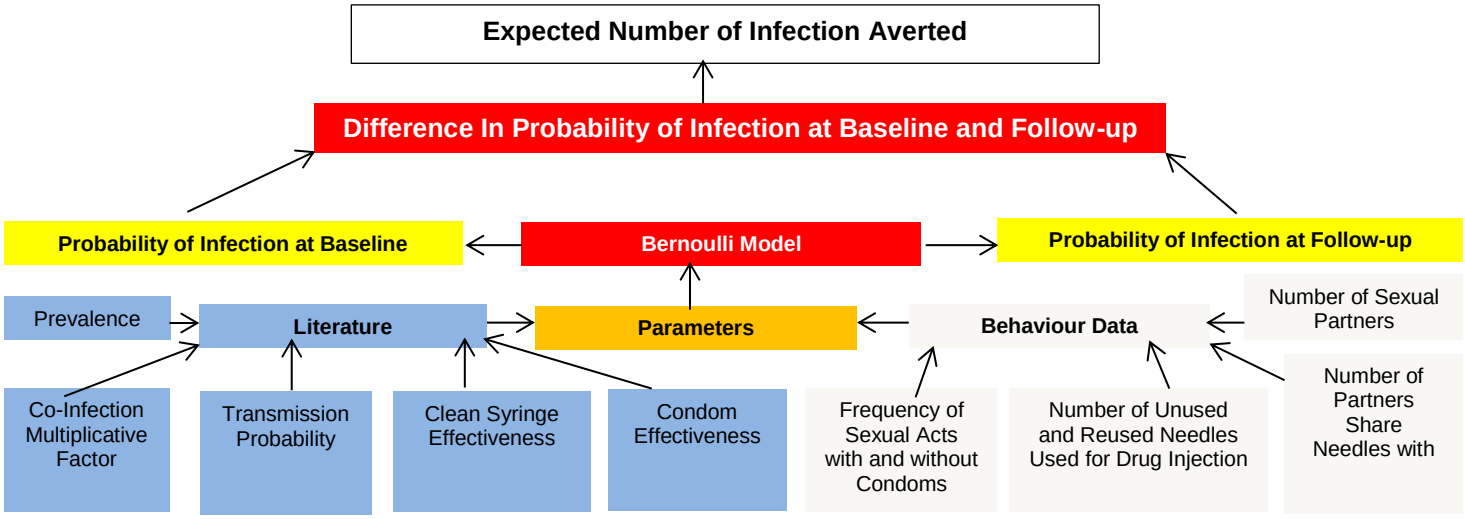
(3) Cleaning needle and syringe effectiveness values for HIV were obtained from the literature.[116]

(4) For HCV, data on per act transmission probabilities was extracted from the literature.[117]

(5) HCV prevalence was obtained from the health units.

(6) Cleaning needle and syringe effectiveness values for HCV were obtained from the literature.[116]

Figure 1: Flow Chart of Calculating Infections Averted with Bernoulli Model



3.2.4 Drug Behaviour Outcome (for Needle Exchange Component only)

The number of primary HIV or HCV infection refers to the number of uninfected individuals becoming infected with HIV or HCV. The Bernoulli-Process Model for estimating the expected probability (P) of primary HIV or HCV cases is expressed as:[109-113]

$$P = 1 - \{1 - \pi[1- (1 - \alpha_b)^k (1 - \alpha)^N]\}^M \quad \text{(Equation 1)}$$

π is the prevalence of the infection in the community, α_b is the transmission probability of infection for unused needles per drug injection, α is the probability of transmission of the infection for reused needle per drug injection, k is the number of drug injections with unused needles, and N is the number of drug injection with reused needles, and M is the number of partners with whom the individual shares needles (see Appendix V for full legend).[109-113]

Moreover, certain participants may already be infected with HIV. A similar equation to that model used above to calculate the expected number of secondary infections averted for the participant's partners was used.[109, 110] To prevent double counting of partners, an overlap factor (λ) is used to account for overlapping partnerships, or the number of partners unique to that one client.[67] This factor is used to correct for possible overlap in the sexual partnership networks of the HIV-infected men in the study.[118] Using the same variables as above, the expected number of partners an infected individual infects is expressed as:[109, 110]

$$S = M (1 - \pi) (1 - \lambda) \{1 – (1 – \alpha_b)^k (1 - \alpha)^N \} \quad \text{(Equation 2)}$$

The expected number of primary and secondary infections was calculated at baseline (P_b and S_b) and follow-up (P_p and S_p) for the intervention. The total number of expected infection per individual, I, is the sum of primary and secondary infection.[109, 110] The difference (ΔI) in the

number of expected infection at baseline and follow-up per individual is assumed to be wholly attributed to the needle exchange intervention.[109, 110]

Step 1 is to calculate the expected probability of primary infection, P_1 and secondary infection , S_1, for an individual at Time 1. Then add the two probabilities for total expected probability of infection at Time 1, A_1 expressed in the equation below:

$$A_1 = P_1 + S_1 \quad \text{(Equation 3)}$$

Step 2 is calculate the sum of the total number of HIV cases averted, A_{1T}, at Time 1 among the sample population, n, in the needle exchange intervention.

$$A_{1T} = \sum_n \quad A_{1\text{-}1} + A_{1\text{-}2} + \ldots + A_{1\text{-}n} \quad \text{(Equation 4)}$$

Step 3 is to calculate the expected probability of primary infection, P_2 and secondary infection , S_2, for an individual at Time 2. Then add the two probabilities for total expected probability of infection at Time 2, A_2 expressed in the equation below:

$$A_2 = P_2 + S_2 \quad \text{(Equation 5)}$$

Step 4 is calculate the sum of the total number of HIV cases averted, A_{2T}, at Time 2 among the sample population, n, in the needle exchange intervention.

$$A_{2T} = \sum_n \quad A_{2\text{-}1} + A_{2\text{-}2} + \ldots + A_{2\text{-}n} \quad \text{(Equation 6)}$$

Step 5 is to calculate total number of HIV cases averted that is attributable to the needle exchange intervention expressed in the equation below:

$$\Delta A = A_{1T} - A_{2T} \quad \text{(Equation 7)}$$

For example, for client # 1, if I assume that HIV prevalence in the community is equal to 0.05, HIV transmission probability is equal to 0.001 and 0 for using unclean and cleaned needles respectively, the number of partners is equal to 5, the number of unused needles is equal 20, the number of used needles is equal to 10, and overlap base factor is equal to [0.25, then the expected number of primary and secondary infections is the following (see Table 1).

Table 1: Calculating primary and secondary infection for HIV at Time 1

Primary Infection at Time 1	Secondary Infection at Time 1
$P_{1\text{-}1} = 1 - \{1 - \pi[1- (1 - \alpha_b)^k (1 - \alpha)^N]\}^M$	$S_{1\text{-}1} = M (1 - \pi) (1 - \lambda) \{1 - (1 - \alpha_b)^k (1 - \alpha)^N\}$
$P_{1\text{-}1} = 1 - \{1 - 0.05[1- (1–0)^{20} (1 – 0.001)^{10}]\}^5$	$S_{1\text{-}1} = 5 (1 – 0.05) (1\text{-}0.25)\{1 – (1 –0)^{20} (1 – 0.001)^{10}\}$
$P_{1\text{-}1} = 0.00249$	$S_{1\text{-}1} = 0.03547$

The expected infection for client #1 at Time 1, $A_{1\text{-}1,}$ is equal to $P_{1\text{-}1}+S_{1\text{-}1}$ = 0.00249+0.03547 =0.03796. For a sample of 100 clients, the expected number of infections, A_{1T}, is equal to $A_{1T}=\sum_{100} . A_{1\text{-}1 +} A_{1\text{-}2} + \ldots + A_{1\text{-}100.}$. For simplicity, assuming every other client had behaviours as client #1. This would result in everyone have the same A_1 as $A_{1\text{-}1}$. Then $A_{1T} = \sum_{100} . A_{1\text{-}1 +} A_{1\text{-}2} + \ldots + A_{1\text{-}100}$ would equal 0.03796+0.03796+…+0.03796 or 3.796.

Now if everyone's drug use behaviour changed in the Time 2 survey from the Time 1 resulting in a decrease of shared partners from 5 to 1 while everything else stayed the same, then the expected number of primary and secondary infection per individual would be 0.00050 and 0.00709 respectively resulting in the total expected HIV infection per individual to be 0.007590. Assuming all 100 individuals have the same A_2, then their expected case of HIV is $A_{2T} = \sum_{100} . A_{2\text{-}1 +} A_{2\text{-}2} + \ldots + A_{2\text{-}100}$ = 0.00759 + 0.007590 +… + 0.007590 = 0.759 cases. The last step is to calculate total number of HIV cases averted that is attributable to the needle exchange

intervention, ΔA. $\Delta A = A_{1T} - A_{2T} = 3.795 - 0.759 = 3.036$. Hence, we expected the needle exchange intervention to avert 3.036 cases of HIV.

3.2.5 Co-Infection

Given that there is a large risk of co-infection between HIV and HCV especially among drug injection users, the model presented here to account for co-infection between HIV and HCV includes different prevalence values compared with the no "co-infection" model. The prevalence of HIV is significantly higher among HCV positive individuals. [19, 23, 27, 32-37] Since literature has yet to find a co-factor effect, the model was be adjusted for the increase in prevalence of HIV among HCV positive individuals. Hence, the cumulative probability that HIV was transmitted from one partner to the other may be expressed as:[119]

$$P_{HIVHCV} = 1 - \{1 - \pi[1- (1 - \alpha_b)^k (1 - \alpha)^N]\}^M \quad \text{(Equation 8)}$$

$$S_{HIVHCV} = M (1 - \pi) (1 - \lambda) \{1 - (1 - \alpha_b)^k (1 - \alpha)^N \} \quad \text{(Equation 9)}$$

The same logic is used to look at HIV attributable effect on HCV transmission.

For illustrative purposes, using the same parameters as above (in which 3.036 HIV cases were averted), and accounting for an increase in HIV prevalence to 50% among HCV positive individuals, then I can calculate the expected number of primary and secondary infections per individual while accounting for HCV co-infection in the table below:

Table 2: Calculating primary and secondary infection for HIV while accounting for HCV co-infection at Time 1

Primary Infection Accounting for HCV Co-infection	Secondary Infection Accounting for HCV Co-infection
$P_{HIVHCV1} = 1 - \{1 - \pi[1- (1 - \alpha_b)^k (1 - \alpha)^N]\}^M$ $P_{HIVHCV1} = 1-\{1- 0.5[1- (1-0)^{20}(1- 0.001)^{10}]\}^5$ $P_{HIVHCV1} = 0.02464$	$S_{HIVHCV2}= M (1 - \pi) \{1 - (1 - \alpha_b)^k (1 - \alpha)^N \}$ $S_{HIVHCV2} = 5(1 - 0.5)(1-0.25)\{1 - (1-0)^{20} (1- 0.001*10)^{10} \}$ $S_{HIVHCV2} = 0.01867$

The total expected HIV infection, $A_{HIVHCV1-1}$ for client #1 after accounting for HCV at Time 1 would be 0.02464+0.01867=0.04331 cases. Assuming every other client in the 100 sample group also had the same $A_{HIVHCV1}$ I can calculate $A_{HIVHCV1T} = \sum_{100} . A_{HIVHCV1-1} + A_{HIVHCH1-2} + \ldots + A_{HIVHCV1-100} = 0.04331 + 0.04331 + \ldots + 0.04331 = 4.331$. Using the same parameters, if the Time 2 survey just noticed a change in partner from 5 to 1 as the above example, then the primary and secondary HIV infections expected while accounting for HCV would be 0.00498 and 0.00373 respectively. I can then calculate the total expected HIV infection averted, $A_{HIVHCV2-1,}$ to be 0.00871 for client #1 at Time 2. Assuming every other client in the 100 sample group also had the same $A_{HIVHCV1}$ I can calculate $A_{HIVHCV2T} = \sum_{100} . A_{HIVHCV2-1} + A_{HIVHCH2-2} + \ldots + A_{HIVHCV2-100} = 0.00871 + 0.00871 + \ldots + 0.00871 = 0.871$. Then I can calculate the number of cases of HIV attributable to the needle exchange intervention while accounting for HCV co-infection, $\Delta A_{HIVHCV} = A_{HIVHCV1T} - A_{HIVHCV2T} = 4.331 - 0.871 = 3.46$.

Hence, 3.460 HIV cases will be averted by the needle exchange interventions after taking into account HCV co-infection. This predicted value is slightly higher than the number of HIV cases averted (3.036) predicted without accounting for HCV co-infection. The difference between the sum that does include and not include HCV co-infection (3.460) is the attributable effect of HCV co-infection on HIV transmission on each average individual. However, this

number assumes that 100% of individuals are HCV infected which is not the case. Assuming that the prevalence of HCV is 0.1 among the community then the true value of HIV averted can be expressed as follows:

$$\Delta A_{true} = (1-\pi_{HCV})\Delta A_{HIV} + \pi_{HCV}\Delta A_{HIVHCV} \quad \text{(Equation 10)}$$

$$\Delta A_{true} = (1-0.1)\ 3.460 + (0.1)\ 3.460$$

$$\Delta A_{true} = 3.078$$

Hence, without accounting for co-infection, for 100 individuals, the example would have shown the needle exchange intervention would have prevented about 3.036 cases of HIV as opposed to 3.078 cases of HIV had HCV co-infection been taken into account. Using the example parameters above, an extra 0.042 HIV (1.4% increase) case was shown to be averted by the intervention by taking into account HCV co-infection compared to not account for it.

3.2.6 Sexual Behaviour Outcome (for Condom Distribution Component)

The following model was used for calculating the number primary and secondary HIV infections expected is expressed as:[109-113]

$$P = 1 - \{1 - \pi[1- (1 - [1-Z]\alpha)^{L} (1 - \alpha)^{Q}]\}^{R} \quad \text{(Equation 11)}$$

$$S = R\ (1 - \pi)\ (1 - \lambda)\ \{1 - (1 - [1-Z]\alpha)^{L} (1 - \alpha)^{R}\} \quad \text{(Equation 12)}$$

where π is the prevalence of the infection in the community, Z is condoms effectiveness, α is the probability of transmission of the infection for each sexual act, L is the frequency of sexual acts with condoms, and Q is the frequency of sexual acts without condoms, and R is the number of sexual partners..[109-113] The same logic of calculating HIV cases averted in drug behaviour outcome applies to calculating HIV cases averted for changes sexual behaviours attributed to the condom and counselling component of the needle exchange intervention.

3.2.7 Calculation of Net Costs

.The savings as a result of preventing A cases of HIV or HCV can be expressed as:

$$SA = \Delta A * T \qquad \text{(Equation 12)}$$

where T are treatment costs and A are HIV or HCV cases averted. Net savings were calculated as :

$$C_{net} = C_I - (SA_{HIV} + SA_{HCV}), \qquad \text{(Equation 13)}$$

where C_I is the cost of the intervention, and SA is the savings in averted medical care treatment costs for the particular HIV and HCV. Details on intervention costs were provided in the Appendix IV from the parent study. How medical care costs associated with HIV and HCV were obtained is described below.

For HIV, the literature on the cost of state-of-the art medical care for HIV disease has been reviewed and updated with respect to existing cost estimates to reflect the latest use of protease

inhibitors and viral load monitoring.[120] In this model, HIV-infected individuals pass through several disease phases, each of which is associated with a medical care cost that reflects HIV related opportunistic infection prophylaxis and treatment and anti-retroviral treatment.[120] The lifetime cost of HIV-related care was estimated at $262 500 (2011 CA dollars).[5] This estimate has been used in several cost-effectiveness analyses of HIV prevention.[108, 115, 121-124] However, prior to the analysis proposed here, a literature search was conducted in order to ascertain whether this value would need to be adjusted for the population for access to care and for new advances in HIV therapeutics.[121] The literature was reviewed to account for the latest medical care costs related to HIV and HCV treatment. Poret *et al.* estimated the average cost of treating an individual in the first year following diagnosis of HCV to be approximately $13,737 (2011 CAN dollars) in direct medical costs.[31]

Before analyses was conducted, these costs was updated, based on the rate of inflation, on adjustments for the population, or based on more recent advances in the treatment of HIV and HCV. See appendix VI for the chart of inflation index.

Note that the survey contained questions regarding clients' sexual and drug use behaviour in the previous month. The number of acts and number of injections were multiplied by 12 to reflect yearly calculations. For the study, each participant was put through the model to estimate the expected cases of HIV and HCV averted. Once all the participants obtain an expected amount of HIV and HCV averted, they were all summed together to estimate the number of HIV and HCV cases averted.

3.2.9 Sensitivity Analysis

Univariate sensitivity analysis was conducted. For univariate sensitivity analysis, the study modelled the results looking at the low and high literature values of the literatures parameters such as transmission probability, HIV and HCV prevalence, HIV prevalence among HCV positives and HCV prevalence HIV positives, medical care costs, and protective effect of cleaning needles. Furthermore, the traditional means method of the Bernoulli model was also modeled to explore the differences between the two models and how they account for co-infection. The traditional means model calculates the averages of each parameter and goes through the model just once and then multiplies the result by the number of individuals instead of running the model through for each individual and then summing the cases averted together to calculate the number of cases averted.

Chapter 4

Results

4.1 Descriptive Results

Table 1 shows the parameter values from literature for Bernoulli Modeling. The mean is shown as well as literature recognized lower and upper bounds for the relevant parameters. **Table 2** shows the breakdown of the expected HIV and HCV cases at Time 1 and Time 2 for both primary and secondary infection as well as total cases. These results are from the application of the Bernoulli model using behaviour changes and literature parameter values used are seen in Appendix III and **Table 1**. The difference between the expected probability of HIV and HCV cases at Time 1 and Time 2 gives us the number of averted cases. It is observed that the intervention has a higher impact in number of secondary cases than the number of primary cases.

When co-infection status was considered, the total number of primary cases averted increased from 0.640 to 1.113 for HIV and increased from 1.664 to 1.685 for HCV when compared to when co-infection status of the clients' partner was not accounted for. However, the opposite result was observed for secondary infections (decreased from 8.802 to 7.980 for HIV and 3.516 to 3.434 for HCV) when co-infection status of the clients' partner was accounted for. This effect resulted in an increase in total number of HIV cases averted, but decrease in total number of HCV cases averted when compared to the model without accounting for co-infection. The effect of this observation on the total number of HIV and HCV cases averted once partner co-infection status is accounted for depended on the magnitude of the change for primary and secondary infections averted.

Table 3 summarizes the number of HIV and HCV cases averted and the medical cost savings discounted at 25 years. The medical costs per individual over the span of 25 years are shown in **Table 1** ($304,900 for HIV and $82, 313 for HCV). The model predicted that for the 63 clients, the total discounted medical costs averted due to the intervention would be approximately $6,950,028 if co-infection status were not considered compared to $6,741,331 if the clients' partners' co-infection status were included.

It was estimated that 14,030 clients used needle exchange programs during 2003-2004 (estimates from the two Health Units). In **Table 4** the model predicted that the expected number of HIV and HCV cases averted by the intervention in the total population of injection drug users in Ontario (equal to 14,030 individuals) would be $1,548,980,230 in direct medical costs were averted by the intervention during the year 2003-2004 while accounting for HIV and HCV independently. The study calculated that $1,502,144,814 in direct medical costs was averted by accounting for the clients' partners' co-infection status. In sum, a negative effect of $46,835,415 in averted medical cost might be attributed to HIV and HCV co-infection status.

Table 5 reveals the total net savings after taking into the cost of running the needle exchange programs for the 63 individuals. The cost of running the programs in both cities was $237,776. The sum method of the Bernoulli model resulted in total medical savings averted of $6,712,253 and $6,503,556 for averted HIV and HCV cases when the clients' partners' co-infection was and not accounted for respectively.

Table 1 Parameter Values from Literature for Bernoulli Modelling

Parameters for Condom Effectiveness	Mean	Lower	Upper	Source
Vaginal Receptive	0.8	0.75	0.85	[101, 125-127]
Vaginal Insertive	0.8	0.75	0.85	[101, 125-127]
Anal Receptive	0.7	0.65	0.75	[101, 125-127]
Anal Insertive	0.7	0.65	0.75	[101, 125-127]
Oral Sex	0.9	0.85	0.95	[101, 125-127]
Cleaning Injection	0	0	0.1	[101, 125-127]
Parameter for Probability of HIV Transmission	**Mean**	**Lower**	**Upper**	**Source**
Vaginal Receptive Intercourse (male to female)	0.0014	0.0007	0.0021	[101, 128, 129]
Vaginal Insertive Intercourse (female to male)	0.001	0.0005	0.0015	[101, 128, 129]
Anal Receptive Intercourse	0.001	0.0005	0.0015	[101, 128, 129]
Anal Insertive Intercourse	0.01	0.005	0.015	[101, 128, 129]
Oral Intercourse	0.0004	0.0002	0.0006	[101, 128, 129]
HIV Needle Injection Transmission Probability	0.0067	0.0033	0.0076	[130-132]
Probability of HCV Transmission Via Injection	0.025	0.02	0.10	[117, 133]
Parameter	**Mean**	**Lower**	**Upper**	**Source**
Prevalence of HIV among HCV Positive Individuals	0.23	0.18	0.28	[134, 135]
Prevalence of HCV among HIV Positive Individuals	0.70	0.5	0.9	[135, 27]
Prevalence of HIV in Sample	0.063	NA	NA	Data
Prevalence of HCV in Sample	0.524	NA	NA	Data

Prevalence of HIV in Health Unit A	0.067*	NA	NA	
Prevalence of HIV in Health Unit B	0.000*	NA	NA	OHRDP Final Outcome Evaluation
Prevalence of HCV in Health Unit A	0.627*	NA	NA	
Prevalence of HCV in Health Unit B	0.509*	NA	NA	
**Medical Cost of HIV over 25 years	$304,900	$262,500	$441,500	[120, 6, 136]
**Medical Cost of HCV over 25 years	$82,313.77	NA	NA	[137]

*did not use these prevalence for calculations, used the prevalence in the sample of 63 individuals at Time 1 due to prevalence of HIV in Health Unit B being 0.0000
**Medical Cost in 2011 Canadian Dollars over 25 years

Table 2 Summary of HIV and HCV cases expected at Time 1 and 2 using sum individual data

	Time 1 (n=63)	Time 2 (n=63)	Difference between Time 1 and 2
Condom and Counselling Intervention			
Expected Primary HIV Cases	1.464	0.602	0.861
Expected Secondary HIV Cases	18.541	7.449	11.092
Total Expected HIV Cases	20.005	8.052	11.953
Needle Exchange Program Intervention			
Expected Primary HIV Cases	0.926	0.286	0.640
Expected Secondary HIV Cases	12.070	3.268	8.802
Total Expected HIV Cases	12.997	3.554	9.443
Expected Primary HIV Cases for Drug Behaviours Co-infection assuming 100% HCV positive	2.524	0.983	1.541
Expected Secondary HIV Cases for Drug Behaviours Co-infection assuming 100% HCV positive	9.919	2.686	7.234
Total Expected HIV Cases for Drug Behaviours Co-infection assuming 100% HCV positive	12.443	3.668	8.775
Expected Primary HIV Cases for Drug Behaviours Co-infection HCV positive	1.764	0.651	1.113
Expected Secondary HIV Cases for Drug Behaviours Co-infection HCV positive	10.943	2.963	7.980
Total Expected HIV Cases for Drug Behaviours Co-infection HCV positive	12.707	3.614	9.093
Expected Primary HCV Cases for Drug Behaviours	4.896	3.233	1.664
Expected Secondary HCV Cases for Drug Behaviours	6.412	2.896	3.516
Total Expected HCV Cases for Drug Behaviours	11.309	6.129	5.180
Expected Primary HCV Cases for Drug Behaviours Co-infection assuming 100% HIV positive	6.083	4.088	1.994
Expected Secondary HCV Cases for Drug Behaviours Co-infection assuming 100% HIV positive	4.041	1.825	2.216
Total Expected HCV Cases for Drug Behaviours Co-infection assuming 100% HIV positive	10.124	5.914	4.210
Expected Primary HCV Cases for Drug Behaviours Co-infection HIV positive	4.971	3.287	1.685
Expected Secondary HCV Cases for Drug Behaviours Co-infection HIV positive	6.263	2.829	3.434
Total Expected HCV Cases for Drug Behaviours Co-infection HIV positive	11.234	6.115	5.119

Table 3: Medical Savings and HIV and HCV cases averted in 12 month time period (n=63)

	HIV Cases Averted due to Sexual Behaviour	HIV Cases Averted due to Drug Behaviour	HCV Cases Averted due to Drug Behaviour	HIV Cases Averted due to Drug Behaviour while accounting for partner HCV co-infection	HCV Cases Averted due to Drug Behaviour while accounting for partner HIV co-infection
Cases Averted	11.953	9.443	5.180	9.093	5.119
*Medical Savings Averted	$3,644,470	$2,879,171	$426,385	$2,772,456	$421,364
		No Co-Infection		Partner Co-Infection Accounted for	
*Total Medical Savings Averted		$6,950,028		$6,838,290	

*Cost in discounted 2011 Canadian dollars over 25 years lifetime

Table 4: Medical Savings and HIV and HCV cases averted extrapolated for full population (n=14,030) in 12 month time period

	HIV Cases Averted due to Sexual Behaviour	HIV Cases Averted due to Drug Behaviour	HCV Cases Averted due to Drug Behaviour	HIV Cases Averted due to Drug Behaviour while accounting for partner HCV co-infection	HCV Cases Averted due to Drug Behaviour while accounting for partner HIV co-infection
Average Change Averted per Client	0.190	0.150	0.082	0.139	0.081
Cases Averted	2665.70	2104.50	1150.46	1954.18	1136.43
*Medical Savings Averted	$812,771,930	$641,509,600	$94,698,700	$595,829,046	$93,543,838
		No Co-Infection		Partner Co-Infection Accounted for	
*Total Medical Savings Averted		$1,548,980,230		$1,502,144,814	

*Cost in discounted 2011 Canadian dollars over 25 years lifetime

Table 5: Net Cost Analysis

	No Co-Infection	Partner Co-Infection Accounted for
HIV and HCV Cases Averted	21.396 HIV and 5.180 HCV Cases Averted	21.046 HIV and 5.119 HCV Cases Averted
*Discounted Lifetime cost of HIV or HCV	$304,900 for HIV and $82,313.77 for HCV	
Cost of Program	$237,775.50	
*Medical Savings Averted	$6,950,028	$6,838,290
*Net Savings	$6,712,253	$6,600,515

*Cost in discounted 2011 Canadian dollars over 25 years lifetime

4.2 Sensitivity Analysis

Table 6 presents the results of univariate sensitivity analysis to observe how certain parameters would affect the number of HIV and HCV cases averted. While logic would agree that the general pattern that an increase in transmission probability would increase the likelihood of becoming infected and a decrease in transmission probability would decrease the likelihood of becoming infected, the pattern does not match the expected number HIV or HCV cases averted by the intervention as seen in **Table 6**. **Table 6** shows that when looking at both lower and upper bound for needle transmission probability for HCV without accounting for co-infection status, the number of cases decreased for both from a Time 1 of 5.180 to 5.137 and 3.712 respectively. This pattern is also observed in calculating the number of HCV averted when accounting for co-infection where the number of cases averted decrease from base of 5.119 to 5.099 and 3.649 for lower and upper bound respectively. While it is true that a decrease in transmission probability decreases the expected probability of becoming infected and an increase in transmission probability increases the expected probability of becoming infected (which both effects are observed when observing the number of cases averted at Time 2 and Time 1 seen in **Table 6** and **Table 7**), the effect of the respective increase or decrease may not correlate to the intended effect for total cases averted.

As seen in **Table 6** and **Table 7**, observing through the Time 1 and Time 2 results compared to **Table 1**, the results do follow the logical pattern. However, the difference between the Time 1 and Time 2 is not correlated probability of transmission. While both Time 1 and Time 2 probability of HCV infection increased with an increase in transmission probability, the expected probability of infection increased at a higher rate compared to the expected probability of infection at Time 1. Hence, the difference between Time 1 and Time 2 for cases HCV averted

becomes smaller resulting in observing less HCV cases averted. This unpredictable effect of the parameters on the outcome is also observed in **Table 5** showing that the parameters have no specific correlation on the actual outcome of the intervention because the outcome is not based on the magnitude of the expected probability of infection at one point in time, but based on the difference at Time 1 and Time 2.

Since the literature has different variation of the Bernoulli Probability Model, another method was used to calculate the number of averted cases.[138] The alternate method is using the means of individual data to calculate the average number of primary and secondary infection expected at baseline and follow-up. This method is most common in literature.[101, 123, 139, 140] The difference between the average at Time 1 and Time 2 calculates the average number of HIV and HCV cases averted per individual. This average number is then multiplied by the sample population which predicts the total number of averted cases. **Table 8** shows the breakdown of average primary and secondary cases avoided at Time 1, Time 2, and overall.

Table 9 summarizes the number of HIV and HCV cases averted and the medical cost savings discounted at 25 years using means. For the 63 clients, the total discounted medical costs averted due to the intervention will be approximately $6,475,427 if co-infection status is not considered compared to $9,056,327 if the clients' partners' co-infection status was accounted for. The discounted medical cost averted attributed to partner's co-infection status is about $2,580,900. The results of savings in the means method ($2,580,900) are more than using the individual sum method (negative $208,697) where the savings for co-infection not accounted and accounted for were $2,580,900 and negative $208,697 respectively.

Table 10 presents the expected number of HIV and HCV cases averted by the intervention from 14,030 individuals using the means method. In total, about $1,444,827,481 or about $57,793,099 per year over 25 years in direct medical costs was averted by the intervention during the year 2003-2004 while accounting for HIV and HCV independently. The study calculated that about $2,018,387,281 or about $80,735,491 per year over 25 years in direct medical costs was averted why accounting for the clients' partners' co-infection status. In sum, about $573,559,800 in averted medical cost is attributed to accounting for HIV and HCV co-infection status. The results of the means averted medical savings ($573,559,800) are significantly more than using the individual sum method (negative $46,835,416) where the total savings for co-infection not accounted and accounted for when extrapolated to the full 14,030 individuals using the intervention during the study period.

Table 6: Estimated cases of HIV and HCV averted and the resulting savings for the interventions when applying lower and upper bound parameter values for drug behaviour (n=63)

Parameters Varied	**HIV cases (medical) averted**		**HCV cases (medical) averted**		**HIV cases (medical) with HCV Co-Infection Accounted**		**HCV cases (medical) with HIV Co-Infection Accounted**	
Base	9.443 ($2,879,171)*		5.180 ($426,385)*		8.775 ($2,675,498)*		5.119 ($421,364)*	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound
Protective Effect of cleaning needles	9.443	9.621	5.180	5.310	9.271	10.027	5.119	5.248
Transmission rate per injection	10.112	9.282	5.137	3.712	9.755	8.935	5.099	3.649
Co-Infection Prevalence					8.635	8.939	5.191	5.043
*Medical costs	($2,478,788)*	($4,169,085)*			($2,303,438)*	($3,874,163)*		

*Costs are all in 2011 Canadian dollars discounted over 25 years lifetime

Table 7: Sensitivity calculations of lower bound of transmission probability for HIV and HCV

	Time 1 (n=63)	Time 2 (n=63)	Difference between Time 1 and 2
Expected Primary HCV Cases for Drug Behaviours	4.871	3.233	1.638
Expected Secondary HCV Cases for Drug Behaviours	6.395	2.896	3.499
Total Expected HCV Cases for Drug Behaviours	11.266	6.129	5.137
Expected Primary HCV Cases for Drug Behaviours Co-infection assuming 100% HIV positive	6.049	3.839	2.210
Expected Secondary HCV Cases for Drug Behaviours Co-infection assuming 100% HIV positive	4.030	1.712	2.318
Total Expected HCV Cases for Drug Behaviours Co-infection assuming 100% HIV positive	10.079	5.551	4.528
Expected Primary HCV Cases for Drug Behaviours Co-infection HIV positive	4.945	3.271	1.674
Expected Secondary HCV Cases for Drug Behaviours Co-infection HIV positive	6.246	2.821	3.424
Total Expected HCV Cases for Drug Behaviours Co-infection HIV positive	11.191	6.092	5.099

Table 8: Showing sensitivity calculations of upper bound of transmission probability for HCV

	Time 1 (n=63)	Time 2 (n=63)	Difference between Time 1 and 2
Expected Primary HCV Cases for Drug Behaviours	4.917	4.091	0.826
Expected Secondary HCV Cases for Drug Behaviours	6.426	3.540	2.886
Total Expected HCV Cases for Drug Behaviours	11.343	7.630	3.712
Expected Primary HCV Cases for Drug Behaviours Co-infection assuming 100% HIV positive	6.110	5.226	0.884
Expected Secondary HCV Cases for Drug Behaviours Co-infection assuming 100% HIV positive	4.050	2.231	1.819
Total Expected HCV Cases for Drug Behaviours Co-infection assuming 100% HIV positive	10.160	7.457	2.703
Expected Primary HCV Cases for Drug Behaviours Co-infection HIV positive	4.992	4.162	0.830
Expected Secondary HCV Cases for Drug Behaviours Co-infection HIV positive	6.276	3.457	2.819
Total Expected HCV Cases for Drug Behaviours Co-infection HIV positive	11.268	7.619	3.649

Table 9 :Summary of HIV and HCV cases expected a Time 1 and 2 using mean data

	Time 1 (n=63)	Time 2 (n=63)	Difference between Time 1 and 2
Condom and Counselling Intervention			
Expected Primary HIV Cases	0.968	0.360	0.608
Expected Secondary HIV Cases	8.422	3.197	5.224
Total Expected HIV Cases	9.390	3.557	5.833
Needle Exchange Program Interventions			
Expected Primary HIV Cases	1.224	0.196	1.028
Expected Secondary HIV Cases	13.352	2.174	11.178
Total Expected HIV Cases	14.577	2.370	12.206
Expected Primary HIV Cases for Drug Behaviours Co-infection assuming 100% HCV positive	19.182	2.384	16.798
Expected Secondary HIV Cases for Drug Behaviours Co-infection assuming 100% HCV positive	10.972	1.786	9.186
Total Expected HIV Cases for Drug Behaviours Co-infection assuming 100% HCV positive	30.155	4.171	25.984
Expected Primary HIV Cases for Drug Behaviours Co-infection HCV positive	10.634	1.343	9.291
Expected Secondary HIV Cases for Drug Behaviours Co-infection HCV positive	12.400	1.971	10.430
Total Expected HIV Cases for Drug Behaviours Co-infection HCV positive	23.924	3.314	20.610
Expected Primary HCV Cases for Drug Behaviours	12.637	4.852	7.785
Expected Secondary HCV Cases for Drug Behaviours	6.783	2.719	4.064
Total Expected HCV Cases for Drug Behaviours	19.420	7.571	11.849
Expected Primary HCV Cases for Drug Behaviours Co-infection assuming 100% HIV positive	19.183	7.079	12.104
Expected Secondary HCV Cases for Drug Behaviours Co-infection assuming 100% HIV positive	4.275	1.714	2.561
Total Expected HCV Cases for Drug Behaviours Co-infection assuming 100% HIV positive	23.458	8.793	14.665
Expected Primary HCV Cases for Drug Behaviours Co-infection HIV positive	13.049	4.992	8.057
Expected Secondary HCV Cases for Drug Behaviours Co-infection HIV positive	6.708	2.689	4.019
Total Expected HCV Cases for Drug Behaviours Co-infection HIV positive	19.743	7.669	12.074

Table 10: Medical Savings and HIV and HCV cases averted in 12 month time period using mean data (n=63)

	HIV Cases Averted due to Sexual Behaviour	HIV Cases Averted due to Drug Behaviour	HCV Cases Averted due to Drug Behaviour	HIV Cases Averted due to Drug Behaviour while accounting for partner HCV co-infection	HCV Cases Averted due to Drug Behaviour while accounting for partner HIV co-infection
Cases Averted	5.833	12.206	11.849	20.610	12.074
Medical Savings Averted*	$1,778,482	$3,721,609	$975,336	$6,283,989	$993,856
		No Co-Infection		Partner Co-Infection Accounted for	
Total Medical Savings Averted*		$6,475,427		$9,056,327	
Net Medical Savings Averted*		$6,237,651		$8,818,552	

*Expressed in discounted 2011 Canadian dollars over 25 years

Table 11: Medical Savings and HIV and HCV cases averted extrapolated for full population using mean data (n=14,030) in 12 month time period

	HIV Cases Averted due to Sexual Behaviour	HIV Cases Averted due to Drug Behaviour	HCV Cases Averted due to Drug Behaviour	HIV Cases Averted due to Drug Behaviour while accounting for partner HCV co-infection	HCV Cases Averted due to Drug Behaviour while accounting for partner HIV co-infection
Average Change Averted per Client	0.093	0.194	0.188	0.327	0.192
Cases Averted	1304.79	2721.82	2637.64	4587.81	2693.76
Medical Savings Averted*	$397,830,471	$829,882,918	$217,114,092	$1,398,823,269	$221,733,541

	No Co-Infection (average per year)	Partner Co-Infection Accounted for (average per year)
Total Medical Savings Averted*	$1,444,827,481 ($57,793,099)	$2,018,387,281 ($80,735,491)
Net Medical Savings Averted*	$1,438,883,081 ($57,555,323)	$2,012,442,881 ($80,497,715)

*Expressed in discounted 2011 Canadian dollars over 25 years

Chapter 5

Discussion and Conclusion

5.1 Key Findings and Interpretations

A key difference was observed when looking at expected cases of HIV or HCV infection when partner co-infection status is taken into account. Through modeling, a total of 21.396 HIV and 5.180 HCV cases were predicted to be averted for the 63 individuals when co-infection was not account while 20.728 HIV and 5.119 HCV cases were predicted to be averted when co-infection was account for. Compared to other studies like the Pinkerton study in Vancouver on Insite, our study predict more HIV cases averted compared to the 83.5 preventable cases of HIV to be prevented for one year in the Vancouver study when we attempt to extrapolate for our whole population.[91] However, the Insite study did not take into co-infection.[91] In the Jacobs study in Edmonton, they observed about 20 cases of HIV averted, but their study is based on the number of street needles used and not sample size population.[89] Moreover, it is difficult to compare our studies to the Edmonton and Vancouver study because they measured by needles disposed of which are around 550,000 and 200,000 respectively without regards to their population sample size in a year while our study did.[89,91] Without, similar sample size, it is difficult to draw a fair comparison. Furthermore, our study also looked at HIV cases prevented from sexual behavioural changes as well as needle use behaviour changes as well. The cost savings observed from the study show that through modeling, the program easily pays for itself multiple times over as seen in **Table 5**. The initial investment for the needle exchange interventions was $237,776 and through modeling with our sample size, we calculated a net savings of $6,712,253 if co-infection status was not accounted for, or $6,503,556 if co-infection

status was accounted for. The savings from the Vancouver study showed $17.6 million in savings each year while the Edmonton study had about $6 million in savings.[89,91] There is no study that looked into the effect of Bernoulli model on HCV nor attempted to account for co-infection, the closest study from the literature search was from the Zhang study which only conceded that HCV would also be prevented from needle exchange interventions.[34]

The results appear counter-intuitive to the idea that after one accounts for the co-infection status, there should be more cases averted. The literature shows that a partner who is HIV positive is highly likely to be infected with HCV compared to a partner who is HIV negative.[19, 23, 27, 32-37] The literature also observes a partner who is HCV positive is highly likely to be infected with HIV compared to a partner who is HCV negative.[19, 23, 27, 32-37]

This study broadens the adaptation of the Bernoulli model and applies it to needle exchange.[108] Other models for needle exchange incorporate bleaching and instead of using HIV prevalence use the probability of contaminated needles to account for transmission.[5] Fortunately, the models in the fundamentals are similar and both studies show that the results of the effectiveness modeling exercise indicate a substantial reduction in risk at the population level even if some of the intervention clients remained at risk owing to their sexual and drug use behaviours.[5] The current study is predominately a modeling exercise to explore the effects of co-infection using a very small sample size and not too much emphasis should placed on the actual results, but more on the modeling aspect.

5.2 Strengths

This study has several key strengths. While there are few studies measuring the economic impact of HIV and HCV, no studies have attempted to estimate the economic impact of

preventing HIV while accounting for HCV co-infection.[33, 37] This study will be the first study to include HCV co-infection effects on HIV transmission using Canadian data. The Bernoulli model proposed here has been used previously because the model is validated and is known to be reliable for estimating the number of HIV cases averted.[109-113] From the literature among the principal advantages of the Bernoulli model is its relative simplicity, generalizability, and intuitive appeal".[109]

The parent study has shown that it is feasible to collect ongoing data. Through detailed discussion and involvement with and from the prevention workers, it was possible to develop survey questions related to the specific interventions identified. Moreover, through getting the data, staff gained valuable experience to lead successful implementation of outcomes and cost monitoring. Study shows that there should be routine assessment of costs and effectiveness of public health programs. Indeed, in these times of economic restraint, it will be increasingly important for health systems managers to evaluate the costs and effectiveness of interventions.

5.3 Weaknesses

This study has a few limitations. The parent study's data had a small sample of 120 clients from 14,030 clients in needle exchange intervention. Out of the 120 clients who completed the initial pretest, only 63 (52.5%) completed the Time 2 survey. There were some significant differences in the population that completed only Time 1 and those that completed Time 1 and Time 2 survey as seen in Appendix II and III. Since the population is a small sample, the results of the behavioural data are not representative of the general population of users. Furthermore, the sample population was not a randomized sample. The sample population was a convenience sample which means there are potential traits (i.e. age, sexual and drug risk behaviours) among the participants that may be different from the population who uses the

needle exchange intervention. Hence, there is a high chance of selection bias because of the loss of follow-up, and those that remained may be the one with more changes in behaviour. Furthermore, there may be a small population of the patients who had used other interventions in the past months, which probably confounded the study results towards the null hypothesis since it would render the intervention less effective if they are already using other interventions in the past months.

The reliability and validity of the behavioural data was not established. However, the parent study did take an effort to ensure that there was no ambiguity in the survey questions because during the pilot phase, many patients were tested to ensure that the questions were understood properly. Furthermore, there may be a small population of the patients who had used other interventions in the past months, which probably confounded the study results.

Regarding the actual modelling itself, the Bernoulli model is a static model. Compared to a dynamic model (which some other studies in literature uses), a static model does not take into account the element of time.[33, 93] A dynamic model is flexible as it can change with time as it shows what may happen with many possibilities that might arise in time. In general, static models are more structural than behavioral while dynamic models are more of a representation of the behaviours of the static components of the system. However, in this study, time does not play a significant factor and due to the explorative nature of the study, the simplicity of the static model is its greatest advantage. The Bernoulli model relies on parameters in the literature. The literature does not always agree and there is a range of literature values that could be used. That is why a sensitivity analyses was conducted to see how much our results was affected. Furthermore, due to the Bernoulli model's stochastic nature, the model assumes that sexual and drug behaviour is uniform across participants for the participants where no data is available,

which may not always be the case.[109] Furthermore, the cost savings is an underestimation because only direct medical costs are involved. The study does not take into account indirect costs such as loss of productivity and patient expenses.

The drug model is an adjustment of the sexual behaviour model and has not been validated by any biological tests. The model is derived from intuition and relies on its parameters from literature to predict the number of cases averted. While the model has not been tested, the logic behind the derivation of the model is intuitive and simple.

Finally, when I adjusted the sexual and drug use behaviour responses (only asked for last month) by multiplying response by 12 to take into account number of acts would be expected in a year, we did not account for change in number of sexual partners or the number of partners the client shared needles with. It is likely the number of partners would have increased, but since no established methods was found, I decided to stay conservative and not adjust number of partners. Thus, we are assuming that there is no increase in partners and so the results will be more on the conservative side and result in a lower prediction than the true amount of HIV and HCV averted.

5.4 Implications for Clinical Practice and Future Studies

Despite the low power of the study, the methods developed here can be used for the evaluation of ongoing programs. This could be part of a regular program evaluation. In the context of a health care system under ever increasing financial pressure, there will be a need to demonstrate that interventions produce benefits and are cost-effective. Studies such as the current one could represent a starting point for ongoing cost-effectiveness analyses of public health interventions in the real world.

5.5 Conclusions

Past needle exchange programs have not accounted for co-infection between HIV and HCV and this study attempts to address this gap in knowledge by looking at co-infection between the two. This study concludes that the medical care savings of needle exchange programs greatly outweigh the initial investment of running the programs. Despite its weaknesses, this study provides the foundation and methodology to conduct future cost-effectiveness analyses of needle exchange programs for HIV and HCV including the relationship between the two.

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Appendices

***Appendix I*:** Demographics of the sample population who completed only Time 1 or both Time 1 and 2 surveys

Variable	Needle Exchange		
	Completed only Time 1	Completed both Time 1 and 2	P Value*
	N=57(%)	N=63 (%)	
Gender			
Male	50 (87.7)	49 (77.8)	0.152
Female	7 (12.3)	14 (22.2)	0.152
Transgender	0 (00.0)	0 (00.0)	----
Mean Age (years)	32.4	39.5	**<.0001****
Ethnicity			
Caucasian	53 (93.0)	56 (88.9)	0.535
African	0 (00.0)	1(01.6)	1.000
Asian	0 (00.0)	0 (00.0)	----
Aboriginal	2 (03.5)	5 (07.9)	0.443
Other	2 (03.5)	1(01.6)	0.604
Education			
Less than high school diploma	38 (66.7)	45 (71.4)	0.573
High school diploma or equivalent	11 (19.3)	6 (09.5)	0.125
Some college/university training or more	8 (14.0)	12 (19.0)	0.462
Other	0 (00.0)	0 (00.0)	----
Sexual Orientation			
Heterosexual	55 (96.5)	60 (95.2)	1.000
Homosexual	1 (01.7)	0 (00.0)	0.475
Bisexual	1 (01.8)	3 (04.8)	0.621
Other	0 (00.0)	0 (00.0)	----
Income ($)			
Less than 10,000	38 (66.7)	47 (74.6)	0.340
10,000-19,999	11 (19.3)	11 (17.5)	0.795
20,000-39,999	4 (07.0)	1 (01.6)	0.189
40,000+	0 (00.0)	3(04.8)	0.246
Other	4 (7.0)	1 (01.6)	0.189
Used other Interventions in past 6 months not from Needle Exchange Program			
Visited any STI/STD clinics for STD or HIV counselling and testing	6 (10.5)	8 (12.7)	0.844
Visited any other needle exchange programs to get or exchange needles	2 (03.5)	5 (07.9)	0.692
Picked up condoms from any other public health programs?	6 (10.5)	4 (06.3)	0.439
Participated in any workshops or group sessions where somebody discussed issues about HIV/AIDS or STIs	4 (07.0)	3 (04.7)	0.625

*chi-square test or Fisher's exact test if n<5
**two-sample t-test

Appendix II: Sexual and drug behaviour of clients at Time 1 and 2

Behaviour Past 30 Days	**Survey Completed**		**P-value***	**Of Clients who did both surveys**		**P-value****
	Time 1 Only	Time 1 and 2		Time 1	Time 2	
	Mean (Range)	Mean (Range)		Mean (Range)	Mean (Range)	
	N = 57	**N = 63**		**N = 63**	**N = 63**	
# of partners (regular and casual)	1.84 (0-20)	1.48 (0-20)	0.7579	1.48 (0-20)	0.68 (0-3)	0.052
# of unprotected sexual acts (regular partners)	4.14 (0-30)	7.41 (0-65)	0.1553	7.41 (0-65)	4.89 (0-60)	0.092
# of protected sexual acts (regular partners)	1.26 (0-16)	1.54 (0-45)	0.7748	1.54 (0-45)	1.97 (0-45)	0.372
# of unprotected sexual acts (casual partners)	2.33 (0-30)	1.13 (0-20)	0.1488	1.13 (0-20)	0.95 (0-15)	0.698
# of protected sexual acts (casual partners)	1.33 (0-20)	0.86 (0-18)	0.4546	0.86 (0-18)	0.54 (0-10)	0.383
# of times injected drugs with clean but shared needle/syringe	3.32 (0-145)	0.57 (0-20)	0.2956	0.57 (0-20)	1.81 (0-60)	0.280
# of time injected drugs with unclean shared needles/syringe	0.00 (0-0)	0.92 (0-30)	0.1116	0.92 (0-30)	0.08 (0-3)	0.127
# of people shared needles/syringes	0.11 (0-1)	0.30 (0-10)	0.2499	0.30 (0-10)	0.16 (0-4)	0.425

*****Two-sample t-test

******Paired sample t-test

Appendix III: Cost of the Needle Exchange Intervention from September 2005 to January 2007

	Needle Exchange	
	2005 CA Dollars (%)	2011 CA Dollars
Facility/overhead	$19,200.00 (9.1)	$21,600.00
Personnel	$144,977.00 (69.0)	$163,099.00
Office Supplies	$5,980.00 (2.8)	$6,728.00
Medical Supplies	$26,880.00 (12.7)	$30,240.00
Van Lease and fuel	$9,920.00 (4.7)	$11,160.00
Communication Services	$1,319.00 (0.6)	$1,484.00
Travel	$3,080.00 (1.5)	$3,465.00
Total Costs of Needle Exchange	$211,356.00	$237,775.50
Cost per client	$15.06	$16.94

Appendix IV: Legend of Variables in the Bernoulli Model

Parameter	Definition	Source
P	Expected cases of HIV or HCV primary infection	Calculated
P_{HIVHCV}	Expected cases of HIV primary infection accounting for HCV co-infection	Calculated
S	Expected cases of HIV or HCV secondary infection	Calculated
S_{HIVHCV}	Expected cases of HIV secondary infection accounting for HCV co-infection	Calculated
α	Per-act transmission probability for each injection with reused needles or sexual act	Literature
ΔA	Total expected change in expected infection cases as a result of the individual's drug or sexual behaviour	Calculated
π_{HIV*}	Prevalence of the HIV in the community	Preliminary Data
π_{HepC*}	Prevalence of the HCV in the community	Preliminary Data
K	Frequency of drug injections with cleaned needles	Preliminary Data
N	Frequency of drug injections with uncleaned needles	Preliminary Data
M	Number of partners shared needles with	Preliminary Data
α_b	Per-act transmission probability for each injection with unused needles	Literature
L	Frequency of sexual acts with condoms	Preliminary Data
Q	Frequency of sexual acts without condoms	Preliminary Data
R	Number of sexual partners	Preliminary Data
Z	Prevention effectiveness of condoms	Literature
A	The expected number of cases averted by an intervention for each individual	Calculated
SA	Savings calculated	Calculated
T	Medical treatment cost for specific outcome	Literature
C_I	Cost of implementing a specific intervention	Preliminary Data
C_{net}	Net costs of a specific intervention	Calculated

*These were taken from sample population despite being available in literature because they were very close and wanted to use actual sample from community

Appendix V: Consumer Price Index of Canada

Geography[10]=Canada

Commodities and commodity groups[15]	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
All-items CPI[16]	100.0	102.8	104.7	107.0	109.1	111.5	114.1	114.4	116.5	119.9
Food[17]	100.0	101.7	103.8	106.4	108.9	111.8	115.7	121.4	123.1	127.7
Shelter[18]	100.0	103.2	105.8	109.2	113.1	116.9	122.0	121.6	123.3	125.6
Household operations, furnishings and equipment	100.0	100.7	101.2	101.7	102.2	103.2	104.6	107.3	108.8	110.9
Clothing and footwear	100.0	98.2	98.0	97.6	95.8	95.7	93.8	93.4	91.6	91.9
Transportation	100.0	105.2	107.7	112.0	115.2	117.1	119.5	113.1	118.0	125.6
Gasoline	100.0	106.4	117.6	132.6	139.8	146.1	164.7	135.8	148.2	177.8
Health and personal care	100.0	101.4	102.8	104.6	105.9	107.3	108.8	112.1	115.1	117.1
Recreation, education and reading	100.0	100.8	101.1	100.8	100.6	101.8	102.2	103.1	104.0	105.3
Alcoholic beverages and tobacco products	100.0	110.1	116.0	119.1	121.7	125.5	127.5	130.7	133.1	135.6
Core Consumer Price Index (CPI) (Bank of Canada definition)[7,23]	100.0	102.2	103.8	105.5	107.5	109.8	111.7	113.6	115.6	117.5
All-items CPI excluding food and energy[25]	100.0	102.5	103.9	105.3	106.9	109.0	110.3	111.5	112.9	114.7
All-items CPI excluding energy[25]	100.0	102.4	103.8	105.4	107.2	109.5	111.3	113.3	114.8	117.0
Energy[25]	100.0	107.9	115.2	126.3	132.8	135.9	149.3	129.2	137.8	154.7
Goods[27]	100.0	101.9	103.4	105.8	107.1	108.0	109.4	107.6	109.2	112.9
Services[28]	100.0	103.6	105.9	108.2	111.1	114.8	118.7	121.2	123.7	126.7

Footnotes:

1.

The Consumer Price Index (CPI) is an indicator of the changes in consumer prices experienced by the target population. The CPI measures price change by comparing, over time, the cost of a fixed basket of goods and services. This basket is based on the expenditures of the target population in a certain reference period, currently 2009. Since the basket contains goods and services of unchanging or equivalent quantity and quality, the index reflects only pure price movements. Separate CPIs are published for Canada, the ten provinces, Whitehorse, Yellowknife and Iqaluit. Some CPI information is also available for sixteen additional urban centres. Since the CPI is a measure of price change from one time period to another, it cannot be used to indicate differences in price levels between provinces or urban centres.

2.

The Consumer Price Index (CPI) is not a cost-of-living index. The objective behind a cost-of-living index is to measure changes in expenditures necessary for consumers to maintain a constant standard of living. The idea is that consumers would normally switch between products as the price relationship of goods changes. If, for example, consumers get the same satisfaction from drinking tea as they do from coffee, then it is possible to substitute tea for coffee if the price of tea falls relative to the price of coffee. The cheaper of the interchangeable products may be chosen. We could compute a cost-of-living index for an individual if we had complete information about that person's taste and spending habits. To do this for a large number of people, let alone the total population of Canada, is impossible. For this reason, regularly published price indexes are based on the fixed-basket concept rather than the cost-of-living concept.

3.

The Consumer Price Index (CPI) compares, in percentage terms, prices in any given time period to prices in the official base period which, at present, is 2002=100. The official time base was changed from 1992=100 to 2002=100 starting with the May 2007 data released in June 2007. The change is strictly an arithmetic conversion, which alters the index levels but leaves the percentage changes between any two periods intact, except for differences in rounding.

4.

The Consumer Price Index (CPI) maintains fixed quantitative proportions (weights) between goods and services during the life of a given basket. The baskets are updated periodically to take into account changes in consumer expenditure patterns. The basket reflecting the 2009 expenditure patterns replaced the 2005 basket starting with the May 2011 data released in June 2011. The continuity of the CPI series is maintained by "linking" the corresponding indexes obtained from consecutive baskets. The CPI is calculated as a weighted average of specified goods and services price indexes. The weights are derived from Survey of Household Spending data. When reconstructing or re-aggregating published CPI series, the changes in weights and the linking procedures must be taken into account. The process of linking is to apply the price movements calculated from the new basket to the series published previously. For a description of the methodology required to reconstruct or re-aggregate CPI series, see publication 62-553 The Consumer Price Index Reference Paper.

5.

For concepts and definitions, see publication 62-557 Your Guide to the Consumer Price Index, or publication 62-553 The Consumer Price Index Reference Paper. Additional information can also be obtained from: CPD Dissemination Unit, Consumer Prices Division, telephone: (613) 951-9606, toll-free: 1-866-230-2248, fax: (613) 951-2848, e-mail: cpd-info-dpc@statcan.gc.ca.

6.

Statistics Canada determined that the weights for mortgage interest cost were too high in the basket update effective January 2003. The effect on the Canada all-items consumer price index (CPI) was very small, within the rounding factor of the index. Effective with the July 2004 release, the 2001 basket weights were adjusted. See the documentation section of Definitions, data sources and methods (http://www.statcan.gc.ca/imdb-bmdi/2301-eng.htm) for updated weights.

7.

The core Consumer Price Index (CPI) (Bank of Canada definition) (1992=100) was previously available in CANSIM table 176-0003 as the Consumer Price Index (CPI) excluding eight of the most volatile components and indirect taxes (CPIX) (1992=100).

9.

This table replaces CANSIM table 326-0002 which terminated with the release of April 2007 data.

10.

The population targeted by the Consumer Price Index (CPI) consists of families and individuals living in urban and rural private households. For practical reasons, residents of the Territories outside Whitehorse, Yellowknife and Iqaluit are not represented by the index. Previous to January 1995, the target population consisted of private households in Canadian urban centres with a population of 30,000 or more.

11.

With the introduction of the 1992 basket in January 1995, emphasis was shifted from urban centre data to provincial data. Urban centre all-items series were continued since many users had come to rely on this service, but the method of calculation was changed. Shelter indexes are calculated for each urban centre. This recognizes the importance of shelter in the basket, the significant and persistent differences in price movements between urban centres, and the availability of local data. For the other seven major components, the movement of the provincial counterpart is used except in the cases of Montréal, Toronto, and Vancouver, where a sub-provincial counterpart is used. The major components are aggregated using the urban centre's expenditure pattern to arrive at each urban centre's all-items index.

12.

Formerly Ottawa (Ottawa-Hull, Ontario part), represents Ottawa only.

13.

The relatively small size of the housing market in these two cities makes it difficult to construct reliable price indexes for new houses. To compensate, the price movements of rental accommodation are used to approximate the price movements of new houses. The rent information itself is collected using different pricing frequencies and collection methods than in the rest of the country. Because of these problems, the indexes for rented accommodation, and owned accommodation are not published for these two cities. Further, the all-items indexes published for these two cities are not strictly comparable with the same indexes for the provinces or the other sixteen urban centres.

14.

Data for Iqaluit are on a December 2002=100 base (200212=100) and the Standard Geographical Classification (SGC) 2001. Previous to April 1, 1999, the town of Iqaluit formed part of the Northwest Territories. On April 1, 1999, the town of Iqaluit formed part of the newly-created territory of Nunavut.

15.

The goods and services that make up the Consumer Price Index (CPI) are organized according to a hierarchical structure with the "all-items CPI" as the top level. Eight major components of goods and services make up the "all-items CPI". They are: "food", "shelter", "household operations, furnishings and equipment", "clothing and footwear", "transportation", "health and personal care", "recreation, education and reading", and "alcoholic beverages and tobacco products". These eight components are broken down into a varying number of sub-groups which are in turn broken down into other sub-groups. Indents are used to identify the components that make up each level of aggregation. For example, the eight major components appear with one indent relative to the "all-items CPI" to show that they are combined to obtain the "all-items CPI". NOTE: Some items are recombined outside the main structure of the CPI to obtain special aggregates such as "all-items CPI excluding food and energy", "energy", "goods", "services", or "fresh fruit and fresh vegetables". They are listed after the components of the main structure of the CPI following the last major component entitled "alcoholic beverages and tobacco products".

16.

The eight major components of the Consumer Price Index (CPI) basket are: "food", "shelter", "household operations, furnishings and equipment", "clothing and footwear", "transportation", "health and personal care", "recreation, education and reading", and "alcoholic beverages and tobacco products".

17.

Food includes non-alcoholic beverages.

18.

Part of the increase first recorded in the shelter index for Yellowknife for December 2004 inadvertently reflected rent increases that actually occurred earlier. As a result, the change in the shelter index was overstated in December 2004, and was understated in the previous two years. The shelter index series for Yellowknife has been corrected from December 2002. In addition, the Yellowknife all-items consumer price index (CPI) and some Yellowknife special aggregate index series have also changed. Data for Canada and all other provinces and territories were not affected.

19.

In July 2004, the 2001 basket weights introduced with the January 2003 data were adjusted; the weights for mortgage interest cost were re-evaluated.

20.

Due to changes in the Ontario electricity market that became effective May 1, 2002, it was necessary to adjust the treatment of electricity prices in the Consumer Price Index (CPI) for that province. A question and answer fact sheet that explains those changes is now available. To obtain the fact sheet on the treatment of electricity prices in Ontario, please contact CPD Dissemination Unit, Consumer Prices Division, telephone: (613) 951-9606, toll-free: 1-866-230-2248, fax: (613) 951-2848, e-mail: cpd-info-dpc@statcan.gc.ca.

21.

About two thirds (4.7%) of the 7.4% decrease registered between September and October 2004 in the "Digital computing equipment and devices" index series represents a revision to source data.

22.

From April 2006, Statistics Canada changed its implementation of the price index formula used for traveller accommodation. As a result, data from April 2006 are not strictly comparable to earlier time periods.

23.

The Bank of Canada's core index excludes eight of the Consumer Price Index's most volatile components (fruit, fruit preparations and nuts; vegetables and vegetable preparations; mortgage interest cost; natural gas; fuel oil and other fuels; gasoline; inter-city transportation; and tobacco products and smokers' supplies) as well as the effects of changes in indirect taxes on the remaining components. For additional information on core CPI, please consult the Bank of Canada website:http://www.bankofcanada.ca/rates/price-indexes/cpi.

24.

Excluded from the all-items Consumer Price Index (CPI) are the following eight of the most volatile components identified by the Bank of Canada: fruit, fruit preparations and nuts; vegetables and vegetable preparations; mortgage interest cost; natural gas; fuel oil and other fuels; gasoline; inter-city transportation; and tobacco products and smokers' supplies. This series is used to obtain core inflation which also excludes the effect of changes in indirect taxes.

25.

The special aggregate "energy" includes: "electricity", "natural gas", "fuel oil and other fuels", "gasoline", and "fuel, parts and supplies for recreational vehicles".

26.

The 1986 basket content was divided into seven major components. With the introduction of the 1992 basket, the "housing" component from the 1986 basket definition was split into two components: "shelter" and "household operations, furnishings and equipment". This brought the number of major components to a total of eight. Also, the definition of "shelter" was changed. The traveller accommodation category, which was part of the 1986 definition of "shelter", was moved to "recreation" with the introduction of the 1992 basket. To provide some continuity certain aggregates were reconstructed using their 1986 basket definitions.

27.

Goods are physical or tangible commodities usually classified according to their life span into non-durable goods, semi-durable goods and durable goods. Non-durable goods are those goods that can be used up entirely in less than a year, assuming normal usage. For example, fresh food products, disposable cameras and gasoline are non-durable goods. Semi-durable goods are those goods that may last less than 12 months or greater than 12 months depending on the purpose to which they are put. For example, clothing, footwear and household textiles are semi-durable goods. Durable goods are those goods which may be used repeatedly or continuously over more than a year, assuming normal usage. For example, cars, audio and video equipment and furniture are durable goods.

28.

A service in the Consumer Price Index (CPI) is characterized by valuable work performed by an individual or organization on behalf of a consumer, for example, car tune-ups, haircuts and city public transportation. Transactions classified as a service may include the cost of goods by their nature. Examples include food in restaurant food services and materials in clothing repair services.

29.

Revision of the methodology of the home insurance component of the Consumer Price Index (CPI) beginning with the February 2008 CPI (http://www.statcan.gc.ca/imdb-bmdi/document/2301_D39_T9_V1-eng.pdf).

30.

Revision of the methodology of the Internet access services component of the Consumer Price Index (CPI) beginning with the March 2008 CPI (http://www.statcan.gc.ca/imdb-bmdi/document/2301_D40_T9_V1-eng.pdf).

31.

In previous years, Statistics Canada updated, by province, the model year of passenger vehicles used in the calculation of the passenger vehicle insurance premiums index over a three month period. Since 2008, this quality adjustment exercise is reflected in the month of May for all provinces.

32.

Revision of the methodology of the Rent component of the Consumer Price Index (CPI) beginning with the July 2009 CPI (http://www.statcan.gc.ca/imdb-bmdi/document/2301_D41_T9_V1-eng.pdf).

Source: Statistics Canada. *Table 326-0021 - Consumer Price Index (CPI), 2009 basket, annual (2002=100 unless otherwise noted),* CANSIM (database).
Back to search

(accessed: 2012-07-11)