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MODELLING THE INCIDENCE AND PREVALENCE OF HEPATITIS C INFECTION AND ITS SEQUELAE IN CANADA, 2007

FINAL REPORT

Community Acquired Infections Division
Centre for Communicable Diseases and Infection Control
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Public Health Agency of Canada

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Canada

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EXECUTIVE SUMMARY

In 1998, a working group evaluated the extent of hepatitis C infection transmitted through blood transfusion in Canada and estimated that a total of about 240,000 persons were infected with hepatitis C in Canada as of July 1998. The working group, however, did not examine specifically the distribution of HCV infection among persons in other exposure categories (such as injection drug use, the most common source of infection) nor did they attempt to estimate the current or future impact of HCV infection.

In 2003, Health Canada wished to re-examine the estimated prevalence of HCV infection in Canada in 2002 and to obtain more detailed estimates by exposure category. For this purpose, Remis and his colleagues developed a novel actuarial approach using a three-stage model, including estimating the populations at risk by place of birth and exposure category, modeling HCV incidence and prevalence among those born in Canada and HCV prevalence at the time of arrival and subsequent HCV incidence for persons born elsewhere and, finally, projecting the outcomes of chronic HCV infection among those infected. The objectives of the HCV modeling study were to estimate the following parameters: hepatitis C incidence and prevalence, the proportion of HCV infections diagnosed, the number of persons living with HCV infection by stage of disease, HCV-related morbidity and the future occurrence of serious complications of HCV infection.

More recently, the Public Health Agency of Canada wished to update the 2002 estimates, incorporating new data on HCV progression and reported HCV cases and incorporating refinements to the analytic approach developed since 2002.

HCV-infected persons may eventually develop serious complications. This was assessed by estimating the number of persons progressing through the following clinical stages: cirrhosis, decompensated cirrhosis (liver failure), hepatocellular carcinoma, liver transplant and liver-related death. The model used annual transition parameters based on published data and modeling studies, incorporating the modifying factors age, sex and HIV status. The model was treated as an integrated continuum from entry through birth or immigration and then transition to exposure-related behaviours or experiences, mortality, HCV infection and progression to serious HCV disease. Estimations and projections of HCV infection, prevalence and sequelae were made from 1960 to 2027.

The results of our updated study may be summarized as follows. We estimated that approximately 242,500 persons in Canada were infected with HCV as of December 2007 and that about 7,900 persons were newly infected in 2007, mostly through injection drug use. The distribution of prevalent HCV infections by exposure category (to the nearest 100) was: injection drug use 52,500, ex-injection drug use 87,500, blood transfusion recipients 25,900, hemophilia patients 900, and “Other” 75,800. In our analysis, IDU accounted for 58% of prevalent HCV infections in Canada, blood transfusion 11%, hemophilia 0.4% and other modes of transmission 31%. Overall, it was estimated that about 192,000 (79%) of HCV-infected persons living in Canada as of December 2007 have been diagnosed.

The impact of the sequelae of hepatitis C infection on the health of Canadians appears to be considerable. In 2007, we estimated that 15,800 persons were living with cirrhosis and 5,500 with liver failure. The annual incidence of newly developing cirrhosis appeared to peak in the late 1990s and early 2000s but, according to the results of our model, the incidence of the more serious outcomes of HCV infection will continue to rise, at least until 2027. We estimated that from 2007 to 2027 the number of prevalent cases of cirrhosis will go from 15,814 to 17,570 and carcinoma will increase from 338 to 379 cases (Table 7b).

We also examined HCV prevalence in two special populations, namely persons of Aboriginal origin and persons incarcerated in federal and provincial prisons. We concluded that approximately 34,900, or 3.0%, of Aboriginal persons were HCV-infected and 6,300 or 18.7% of incarcerated persons were HCV-infected. The distribution of HCV-infected prisoners by type of institution was 2,700 and 3,500 in provincial and federal prisons, respectively.

There are several important lessons to be learned from our study. The impact of this disease on the health of Canadians is considerable. It is essential to encourage the estimated 50,000 HCV-infected persons who remain undiagnosed to undergo HCV testing. Otherwise these infected individuals might unknowingly spread the virus to others and do not benefit from treatment and care. It is important to provide health care services to HCV-infected patients; this includes specialized physician and laboratory services and provision of effective antiviral drugs. Further research is also required at many levels, including studies to: better evaluate the extent and the factors responsible for HCV infection in Canada. Finally, it would be important to undertake necessary research to obtain population-based estimates of HCV prevalence and incidence in the Canadian population, develop more effective programs to prevent new infection, better understand HCV infection and disease and develop and implement more effective methods of treatment. These suggested improvements to the HCV program will reduce the burden of disease and associated health costs.

1. INTRODUCTION

1.1 Background

A serologic test for the hepatitis C virus (HCV) was developed in 1989. In the ensuing several years, seroepidemiologic studies were undertaken throughout the world to better characterize the distribution and natural history of HCV infection. It soon became clear that, in most Western industrialized countries, injection drug use was responsible for the majority of both prevalent and incident HCV infections. Following the realization that clotting factors and blood transfusion could also transmit HCV and accounted for 15-20% of HCV infections, routine HCV screening of plasma and blood donors was rapidly implemented, beginning in 1990. Donor screening markedly reduced, though not immediately, transfusion-transmitted infections and most of the residual incident HCV infections were due to injection drug use.

Though the first serologic HCV test was licensed in 1990, diagnostic testing on a large scale did not occur immediately in part due to the lack of clear guidelines for its use and the lack of effective treatments. HCV testing began on a broad scale in the mid-1990s. In the early to mid-1990s, HCV infection became reportable in most Canadian provinces. As of 2002, HCV reporting was mandatory in all provinces and territories.

In 1998, we carried out a modeling study for the Laboratory Centre for Disease Control, Health Canada to estimate the number of persons living as of July 1998 who were infected by hepatitis C through blood transfusion in Canada <1>. In collaboration with an expert working group constituted for this purpose, we developed three independent models to "triangulate" the number of persons infected in the periods before 1986 and 1990 and after. One of these models involved the estimation of the total number of persons in Canada infected with HCV. This was stratified in the final output by province of residence based primarily on relative HCV prevalence among blood donors. We estimated that, as of July 1998, 240,000 HCV-infected persons were living in Canada, for a crude prevalence rate of 0.80%.

In early 2003, we were asked by the Hepatitis C Division, Centre for Infectious Disease Prevention and Control, Health Canada to update the HCV estimates to December 2002 and to estimate the number of HCV-infected persons stratified by exposure category <2>. We were also asked to estimate the number of persons by stage of liver disease, including cirrhosis, decompensated liver failure, hepatocellular carcinoma, transplantation and HCV-related mortality. The findings were first presented at the 2nd Canadian Conference on Hepatitis C in Vancouver in March 2004. No province-specific estimates of hepatitis C infection or its sequelae were made in the course of this study.

The 2003 study also examined in a preliminary fashion the number of HCV infections reported since HCV testing became available. The estimate was preliminary in part because it was difficult to determine: 1) whether all reported infections had been validated; 2) the extent to which duplicates had been removed, and 3) if recent infections were effectively differentiated from remote infections. Also, data were missing in some jurisdictions for several of the early years and the most recent year. Nevertheless, we estimated that 156,590 infections had been diagnosed in Canada from 1991 to 2002, 52,390 (33%) of which were in Ontario.

In early 2008, the Community Acquired Infections Division, Centre for Communicable Disease and Infection Control, Public Health Agency of Canada wished to update the estimates of the incidence and prevalence of HCV infection and its sequelae in Canada.

1.2 *Study objectives*

The objectives of the present HCV modeling study were as follows:

1. Estimate the prevalence and incidence of HCV infection among persons living in Canada as of December 2007 by exposure category, age and sex;
2. Estimate the incidence and prevalence of serious sequelae among HCV-infected persons in Canada from 1960 to 2027;
3. Estimate the prevalence of HCV infection as of December 2007 by province and territory;
4. Estimate the number of persons with HCV infection incarcerated in provincial and federal prisons in Canada;
5. Estimate the number of Aboriginal persons with HCV infection living in Canada;
6. Estimate the number of persons diagnosed with HCV infection in Canada from 1991 to 2007; and
7. Estimate the proportion of persons living with HCV as of December 2007 who have been diagnosed (overall and by exposure category, if possible).

2. METHODS

The present updated modeling study was carried out using the methodology originally developed in 2003 to estimate HCV incidence and prevalence in Canada in 2002. However, while the basic structure of the approach remains the same, several important refinements, modifications and updates were incorporated into the present project.

2.1 HCV infection and outcomes model - overview

The HCV modelling study was carried out in three stages using spreadsheet software (Excel 97, Microsoft Corporation 1999). The first stage obtained estimates of the population at risk stratified by age and gender. The second stage modelled HCV incidence rate among those born in Canada and HCV prevalence at the time of arrival and subsequent incidence for persons immigrating to Canada. The third stage projected outcomes of chronic HCV infection among those infected as estimated in Stage 2.

Further details of the approach used in each of the three stages follows:

Stage 1

Stage 1 was carried out in two phases. In the first phase, we estimated the populations potentially at risk for HCV infection. The population was treated in two major categories, namely persons born in Canada and persons born elsewhere who immigrated to Canada. In the second phase, we estimated the numbers of persons in four mutually exclusive exposure categories defined as a function of risk of HCV infection, within each of these two populations and together. The four exposure categories were: injection drug users (IDU), recipients of blood transfusion, hemophilia patients and others. For those born in Canada, the birth cohort was modeled from 1960 to 2027 and life table values for mortality specific for gender and age were applied to obtain an estimate of the persons alive at each age by gender for each year from 1960 to 2027. Projections from Statistics Canada were used for the population after 2006 <3>.

Data from Statistics Canada and Citizenship and Immigration Canada were used to estimate the number of immigrants arriving in Canada and the distribution by age and sex of those arriving for each of 84 major countries or groupings of countries produced routinely by Statistics Canada. The resulting populations were compared with Census Canada data stratified on age, gender and whether born in Canada or elsewhere and, for those who immigrated, by country of birth, since 1960. Where digressions from census statistics were greater than 5%, the input parameters, including births, immigrants and life table mortality were adjusted to fit the observed census data.

In the second phase, populations in each of the four exposure categories were obtained using an approach specific to each category as described below. In general, the rate of uptake of HCV-risk associated behaviours and mortality rates were incorporated to estimate age and sex-specific prevalence of the behaviour and vital status. These were then compared to values from observed studies and from previous modeling exercises and adjusted accordingly.

Limited data are available to estimate the number of IDUs in Canada. One study used the capture-recapture methodology to estimate the number of active IDUs in Montreal, Toronto and Vancouver <4>. An independent study estimated the number of IDUs in these three cities based on HIV testing data <5>. In 2000, Eric Single estimated the number of IDUs in Canada to be from 75,000 to 125,000 <6>, a number consistent with the results of both these studies.

Triangulation techniques used HIV diagnostic data and estimated HIV prevalence rates for the three major cities (Montreal, Toronto and Vancouver), the rest of the three provinces (Quebec, Ontario and British Columbia) and the other seven provinces to help converge the estimate.

For IDUs, we took into account the proportion of the population initiating injection as a population rate and the proportion of drug users who stop injecting drugs in the course of each year to generate a second population of ex-IDUs. It is important to take this into account in estimating the extent of hepatitis C infection since the burden of HCV infection is considerable among persons who are not actively injecting but may have injected at sometime in the past. A preliminary model of this type had been developed by the contractor for HIV infection among IDUs in New York City, Montreal and Toronto which closely fit the observed HIV prevalence data. In this approach, the number of IDUs was obtained by varying the rates of initiation and cessation of injection drug use so as to "generate" estimates which approximated the existing, though imprecise, estimates of the number of IDUs in Canada. This analysis incorporated values for both active IDUs and ex-IDUs.

Patterns of blood transfusion were based on the modeling work carried out by the Expert Working Group in 1998 <1>.

For hemophilia patients, a fixed proportion was initially applied to male births and then modified to fit the known numbers of hemophilia patients in Canada, after taking into account mortality rates.

The "Other" category included persons infected by HCV primarily through sexual transmission and through parenteral exposures as health care workers and was estimated by subtraction from the total population after accounting for persons in the three higher risk categories, namely IDUs, blood transfusion recipients and hemophilia patients.

To estimate the population size in each year accurately, the components and rates of mortality were modeled specifically for each of the three major exposure categories. For IDUs, mortality was considered in three categories, namely, 1) life table mortality; 2) mortality directly related to injection drug use, including overdose, serious systemic infections, infection and trauma and 3) mortality due to HIV disease. HIV-related mortality among IDUs began, for the most part, in around 1985. The excess mortality related to overdose, etc. was greater among those who are HIV-infected since these persons tend to be more active injectors.

For blood transfusion recipients, the high level of mortality following transfusion associated with the illness for which the patient was transfused was incorporated. Mortality for blood transfusion recipients was based on the 1998 study <1> which incorporated high level of mortality within the first three years following transfusion with gradually declining excess mortality until 10 years after which life table mortality was used. However, to simplify the model construction, we used a two rather than a three stage approach with an appropriately high mortality in the year following the transfusion and a weighted mortality thereafter to approximate the mortality rates from the 1998 study. The numbers specific for each year by age and sex were generated and then compared to available estimates of populations so that the size of the population at risk was plausible.

For hemophilia patients, data on mortality were derived from the published studies <7-9> and included the effect of the advent of specific treatment for hemophilia in the 1970s, in decreasing mortality. In this population, mortality due to HIV infections acquired in the period 1978-1985 was incorporated in the model.

For persons in all exposure categories, mortality based on lifetable values was applied. This was the only mortality applied to persons in the "Other" exposure category.

It is important to note that HIV incidence was included in the model only to take into account competing mortality from HIV infection. Therefore, HIV infection was limited to exposure categories with relatively high rates of HIV, namely IDUs and hemophilia patients. Also, to simplify the model and due to the higher incidence and prevalence of HCV in these groups, incident HIV infections were considered to occur only in persons already infected by HCV. Thus, the final estimate of HIV among those HCV-infected is not an accurate estimate of HCV-HIV co-infection in Canada since it does not include co-infected men who have sex with men. Estimating HCV-HIV co-infection was beyond the scope of the current project.

Stage 2

HCV incidence rates derived from published studies and previous modeling studies were used to estimate the number of HCV-infected persons for each of the four groups defined above. With respect to immigrants, the prevalence in their country of origin stratified by gender and appropriate for the age at arrival was used to generate the number of prevalent HCV infections at time of arrival. Immigrant populations were also subjected to incident HCV infection related to injection drug use, blood transfusion and "Other" modes of transmission category but not risk associated with hemophilia.

Many hemophilia patients may not be admissible for immigration into Canada. More importantly, the number of non-Canadian-born hemophilia patients would likely be small due to prior higher mortality in countries where limited specialty care is available and to restricted admissibility for immigration. In any case, no data were available on hemophilia patients by region of birth. For these reasons and for the sake of simplicity, hemophilia patients were modeled within the Canadian-born population.

Data on HCV incidence rates from the Enhanced Hepatitis Strain Surveillance System (EHSSS) <10, 11> adjusted for under-reporting and asymptomatic infection were used for initial values for overall HCV incidence. In a second approach, data from the limited available epidemiologic studies were also used to guide initial HCV incidence values. In this approach, incidence was applied only to susceptible persons; this is particularly important for IDUs. The numbers of prevalent HCV infections were subsequently compared to available data from special studies and previous modeling exercises to fit with observed HCV prevalence data <12-43>.

Stage 3

HCV-infected persons by stage of infection was progressed using annual transition parameters of a Markov model based on both observed data and modeling studies previously published. With respect to the natural history of HCV infection, the true transition probabilities and the important covariates are still somewhat incompletely characterized but there is the emergence of a consensus around the likely values of many of these parameters. Several studies have examined or reviewed the progression from HCV infection through serious sequelae <44-49>. A critical review of a large number of natural history studies published recently by Freeman <50> was of particular interest in this regard as was the modeling study by Salomon <51>, which used observed data to constrain the true values of these progression parameters. Finally, the report of Krahn and colleagues <52, 53> was also extremely helpful since it included a systematic review of transition parameters and the important modifying factors such as age, sex and alcohol intake.

For the purposes of this study, the following stages of HCV-related morbidity were included: cirrhosis, decompensated cirrhosis (liver failure), hepatocellular carcinoma, liver transplant and liver-related death. The final estimates were compared to reported and modeled numbers of liver-related deaths and incidence of hepatocellular carcinoma published by investigators at Health Canada <54-56>. See Sections 2.6 and 2.7 below for further details of the methodology used to model HCV sequelae.

The above modeling exercise did not include the impact of treatment mainly because the numbers of persons under treatment are poorly defined and would be low in relation to the reservoir of HCV infections in Canada.

2.2 Modeling HCV prevalence

To estimate HCV prevalence in Canada in 2007, the reference year, we considered separately each population stratum defined by exposure category and place of birth (Canada versus elsewhere). We reviewed studies carried out in Canada <12-43> including those done in prisons available as of September 2008 <21-31>. We used HCV prevalence and incidence in IDUs as observed in through the Canadian Street Youth Surveillance <32>, studies in Montreal <33>, Vancouver <34,35>, and Toronto <36>as well as from studies in other countries. We also reviewed the results from I-track <37> and SurvUDI, a sentinel surveillance project of IDUs recruited primarily at needle exchanges based in multiple centres in Quebec and in Ottawa <38,39>.

The data for modeling HCV infection acquired through blood transfusion were based on work carried out in a previous study <1> and integrated into the model of HCV prevalence and incidence.

A model developed for hemophilia patients carried out by the contractor for the purpose of estimating HCV and HCV-HIV co-infection was adapted for the purposes of the present study. Data from two studies of hemophilia patients in the UK were also useful in this regard <7, 8>.

The number of HCV transmissions in the “Other” category was developed on a proportional basis to fix the percentage of infections related to non-parenteral drug use, sexual transmission, and transmission in the health care setting based on data from the EHSSS as well as studies carried out in the United States.

2.3 HCV infection among persons not born in Canada

Extensive analyses were carried out to determine the contribution of HCV infections in Canada related to infections acquired before arrival in Canada among persons born elsewhere but who have immigrated to this country. An initial model was developed for each country in the world using data from the World Health Organization on country-specific HCV prevalence and applied to the population of each country. Adjustments were made as necessary such that the total world prevalence of HCV matched the 170 million HCV-infected persons estimated by the World Health Organization. Data from the 2001 census from Statistics Canada on persons living in Canada by country of birth were then applied to the HCV prevalence in the country of origin to determine the number of HCV-infected persons living in Canada and as well to make a preliminary characterization of the extent of HCV infection among immigrants from the most important countries of origin.

2.4 Use of data from the Enhanced Hepatitis Strain Surveillance System (EHSSS)

Data were kindly provided by the Public Health Agency of Canada on acute and chronic HCV infections collected at eight sentinel sites in Canada beginning in 1998. Custom outputs were kindly

provided by the Public Health Agency of Canada on the distribution of cases by mutually exclusive risk factor by year, country of birth, acute versus chronic infection for each sentinel site. We performed a cross-tabulation of risk factors by country of birth. The purpose of this analysis was, for each sentinel site, to compare the EHSSS data to census data to determine the degree to which HCV prevalence may be different than among persons born outside Canada. We also wished to validate the initial results from the country-specific HCV prevalence analysis as noted in Section 2.3 above to identify the most important countries involved. Finally, we wished to test our initial hypothesis that the majority of HCV infection among persons born outside Canada was related to exposures other than injection drug use, the most important exposure for persons born in Canada.

2.5 HCV incidence

HCV incidence is unknown for most groups in Canada with the possible exception of IDUs in selected urban centers in Canada We used two approaches to obtain plausible estimates of the annual number of new HCV infections in Canada. The first approach consisted of examining the incidence of clinically apparent and reported cases of confirmed acute HCV infection through data collected by EHSSS. The "true" HCV incidence was derived by dividing this rate by the proportion of acute HCV infections that are icteric (and therefore presumably severe enough as to motivate the seeking of medical care and serologic diagnosis) reporting. The value for the proportion that would be symptomatic was 20% and the proportion of symptomatic infections that would be reported was 75% since most of such infections would be laboratory diagnosed and thus be reported.

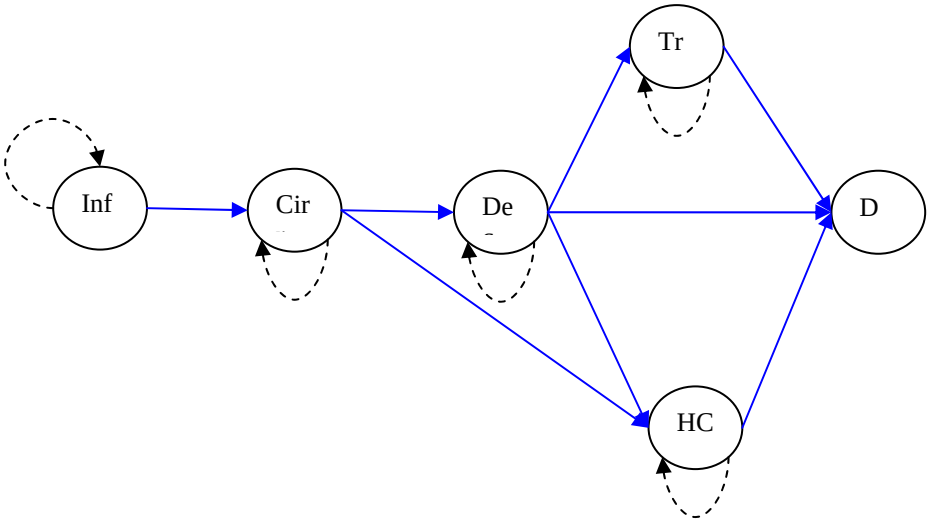
We also used a second, independent approach to estimate HCV incidence. We estimated the proportion and number of active IDUs in Canada who would be susceptible to HCV infection (i.e. not already HCV-infected) and multiplied this number by the HCV incidence observed in epidemiologic studies among IDUs <55, 56>. This number of new infections among IDUs was then divided by the estimated proportion of new HCV infections that are thought to occur among IDUs, based largely on the observations at the eight sites of the EHSSS from 1998-2002.

The methodology for estimating HCV incidence was based on collaborative work carried out with Dr. Shimian Zou in 2001, who worked at Health Canada at the time.

2.6 Modeling HCV outcomes

We carried out an extensive review of the medical literature to determine the annual rates of transition from initial HCV infection to the more advanced stages of HCV disease and its sequelae. We took into account the proportion of persons newly infected with HCV who remained viremic (i.e. had detectable HCV RNA) and, subsequently, the annual rate of HCV RNA loss and the rate of HCV antibody loss. Thus, the model incorporated three stages of HCV serologic status: RNA+ Ab+, RNA- Ab+, and RNA- Ab-. Following HCV infection, the natural history of hepatitis C was simulated using a Markov model through the following stages: infection (pre-cirrhotic), cirrhosis, decompensation, transplantation, hepatocellular carcinoma and death. The values of the annual transition probabilities were obtained from published studies and reports <44-53>. The schematic model and transition probabilities used are shown in Figure 1.

Figure 1: Markov Model of Transition Through Stages of HCV Infection



Legend:
Inf = HCV infection
Ci = Cirrhosis
De = Decompensated liver failure
H = Hepatocellular carcinoma
Tr = Liver transplant
D = HCV-related death

Summary of HCV stage transition probabilities

		HCV neg.				HCV pos			
		Female		Male		Female		Male	
From:	**To:**	<40	40+	<40	40+	<40	40+	<40	40+
Inf	Ci	.0025	.0038	.0035	.0052	.0036	.0054	.0050	.0075
Ci	De	.0450	.0450	.0450	.0450	.1350	.1350	.1350	.1350
Ci	H	.0170	.0170	.0170	.0170	.0170	.0170	.0170	.0170
De	H	.0300	.0300	.0300	.0300	.0300	.0300	.0300	.0300
De	Tr	.0330	.0330	.0330	.0330	.0330	.0330	.0330	.0330
De	D	.1380	.1380	.1380	.1380	.4526	.4526	.4526	.4526
H	D	.8600	.8600	.8600	.8600	.8600	.8600	.8600	.8600
Tr	D	.0730	.0730	.0730	.0730	.0730	.0730	.0730	.0730

2.7 The integrated analytic HCV model

The entire model was treated as a Markov model in an integrated continuum from entry through birth or immigration and then transition to exposure-related behaviours or experiences, mortality, HCV infection and progression to HCV disease.

All tables and rates were developed in Excel spreadsheets. Required parameters were consolidated in a consistent and usable format in two Excel "input" spreadsheets.

The model engine was written in the programming language APL+Win Version 4.0.03 supplied by APL2000 Inc. Data from the two parameters spreadsheets were copied into the APL workspace and saved. Any subsequent changes were recopied and saved. Adjustment and control parameters were developed and stored directly in the APL workspace.

The raw product of the model was a series of arrays of the sub-populations as defined above and the decrements of every type to which each population is subjected. For example, the shape of the array MaleResults is 63 (years 1960-2027) by 111 (ages 0-110) by 386 (number of population and decrement columns). Note that, except for death, each decrement column is the new-entrant column for a subsequent sub-population.

Subsidiary programs condensed and consolidated the raw output in various ways such as for 5-year periods, summing over age and combining some columns. Finally, selected condensed and consolidated data were exported directly by program to Excel spreadsheets. In the spreadsheets, simple further calculations such as summing and ratioing plus formatting were performed.

For immigrants, a "super-model" was developed which ran the basic model for each country/region and summed the results. It differed in basic model processes only as follows:

- Instead of births at age* zero each year, new immigrants entered the model at age of arrival
- A proportion of new immigrants were considered to be infected with HCV on arrival
- Hemophilia patients were all modeled within the Canadian-born population for the reasons stated in Section 1 above and because this simplified the analytic approach by modeling this group as one rather than two populations.

To account for competing mortality, HIV infection (including HIV incidence and HIV-related mortality) was incorporated into the model. This was carried out only for IDUs and hemophilia patients since the contribution of mortality among blood transfusion recipients (likely fewer than 100 persons also infected with HIV among an estimated 35,000 HCV-infected blood transfusion recipients) and other persons (likely fewer than 1,000 HIV-HCV coinfected persons among the estimated 74,000 HCV-infected persons +in the "Other" category). Among ex-IDUs, HIV incidence was considered to be zero since essentially all their HIV risk is related to active drug injection.

As indicated in Section 2.1 in the description of Stage 1, we also incorporated mortality due to other causes than HCV and HIV infection into the final model. For this purpose, we used life table values specific for each age and sex.

To model populations at risk and HCV incidence and prevalence, we adjusted model parameters so that model estimates were within 2% of the epidemiologically modeled estimates for these values.

2.8 Prevalence of HCV infection by province/territory

We used the number of reported HCV cases and populations of each Canadian province and territory that was reported to the Canadian Notifiable Surveillance System as of September 2008, the results of the 1998 provincial/territorial HCV model and the number of modeled HCV infection by exposure category in 2007 to impute the number and rate of HCV-infected persons in each province/territory by exposure category for 2007.

2.9 Prevalence of HCV infection in incarcerated populations

The number and rate of HCV infections among incarcerated persons was determined by reviewing the results of epidemiologic studies of HCV infection in this population. Rates of HCV infection were examined according to history of injection drug use for federal and provincial prisons independently. We concentrated on studies of penal institutions in Canada examining key studies and reviews available as of September 2008 <21-31>. We also reviewed special studies from Montreal <33> and Vancouver <34, 35> and a situation report on blood-borne infections among IDUs in Ontario <36>.

It is clear from the above and other studies that a prisoner's history of injection drug use is by far the most important factor for acquiring HCV infection. Drug injection while in prison may account for some HCV infections. This, however, is likely relatively rare and, in any case, such infections would be primarily among prisoners who injected drugs before being incarcerated and would therefore be reflected in the results of seroepidemiologic studies.

Based on our review, we estimated that approximately 30% of prisoners had injected drugs at some time in their life. We also concluded that, in Canada, HCV prevalence among prisoners in provincial institutions with an IDU history was 56% and in federal institutions 70%. Among prisoners without such a history, HCV prevalence was 0.10% and 1.0%, respectively.

2.10 Prevalence of HCV infection in Aboriginal populations

Few studies of HCV infection in Aboriginal populations have been carried out <40-43> and those that have usually focus on high risk non-representative populations. However, Minuk et al. <41> recently published a review of viral hepatitis among Aboriginal populations which draws on both published and unpublished data and was extremely useful in beginning to quantify the risk of HCV infection in this population. One study <43> of a "street-involved" population in Winnipeg, of whom 63% were Aboriginal, found an HCV prevalence of 22.3% in Metis, 19.4% in First Nations, and 14.4% in non-Aboriginal subjects. Overall, HCV prevalence was 47.7% in IDUs but only 3.7% among non-IDUs.

We also used a recent analysis from the Ontario AIDS surveillance program on reported AIDS cases among Aboriginal IDUs <58> to help shed light on the relative risk of HCV in this population. This was done for each exposure category but special attention was given to AIDS cases among the men who have sex with other men and inject drugs (MSM-IDU) and IDU categories. Among MSM-IDUs, six of 219 AIDS cases to 2004 with known ethnicity (or 2.7%) were Aboriginal persons and among IDUs, 18 of 236 AIDS cases to 2004 with known ethnicity (7.6%) were Aboriginal persons. Thus, Aboriginals are over-represented among IDU-related AIDS cases since they constituted only about 1.5% of the Ontario population in 2004 (188,000 of 12,407,000). AIDS cases in the other exposure categories taken together among Aboriginal persons accounted for 0.7% of cases. Thus, the number of HIV infections among Aboriginal IDUs was five-fold greater than for the rest of the population. This is likely a reflection of higher rates of injection drug use in Aboriginal populations,

though it is difficult to eliminate higher HIV prevalence in Aboriginal IDUs as a contributing factor. Both would lead to a higher HCV prevalence in this population.

Based on his review of both published and unpublished data, Minuk et al. concluded the prevalence of HCV among Aboriginal populations in Manitoba was approximately three-fold greater than in non-Aboriginal Manitobans. In contrast, Calzavara et al. <27> found HCV prevalence among inmates in an Ontario provincial prison to be similar among Aboriginal and non-Aboriginal participants.

Thus, it is difficult to come to any firm conclusion about HCV prevalence among Aboriginal persons based on the limited and conflicting data available. Nevertheless, we believe it is likely that HCV prevalence is higher among Aboriginal population and that a three-fold difference is plausible.

2.11 Proportion of HCV infections diagnosed and reported

One of the objectives of the present study was to estimate the number and proportion of HCV-infected persons living in Canada as of 2007 who had been diagnosed. To estimate this, data on HCV cases (including both acute and chronic HCV infections) reported from 1991 to 2007 and that reported to the Canadian Notifiable Disease Reporting System as of September 2008, were provided by the Public Health Agency of Canada. For jurisdictions in which HCV data from 1991 were not available via the Canadian Notifiable Disease Reporting System, the number of HCV diagnoses before case reporting data were available was estimated by using relative weights among the provinces derived from years for which data on reported cases were available. Cases reported to the Canadian Notifiable Disease Reporting System include chronic, acute and undifferentiated cases.

2.12 Number of persons with diagnosed HCV infection still living

Some persons diagnosed with HCV infection and reported from 1991 to 2007 died during this period, both related to their disease as well from other causes. This may represent a significant proportion of diagnosed cases during the 18-year period. Therefore, we used the annual mortality rates derived for the actuarial model over this period to estimate the number of deaths in each year subsequent to HCV diagnosis. Thus, we were able to estimate the number of diagnosed HCV cases alive as of December 2007 and, in turn, more accurately calculate the proportion of modeled HCV-infected persons alive as of 2007 who have been diagnosed.

3. RESULTS

3.1 Actuarial model of HCV infection

The results of the modeling of HCV infection in Canada are presented in Tables 1 through 4.

Tables 1a, 1b and 1c present the estimated number of prevalent and incident HCV infections by place of birth, sex and exposure category in Canada in 2007. Overall, among 31,220,455 persons living in Canada as of December 2007, we estimated that 242,521 were infected with hepatitis C, for a prevalence rate of 0.78% or about one in 129 persons. Persons born in Canada accounted for 190,960 (79%) of these infections compared to 51,560 (21%) among immigrants. The HCV prevalence rate in persons born outside Canada was only slightly higher than that among persons born in Canada (0.80% compared to 0.77%). Sixty-one percent of prevalent HCV infections were among males, who had a prevalence rate 1.6-fold higher than females.

As expected, the majority of prevalent HCV infections were among IDUs. Current and ex-IDUs accounted for 139,964 (58%) of HCV-infected persons in Canada. Persons who were infected through the receipt of a blood transfusion accounted for 25,905 (11%) of HCV infections, hemophilia patients 861 (0.3%) and persons infected by other routes of transmission 75,790 (31%).

Tables 1a, 1b and 1c also present the estimated number of incident HCV infections by exposure category and sex in Canada in calendar year 2007 for all Canadian residents, persons born in Canada, and immigrants, respectively. Overall, we estimated that 7,945 persons in Canada were newly infected with HCV in 2007, for an overall incidence rate of 0.026% or about one in 3,900 persons. 5,185 (65%) of new HCV infections occurred in men, whose incidence rate was almost double that of women (0.034% compared to 0.018%). As expected, 83% of new HCV infections occurred in active IDUs.

Tables 1a, 1b and 1c include estimates of HIV prevalence and incidence. In our model, we estimated that 10,458 HCV-infected persons were also infected with HIV. This cannot be interpreted as an estimate of total HCV-HIV co-infection in Canada since HIV infection was included only to allow for competing mortality and therefore limited to IDU and hemophilia patients as described in Section 2.1 above. IDUs accounted for 98% of HCV-HIV co-infected persons in our model.

Table 1a **Modeled prevalence and incidence of HCV Infection and HCV/HIV co-infection by exposure category and sex among all persons, Canada, 2007**

Exposure category			Prevalence				Incidence			
			HCV		HIV co-infection		HCV		HIV co-infection	
	Sex	Population	n	rate	n	rate	n	rate	n	rate
IDU										
	Male	56,626	35,373	62.5%	3,765	6.6%	4,481	21.1%	571	1.1%
	Female	27,735	17,139	61.8%	1,788	6.4%	2,126	20.1%	270	1.0%
	Total*	**84,361**	**52,512**	**62.2%**	**5,553**	**6.6%**	**6,607**	**20.7%**	**841**	**1.1%**
Ex-IDU										
	Male	122,550	58,476	47.7%	3,178	2.6%	0	0.0%	0	0.0%
	Female	61,290	28,977	47.3%	1,530	2.5%	0	0.0%	0	0.0%
	Total*	**183,839**	**87,452**	**47.6%**	**4,708**	**2.6%**	**0**	**0.0%**	**0**	**0.0%**
Hemophilia										
	Male	2,162	861	39.8%	197	9.1%	0	0.0%	0	0.0%
	Female	0	0	0.0%	0	0.0%	0	0.0%	0	0.0%
	Total*	**2,162**	**861**	**39.8%**	**197**	**9.1%**	**0**	**0.0%**	**0**	**0.0%**
Transfused										
	Male	1,577,958	12,847	0.81%	-	-	1	0.000%	-	-
	Female	1,747,788	13,058	0.75%	-	-	1	0.000%	-	-
	Total*	**3,325,746**	**25,905**	**0.78%**	-	-	**1**	**0.000%**	-	-
Other										
	Male	13,653,813	39,224	0.29%	-	-	704	0.005%	-	-
	Female	13,970,533	36,566	0.26%	-	-	633	0.005%	-	-
	Total*	**27,624,347**	**75,790**	**0.27%**	-	-	**1,337**	**0.005%**	-	-
Total										
	Male	15,413,109	146,781	0.95%	7,140	0.046%	5,185	0.034%	571	0.0%
	Female	15,807,346	95,740	0.61%	3,318	0.021%	2,760	0.018%	270	0.0%
	Total*	**31,220,455**	**242,521**	**0.78%**	**10,458**	**0.033%**	**7,945**	**0.026%**	**841**	**0.0%**

**Numbers may not add up exactly due to a combination of modelling uncertainities and the use of rounded whole numbers in the calculations*

Note: A dash "-" indicates a category not included in the model

Table 1b **Modeled prevalence and incidence of HCV Infection and HCV/HIV co-infection by exposure category and sex among persons born in Canada, Canada, 2007**

Exposure category / Sex	Population	Prevalence				Incidence			
		HCV		HIV co-infection		HCV		HIV co-infection	
		n	rate	n	rate	n	rate	n	rate
IDU									
Male	49,735	31,388	63.1%	3,400	6.8%	3,945	21.5%	511	1.1%
Female	24,338	15,186	62.4%	1,611	6.6%	1,865	20.4%	241	1.1%
Total*	**74,073**	**46,574**	**62.9%**	**5,011**	**6.8%**	**5,810**	**21.1%**	**751**	**1.1%**
Ex-IDU									
Male	107,678	51,902	48.2%	2,869	2.7%	0	0.0%	0	0.0%
Female	53,950	25,746	47.7%	1,379	2.6%	0	0.0%	0	0.0%
Total*	**161,628**	**77,647**	**48.0%**	**4,248**	**2.6%**	**0**	**0.0%**	**0**	**0.0%**
Hemophilia									
Male	2,162	861	39.8%	197	9.1%	0	0.0%	0	0.0%
Female	0	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Total*	**2,162**	**861**	**39.8%**	**197**	**9.1%**	**0**	**0.0%**	**0**	**0.0%**
Transfused									
Male	1,247,010	10,599	0.85%	-	-	0.4	0.0%	-	-
Female	1,353,113	10,775	0.80%	-	-	0.5	0.0%	-	-
Total*	**2,600,122**	**21,374**	**0.82%**	-	-	**0.9**	**0.0%**	-	-
Other									
Male	10,918,419	23,457	0.21%	-	-	658	0.006%	-	-
Female	11,027,878	21,048	0.19%	-	-	557	0.005%	-	-
Total*	**21,946,297**	**44,504**	**0.20%**	-	-	**1,215**	**0.006%**	-	-
Total									
Male	12,325,003	118,207	0.96%	6,466	0.052%	4,604	0.038%	511	0.004%
Female	12,459,279	72,754	0.58%	2,990	0.024%	2,423	0.020%	241	0.002%
Total*	**24,784,282**	**190,960**	**0.77%**	**9,456**	**0.038%**	**7,026**	**0.029%**	**751**	**0.003%**

**Numbers may not add up exactly due to a combination of modelling uncertainities and the use of rounded whole numbers in the calculations*

Note: A dash "-" indicates a category not included in the model

Table 1c **Modeled prevalence and incidence of HCV Infection and HCV/HIV co-infection by exposure category and sex among persons born outside Canada, Canada, 2007**

Exposure category		Prevalence				Incidence			
		HCV		HIV co-infection		HCV		HIV co-infection	
Sex	Population	n	rate	n	rate	n	rate	n	rate
IDU									
Male	6,891	3,984	57.8%	365	5.3%	535	18.4%	60	0.92%
Female	3,397	1,953	57.5%	177	5.2%	261	18.1%	29	0.91%
Total*	**10,287**	**5,938**	**57.7%**	**542**	**5.3%**	**797**	**18.3%**	**89**	**0.92%**
Ex-IDU									
Male	14,871	6,574	44.2%	309	2.1%	0	0.0%	0	0.0%
Female	7,340	3,231	44.0%	151	2.1%	0	0.0%	0	0.0%
Total*	**22,211**	**9,805**	**44.1%**	**460**	**2.1%**	**0**	**0.0%**	**0**	**0.0%**
Hemophilia									
Male	0	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Female	0	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Total*	**0**	**0**	**0.0%**	**0**	**0.0%**	**0**	**0.0%**	**0**	**0.0%**
Transfused									
Male	330,949	2,248	0.68%	-	-	0	0.0%	-	-
Female	394,675	2,283	0.58%	-	-	0	0.0%	-	-
Total*	**725,624**	**4,531**	**0.62%**	-	-	**0**	**0.0%**	-	-
Other									
Male	2,735,395	15,768	0.58%	-	-	46	0.002%	-	-
Female	2,942,655	15,518	0.53%	-	-	76	0.003%	-	-
Total*	**5,678,050**	**31,286**	**0.55%**	-	-	**122**	**0.002%**	-	-
Total									
Male	3,088,105	28,574	0.93%	674	0.022%	582	0.019%	60	0.002%
Female	3,348,067	22,986	0.69%	328	0.010%	337	0.010%	29	0.001%
Total*	**6,436,172**	**51,560**	**0.80%**	**1,002**	**0.016%**	**919**	**0.014%**	**89**	**0.001%**

**Numbers may not add up exactly due to a combination of modelling uncertainities and the use of rounded whole numbers in the calculations*

Note: A dash "-" indicates a category not included in the model

Tables 2a, 2b and 2c present the prevalence of HCV infection in Canada in 2007 by sex and age group for all Canadian residents, persons born in Canada, and immigrants, respectively. The pattern of HCV prevalence by age was somewhat different among those born in Canada than among immigrants. For persons born in Canada, HCV prevalence increased with increasing age to a peak of 1.37% in persons 55-59 years of age and then decreased thereafter. For persons born elsewhere, HCV prevalence increased with increasing age, attaining 2.15% in those 90+ years of age, the oldest age group. Overall, the HCV prevalence rate was 0.95% in males and 0.61% in females.

Table 2a Modeled HCV prevalence by age group and sex among all persons, Canada, 2007

	Male			Female			Both sexes		
Age (years)	Population	HCV number	HCV rate	Population	HCV number	HCV rate	Population	HCV number*	HCV rate
0-4	883,789	36	0.004%	850,404	54	0.006%	1,734,193	89	0.005%
5-9	888,541	106	0.012%	854,537	149	0.017%	1,743,078	256	0.015%
10-14	1,020,302	186	0.018%	979,790	253	0.026%	2,000,091	439	0.022%
15-19	1,124,092	1,099	0.098%	1,082,505	752	0.069%	2,206,597	1,851	0.084%
20-24	1,091,925	4,420	0.40%	1,063,587	2,505	0.24%	2,155,512	6,925	0.32%
25-29	1,096,850	9,966	0.91%	1,090,286	5,500	0.50%	2,187,136	15,465	0.71%
30-34	1,079,204	13,822	1.28%	1,088,544	7,730	0.71%	2,167,748	21,552	0.99%
35-39	1,112,922	16,112	1.45%	1,130,875	9,319	0.82%	2,243,798	25,431	1.13%
40-44	1,248,603	17,864	1.43%	1,269,229	10,632	0.84%	2,517,832	28,496	1.13%
45-49	1,400,255	20,107	1.44%	1,427,374	12,354	0.87%	2,827,629	32,460	1.15%
50-54	1,298,141	19,196	1.48%	1,336,508	12,232	0.92%	2,634,649	31,428	1.19%
55-59	1,048,727	15,955	1.52%	1,098,456	10,602	0.97%	2,147,183	26,557	1.24%
60-64	807,019	12,033	1.49%	861,344	8,465	0.98%	1,668,363	20,498	1.23%
65-69	541,287	7,518	1.39%	598,454	5,839	0.98%	1,139,741	13,357	1.17%
70-74	361,043	4,418	1.22%	430,575	3,967	0.92%	791,618	8,385	1.06%
75-79	238,948	2,369	0.99%	324,150	2,621	0.81%	563,098	4,990	0.89%
80-84	118,654	998	0.84%	195,459	1,519	0.78%	314,113	2,517	0.80%
85-89	42,735	404	0.94%	91,554	840	0.92%	134,288	1,244	0.93%
90+	10,071	172	1.71%	33,715	408	1.21%	43,786	580	1.33%
Total*	**15,413,109**	**146,781**	**0.95%**	**15,807,346**	**95,740**	**0.61%**	**31,220,455**	**242,521**	**0.78%**

**Numbers may not add up exactly due to a combination of modelling uncertainities and the use of rounded whole numbers in the calculations*

Table 2b

Modeled HCV prevalence by age group and sex among persons born in Canada, Canada, 2007

Age (years)	Male			Female			Both sexes		
	Population	HCV number	HCV rate	Population	HCV number	HCV rate	Population	HCV number*	HCV rate
0-4	864,684	4	0.000%	830,727	3	0.000%	1,695,411	7	0.000%
5-9	833,279	10	0.001%	800,939	8	0.001%	1,634,219	18	0.001%
10-14	927,883	18	0.002%	892,550	15	0.002%	1,820,433	32	0.002%
15-19	993,638	811	0.082%	957,931	384	0.040%	1,951,569	1,195	0.061%
20-24	925,422	3,708	0.40%	896,501	1,852	0.21%	1,821,924	5,560	0.31%
25-29	901,281	8,460	0.94%	879,338	4,341	0.49%	1,780,619	12,801	0.72%
30-34	849,516	11,520	1.36%	835,708	6,064	0.73%	1,685,223	17,585	1.04%
35-39	843,433	13,134	1.56%	836,410	7,214	0.86%	1,679,843	20,348	1.21%
40-44	957,000	14,738	1.54%	956,860	8,434	0.88%	1,913,860	23,172	1.21%
45-49	1,056,494	16,564	1.57%	1,065,175	9,838	0.92%	2,121,669	26,402	1.24%
50-54	948,282	15,580	1.64%	967,158	9,586	0.99%	1,915,440	25,166	1.31%
55-59	748,060	12,767	1.71%	775,995	8,172	1.05%	1,524,055	20,939	1.37%
60-64	563,752	9,418	1.67%	596,692	6,375	1.07%	1,160,444	15,793	1.36%
65-69	364,918	5,585	1.53%	400,258	4,166	1.04%	765,176	9,751	1.27%
70-74	246,464	3,166	1.28%	292,606	2,743	0.94%	539,070	5,908	1.10%
75-79	173,044	1,677	0.97%	234,790	1,803	0.77%	407,834	3,480	0.85%
80-84	88,085	669	0.76%	144,859	989	0.68%	232,944	1,658	0.71%
85-89	32,440	268	0.83%	69,494	536	0.77%	101,934	804	0.79%
90+	7,329	109	1.49%	25,288	231	0.91%	32,616	340	1.04%
Total*	**12,325,003**	**118,207**	**0.96%**	**12,459,279**	**72,754**	**0.58%**	**24,784,282**	**190,960**	**0.77%**

**Numbers may not add up exactly due to a combination of modelling uncertainities and the use of rounded whole numbers in the calculations*

Table 2c

Modeled HCV prevalence by age group and sex among persons born outside Canada, Canada, 2007

Age (years)	Male			Female			Both sexes		
	Population	HCV number	HCV rate	Population	HCV number	HCV rate	Population	HCV number*	HCV rate
0-4	19,105	32	0.17%	19,676	50	0.26%	38,782	82	0.21%
5-9	55,262	96	0.17%	53,598	141	0.26%	108,860	237	0.22%
10-14	92,419	168	0.18%	87,240	238	0.27%	179,659	407	0.23%
15-19	130,454	288	0.22%	124,574	367	0.29%	255,028	656	0.26%
20-24	166,502	713	0.43%	167,086	653	0.39%	333,588	1,365	0.41%
25-29	195,569	1,506	0.77%	210,948	1,158	0.55%	406,517	2,664	0.66%
30-34	229,688	2,302	1.00%	252,836	1,666	0.66%	482,524	3,967	0.82%
35-39	269,490	2,978	1.11%	294,465	2,105	0.71%	563,955	5,083	0.90%
40-44	291,603	3,126	1.07%	312,369	2,198	0.70%	603,972	5,324	0.88%
45-49	343,761	3,542	1.03%	362,200	2,516	0.69%	705,960	6,058	0.86%
50-54	349,859	3,616	1.03%	369,350	2,646	0.72%	719,209	6,262	0.87%
55-59	300,667	3,188	1.06%	322,461	2,430	0.75%	623,127	5,618	0.90%
60-64	243,267	2,615	1.07%	264,652	2,090	0.79%	507,920	4,705	0.93%
65-69	176,369	1,933	1.10%	198,197	1,673	0.84%	374,566	3,606	0.96%
70-74	114,579	1,253	1.09%	137,969	1,224	0.89%	252,548	2,477	0.98%
75-79	65,904	692	1.05%	89,360	818	0.92%	155,264	1,510	0.97%
80-84	30,570	329	1.08%	50,600	530	1.05%	81,169	859	1.06%
85-89	10,295	135	1.32%	22,060	304	1.38%	32,355	440	1.36%
90+	2,742	63	2.29%	8,427	178	2.11%	11,169	240	2.15%
Total*	**3,088,105**	**28,574**	**0.93%**	**3,348,067**	**22,986**	**0.69%**	**6,436,172**	**51,560**	**0.80%**

**Numbers may not add up exactly due to a combination of modelling uncertainities and the use of rounded whole numbers in the calculations*

Tables 3a, 3b and 3c present the incidence of new HCV infection in Canada in 2007 by sex and age for all Canadian residents, persons born in Canada, and immigrants, respectively. HCV incidence was 2.1-fold higher among persons born in Canada than among immigrants. HCV incidence in males was about double that of females in both groups. However, the higher rate among persons born in Canada was observed for both males and females. In both groups and both sexes, the peak incidence of HCV infection was observed in persons 25-29 years of age. Men 25-29 years of age born in Canada had the highest incidence of any group defined by sex, age and place of birth, with an annual HCV infection rate of 0.159%, or one in 630.

Table 3a Modeled HCV incidence by age group and sex among all persons, Canada, 2007

	Male		Female		Both sexes	
Age (years)	HCV number	Rate	HCV number	Rate	HCV number*	Rate
0-4	1	0.000%	1	0.000%	3	0.000%
5-9	1	0.000%	1	0.000%	2	0.000%
10-14	2	0.000%	1	0.000%	3	0.000%
15-19	318	0.028%	147	0.014%	464	0.021%
20-24	976	0.090%	512	0.048%	1,488	0.069%
25-29	1,588	0.146%	809	0.075%	2,397	0.110%
30-34	1,185	0.111%	627	0.058%	1,812	0.084%
35-39	710	0.065%	402	0.036%	1,112	0.050%
40-44	231	0.019%	131	0.010%	362	0.015%
45-49	127	0.009%	83	0.006%	210	0.008%
50-54	17	0.001%	15	0.001%	32	0.001%
55-59	11	0.001%	11	0.001%	22	0.001%
60-64	8	0.001%	8	0.001%	16	0.001%
65-69	5	0.001%	5	0.001%	10	0.001%
70-74	3	0.001%	3	0.001%	6	0.001%
75-79	2	0.001%	2	0.001%	4	0.001%
80-84	1	0.001%	1	0.001%	2	0.001%
85-89	0	0.001%	1	0.001%	1	0.001%
90+	0	0.001%	0	0.001%	0	0.001%
Total*	**5,185**	**0.034%**	**2,760**	**0.018%**	**7,945**	**0.026%**

**Numbers may not add up exactly due to a combination of modelling uncertainities and the use of rounded whole numbers in the calculations*

Table 3b **Modeled HCV incidence by age group and sex among persons born in Canada, Canada, 2007**

Age (years)	Male		Female		Both sexes	
	HCV number	Rate	HCV number	Rate	HCV number*	Rate
0-4	1	0.000%	1	0.000%	3	0.000%
5-9	1	0.000%	1	0.000%	2	0.000%
10-14	1	0.000%	1	0.000%	3	0.000%
15-19	297	0.030%	138	0.014%	435	0.022%
20-24	895	0.097%	468	0.052%	1,363	0.075%
25-29	1,421	0.159%	718	0.082%	2,139	0.121%
30-34	1,036	0.124%	540	0.065%	1,576	0.095%
35-39	605	0.073%	337	0.041%	942	0.057%
40-44	195	0.021%	110	0.012%	305	0.016%
45-49	109	0.011%	70	0.007%	180	0.009%
50-54	15	0.002%	12	0.001%	27	0.001%
55-59	10	0.001%	9	0.001%	19	0.001%
60-64	7	0.001%	6	0.001%	13	0.001%
65-69	4	0.001%	4	0.001%	8	0.001%
70-74	2	0.001%	2	0.001%	5	0.001%
75-79	2	0.001%	2	0.001%	3	0.001%
80-84	1	0.001%	1	0.001%	2	0.001%
85-89	0	0.001%	1	0.001%	1	0.001%
90+	0	0.001%	0	0.001%	0	0.001%
Total*	**4,604**	**0.038%**	**2,423**	**0.020%**	**7,026**	**0.029%**

**Numbers may not add up exactly due to a combination of modelling uncertainities and the use of rounded whole numbers in the calculations*

Table 3c Modeled HCV incidence by age group and sex among persons born outside Canada, Canada, 2007

Age (years)	Male HCV number	Male Rate	Female HCV number	Female Rate	Both sexes HCV	Both sexes Rate
0-4	0	0.000%	0	0.000%	0	0.000%
5-9	0	0.000%	0	0.000%	0	0.000%
10-14	0	0.000%	0	0.000%	0	0.000%
15-19	21	0.016%	9	0.007%	30	0.012%
20-24	81	0.049%	44	0.026%	124	0.037%
25-29	167	0.086%	91	0.043%	258	0.064%
30-34	149	0.066%	86	0.034%	235	0.049%
35-39	105	0.039%	65	0.022%	170	0.030%
40-44	36	0.012%	22	0.007%	57	0.010%
45-49	18	0.005%	13	0.004%	31	0.004%
50-54	2	0.001%	3	0.001%	5	0.001%
55-59	1	0.000%	2	0.001%	3	0.000%
60-64	1	0.000%	1	0.001%	2	0.000%
65-69	1	0.000%	1	0.000%	2	0.000%
70-74	0	0.000%	1	0.000%	1	0.000%
75-79	0	0.000%	0	0.000%	1	0.000%
80-84	0	0.000%	0	0.000%	0	0.000%
85-89	0	0.000%	0	0.000%	0	0.000%
90+	0	0.000%	0	0.000%	0	0.000%
Total*	**582**	**0.019%**	**337**	**0.010%**	**919**	**0.014%**

**Numbers may not add up exactly due to a combination of modelling uncertainities and the use of rounded whole numbers in the calculations*

3.2 HCV prevalence by province/territory and exposure category

Tables 4a and 4b show the modeled HCV prevalence number and rate in Canada in 2007 by province/territory and exposure category. As seen in Table 4a, the HCV prevalence rate was highest in the Yukon Territories, followed by the Northwest Territories and British Columbia. Three provinces accounted for 80% of HCV infections in Canada, namely Ontario (42%), British Columbia (22%) and Quebec (16%). According to Table 4b, IDUs accounted for 54% to 70% of modeled HCV prevalent infections across provinces and territories.

Table 4a **Modeled* HCV prevalence by province/territory and exposure category, Canada, 2007**

Province / Territory	IDU			Transfused	Hemophilia	Other	Total**	Rate (per total population)
	Current-IDU	Ex-IDU	Total IDU					
British Columbia	11,238	18,715	29,952	5,388	102	17,811	53,254	1.21%
Alberta	4,884	8,133	13,017	2,798	81	8,185	24,081	0.69%
Saskatchewan	1,470	2,449	3,919	466	29	1,819	6,234	0.62%
Manitoba	2,100	3,498	5,599	648	33	2,122	8,401	0.70%
Ontario	21,793	36,293	58,085	11,476	328	32,969	102,858	0.80%
Quebec	8,664	14,430	23,094	3,963	215	10,232	37,505	0.49%
New Brunswick	630	1,049	1,680	311	22	455	2,467	0.33%
Nova Scotia	945	1,574	2,519	492	28	1,213	4,252	0.45%
PEI	158	262	420	26	4	152	602	0.43%
Newfoundland	158	262	420	52	16	152	640	0.13%
Yukon	263	437	700	130	1	379	1,209	3.87%
Nunavut	53	87	140	26	1	76	243	0.78%
NWT	158	262	420	130	1	227	778	1.83%
Canada Total**	**52,512**	**87,452**	**139,964**	**25,905**	**861**	**75,790**	**242,521**	0.73%

**The provincial and territorial estimates of HCV prevalence presented here are based on an interpolation from national estimates and may be subject to considerable uncertainty. Provincial/territorial data are definitive should a discrepancy exist*

***Numbers may not add up exactly due to a combination of modelling uncertainities and the use of rounded whole numbers in the calculations*

Table 4b Modeled* HCV prevalence (number and proportion) by province/territory and by exposure category, Canada, 2007

	IDU													
	Current-IDU		Ex-IDU		Total IDU		Transfused		Hemophilia		Other		Total	
Province / Territory	HCV number	%[1]	HCV number	%[1]	HCV number	%[1]	HCV number	%[1]	HCV number	%[1]	HCV number	%[1]	HCV number**	%[1]
British Columbia	11,238	21.1%	18,715	35.1%	29,952	56.2%	5,388	10.1%	102	0.19%	17,811	33.4%	53,254	100.0%
Alberta	4,884	20.3%	8,133	33.8%	13,017	54.1%	2,798	11.6%	81	0.34%	8,185	34.0%	24,081	100.0%
Saskatchewan	1,470	23.6%	2,449	39.3%	3,919	62.9%	466	7.5%	29	0.47%	1,819	29.2%	6,234	100.0%
Manitoba	2,100	25.0%	3,498	41.6%	5,599	66.6%	648	7.7%	33	0.39%	2,122	25.3%	8,401	100.0%
Ontario	21,793	21.2%	36,293	35.3%	58,085	56.5%	11,476	11.2%	328	0.32%	32,969	32.1%	102,858	100.0%
Quebec	8,664	23.1%	14,430	38.5%	23,094	61.6%	3,963	10.6%	215	0.57%	10,232	27.3%	37,505	100.0%
New Brunswick	630	25.5%	1,049	42.5%	1,680	68.1%	311	12.6%	22	0.87%	455	18.4%	2,467	100.0%
Nova Scotia	945	22.2%	1,574	37.0%	2,519	59.3%	492	11.6%	28	0.65%	1,213	28.5%	4,252	100.0%
PEI	158	26.2%	262	43.6%	420	69.8%	26	4.3%	4	0.72%	152	25.2%	602	100.0%
Newfoundland	158	24.6%	262	41.0%	420	65.6%	52	8.1%	16	2.56%	152	23.7%	640	100.0%
Yukon	263	21.7%	437	36.2%	700	57.9%	130	10.7%	1	0.071%	379	31.3%	1,209	100.0%
Nunavut	53	21.7%	87	36.1%	140	57.7%	26	10.7%	1	0.35%	76	31.3%	243	100.0%
NWT	158	20.3%	262	33.7%	420	54.0%	130	16.7%	1	0.11%	227	29.2%	778	100.0%
Canada Total**	**52,512**	**21.7%**	**87,452**	**36.1%**	**139,964**	**57.7%**	**25,905**	**10.7%**	**861**	**0.35%**	**75,790**	**31.3%**	**242,521**	**100.0%**

[1] *Row percent*

**The provincial and territorial estimates of HCV prevalence presented here are based on an interpolation from national estimates and may be subject to considerable uncertainity. Provincial/territorial data are definitive should a discrepancy exist.*

***Numbers may not add up exactly due to a combination of modelling uncertainities and the use of rounded whole numbers in the calculations*

3.3 HCV infections among Aboriginal persons

Table 5 presents the number and prevalence of HCV infection among Aboriginal persons in Canada as 2007. We estimated that 34,865 Aboriginal persons were HCV-infected, for a prevalence of 3.0% overall, 4.1% in men and 1.9% in women. It must be realized, however, that this estimate is more of an hypothesis than a conclusion, given the lack of representative data in this population (see Discussion below).

Table 5 Modeled HCV infection in the Aboriginal population, Canada, 2007

Sex	Population	Proportion IDU	Number IDU	HCV-infected IDU	HCV-infected other	HCV-infected total	HCV-infected rate
Male	572,090	6.0%	34,325	20,595	2,689	23,284	4.1%
Female	600,695	2.4%	14,417	8,650	2,931	11,581	1.9%
Total*	**1,172,785**	**4.2%**	**48,742**	**29,245**	**5,620**	**34,865**	**3.0%**

**Numbers may not add up exactly due to a combination of modelling uncertainities and the use of rounded whole numbers in the calculations*

HCV prevalence among IDUs	60%
HCV prevalence among others	0.5%

3.4 HCV prevalence among incarcerated persons

Table 6a presents the number and prevalence of HCV infection among incarcerated persons in Canada in 2005. In that year, 20,930 persons were incarcerated in provincial institutions and 12,582 in federal institutions in Canada. We estimated that, overall, 6,261 were HCV-infected, for a prevalence of 18.7%. HCV prevalence among prisoners who were IDU was 61.3% (6,158/10,054) and 0.44% (103/23,458) among others.

Table 6b presents the number and prevalence of HCV infection among incarcerated persons in Canada by federal versus provincial institution and geographic region. HCV prevalence was slightly higher in federal compared to provincial prisons. It must be realized, however, that this estimate is not precise given the lack of representative data in this population and differences in interpreting and reporting practices across the regions (see Discussion below). Slightly more than half (55%) of HCV-infected prisoners were incarcerated in Ontario or Quebec.

Table 6c presents the number and prevalence of HCV infection among incarcerated persons in Canada by IDU status and geographic region. The high relative rate of HCV infection among IDU versus non-IDU was consistent across the geographic regions of Canada.

Table 6a Modeled HCV infection among incarcerated persons, Canada, 2005

	Provincial	Federal	Total
Prison population	20,930	12,582	**33,512**

Proportion prisoners with history of IDU 30%

		Active IDU ?		
		Yes	No	**Total**
	Yes	10,054	23,458	**33,512**
In prison?	No	90,000		
	Total	**100,054**		

Proportion HCV positive	**Provincial**	**Federal**
IDU	56%	70%
Non-IDU	0.10%	1.0%

	HCV positive	**HCV negative**	**Total***
Federal prisoners			
IDU	2,642	1,132	3,775
Non-IDU	88	8,719	8,807
Total*	**2,730**	**9,852**	**12,582**
	21.7%	*78.3%*	*100.0%*
Provincial prisoners			
IDU	3,516	2,763	6,279
Non-IDU	15	14,636	14,651
Total*	**3,531**	**17,399**	**20,930**
	16.9%	*83.1%*	*100.0%*
All prisoners, Ontario			
IDU	6,158	3,895	10,054
Non-IDU	103	23,356	23,458
Total*	**6,261**	**27,251**	**33,512**
	18.7%	*81.3%*	*100.0%*

	HCV prevalence
IDU	61.3%
Non-IDU	0.44%
Total	**18.7%**

**Numbers may not add up exactly due to a combination of modelling uncertainities and the use of rounded whole numbers in the calculations*

Table 6b Modeled HCV prevalence among incarcerated persons by type of institution and region, Canada, 2005

		Pacific	Prairie	Ontario	Quebec	Atlantic	Canada*
Federal							
	Number	1,818	2,960	3,426	3,104	1,274	12,582
	Prevalence no.	395	642	743	674	276	2,730
	Prevalence rate	21.7%	21.7%	21.7%	21.7%	21.7%	21.7%
Provincial							
	Number	2,470	5,365	8,115	3,946	1,034	20,930
	Prevalence no.	417	905	1,369	666	174	3,531
	Prevalence rate	16.9%	16.9%	16.9%	16.9%	16.9%	16.9%
All prisoners*							
	Number	4,288	8,325	11,541	7,050	2,308	33,512
	Prevalence no.	811	1,547	2,112	1,339	451	6,261
	Prevalence rate	18.9%	18.6%	18.3%	19.0%	19.5%	18.7%

**Numbers may not add up exactly due to a combination of modelling uncertainities and the use of rounded whole numbers in the calculations*

Table 6c Modeled HCV prevalence among incarcerated persons by region and IDU vs non-IDU, Canada, 2005

		Pacific	Prairie	Ontario	Quebec	Atlantic	Canada*
IDUs							
	Number	1,286	2,498	3,462	2,115	692	10,054
	Prevalence no.	797	1,523	2,083	1,315	441	6,158
	Prevalence rate	61.9%	61.0%	60.2%	62.2%	63.7%	61.3%
Non-IDUs							
	Number	3,002	5,828	8,079	4,935	1,616	23,458
	Prevalence no.	14	24	30	24	10	103
	Prevalence rate	0.48%	0.42%	0.37%	0.50%	0.60%	0.44%
All prisoners*							
	Number	4,288	8,325	11,541	7,050	2,308	33,512
	Prevalence no.	811	1,547	2,112	1,339	451	6,261
	Prevalence rate	18.9%	18.6%	18.3%	19.0%	19.5%	18.7%

**Numbers may not add up exactly due to a combination of modelling uncertainities and the use of rounded whole numbers in the calculations*

3.5 The sequelae of HCV infection

Table 7a presents the modeled incidence of sequelae of HCV infection in Canada from 1967 to 2027. In 2007, we estimated that 802 persons developed cirrhosis, 473 persons progressed to decompensated liver failure, 292 cases of hepatocellular carcinoma occurred and 134 persons received a liver transplant due to HCV infection. In all, 483 persons died of HCV-related causes in 2007. Sequelae estimated assumed that infection incidence and immigration trends were stable after 2007. Note also that projections from 2007 to 2027 do not take into account the possible impacts of treatment. According to our model, the incidence of cirrhosis increased from 1967 to 1992, was relatively stable at around 800 new cases annually from 1992 to 2012 and will decrease slightly in subsequent years. However, the incidence of more advanced sequelae appears to peak later and mortality due to HCV continues to increase over the study period. The number of deaths from all HCV-related causes is projected to increase from 483 in 2007 to 613 in 2027, an increase of 27%.

The time trend in incidence of HCV sequelae is graphically depicted in Figure 2.

Table 7a

Modeled incidence of HCV infection and sequelae by five-year interval, Canada, 1967-2027

		HCV sequelae							
Year	Infections	Cirrhosis	Decomp	HCC	Transplant	Decomp deaths	HCC deaths	Transplant deaths	Total liver deaths
1967	16,563	120	39	20	5	5	18	1	24
1972	21,724	262	66	35	10	9	30	3	43
1977	24,233	430	117	61	19	16	54	7	77
1982	24,834	591	180	96	31	26	87	12	125
1987	18,497	733	254	139	49	41	128	20	189
1992	9,486	792	333	187	70	60	175	32	266
1997	8,058	808	397	230	94	80	220	47	346
2002	7,899	809	441	265	115	99	257	65	419
2007	7,945	802	473	292	134	114	285	82	483
2012	8,135	787	489	310	149	127	306	101	534
2017	8,269	772	494	321	160	137	319	117	572
2022	8,166	756	492	326	167	142	325	132	599
2027	7,959	736	483	325	171	146	326	142	613

Figure 2 Modeled incidence of HCV sequelae by five-year interval, Canada, 1967-2027

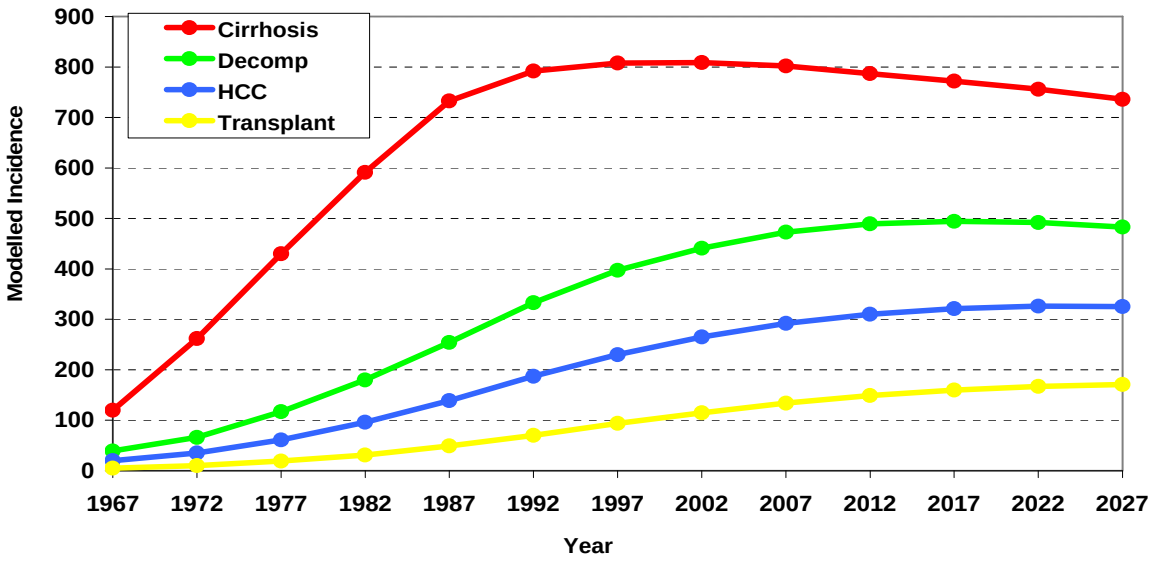


Table 7b presents the modeled prevalence of sequelae of HCV infection in Canada from 1967 to 2027. This table presents the total number of persons living with each complication of HCV infection and, thus, the numbers are not mutually exclusive. In 2007, an estimated 15,814 persons were living with cirrhosis, 5,495 in decompensated liver failure, 338 persons diagnosed with hepatocellular carcinoma and 1,187 post-transplant patients. According to our model, the prevalence of all sequelae of HCV infection will continue to increase in the future. The most dramatic increase is observed among post-transplant patients, from 1,187 in 2007 to 1,976 in 2027, an increase of 66%.

Table 7b **Modeled prevalence of HCV infection and sequelae (not exclusive*) by five-year interval, Canada, 1967-2027**

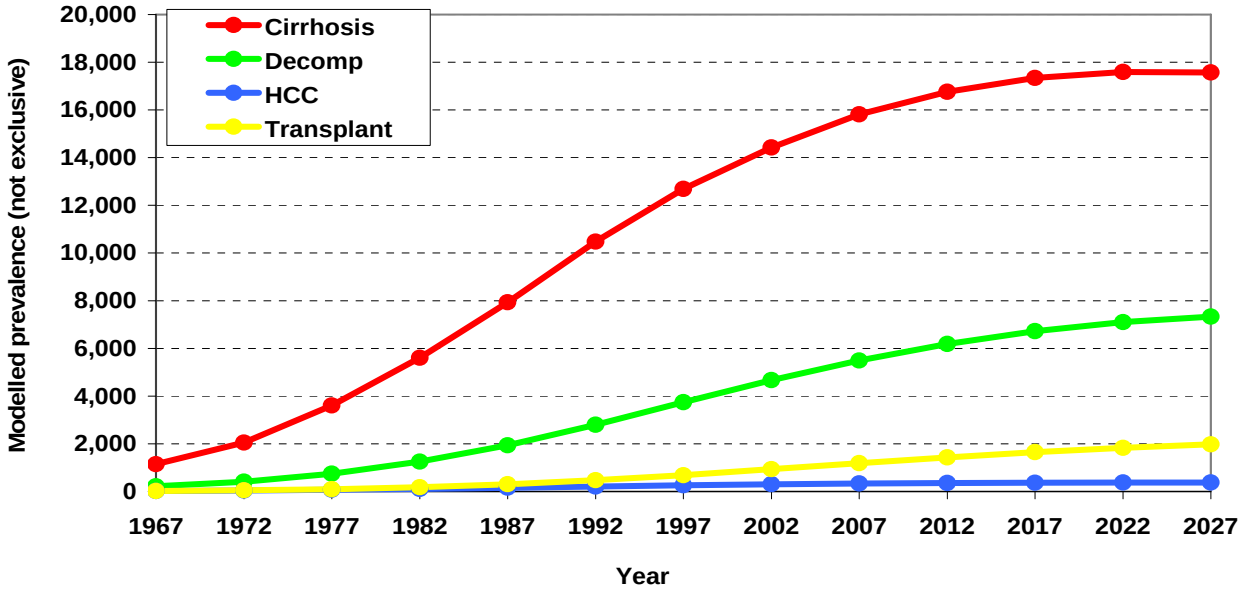
	HCV sequelae				
Year	**Infection**	**Cirrhosis**	**Decomp**	**HCC**	**Transplant**
1967	60,632	1,148	221	23	21
1972	117,726	2,054	410	39	50
1977	179,224	3,611	743	69	99
1982	232,945	5,605	1,252	109	181
1987	264,095	7,934	1,940	158	304
1992	263,878	10,477	2,799	215	474
1997	254,165	12,690	3,748	266	688
2002	246,682	14,421	4,666	305	933
2007	242,521	15,814	5,495	338	1,187
2012	239,134	16,755	6,186	360	1,430
2017	236,343	17,333	6,721	373	1,649
2022	232,684	17,592	7,101	378	1,833
2027	227,371	17,570	7,333	379	1,976

** Estimates are not mutually exclusive and include all persons in the category*

The data in Table 7b is graphically depicted in Figure 3.

Tables 7c presents the modeled prevalence of sequelae of HCV infection in Canada from 1967 to 2027 in mutually exclusive categories classified according to the most advanced sequela (i.e. transplant, farthest to the right in the table).

Figure 3 **Modeled prevalence§ (not exclusive*) of HCV sequelae by five-year interval, Canada, 1967-2027**



§ Estimates assume stable risk populations and HCV infection risks and do not adjust for treatment.
** Estimates are mutually exclusive and are classified according to the category furthest to the bottom.*

Table 7c Modeled prevalence of HCV infection and sequelae (exclusive*) by five-year interval, Canada, 1967-2027

	HCV sequelae				
Year	**Infection**	**Cirrhosis**	**Decomp**	**HCC**	**Transplant**
1967	59,484	910	194	23	21
1972	115,672	1,615	350	39	50
1977	175,613	2,818	625	69	99
1982	227,340	4,276	1,039	109	181
1987	256,161	5,886	1,586	158	304
1992	253,401	7,536	2,252	215	474
1997	241,475	8,774	2,962	266	688
2002	232,261	9,571	3,612	305	933
2007	226,707	10,122	4,167	338	1,187
2012	222,379	10,366	4,599	360	1,430
2017	219,010	10,408	4,903	373	1,649
2022	215,092	10,289	5,092	378	1,833
2027	209,801	10,038	5,177	379	1,976

** Estimates are mutually exclusive and are classified according to the category furthest to the right in the table*

3.6 Reported cases of HCV in Canada

Hepatitis C was first made a reportable disease in some provinces in Canada in 1991. Almost all reports come from laboratory tests confirming the presence of HCV infection. Duplicates are removed at data entry at the public health units when the identifying information of a new case report matches perfectly or almost perfectly with a case previously entered. Case data is collected by provinces and territories in Canada and transmitted regularly to the Public Health Agency of Canada. Obvious duplicates are also identified and removed at the provincial and territorial level.

Table 8a presents the number of HCV cases reported in Canada from 1991 to 2007 that were reported to the Public Health Agency of Canada as of September 2008. Cumulatively, 212,782 cases were reported in Canada during this period. The data provided were missing cases from several jurisdictions in the early years following the licensing of the HCV test. This is unlikely due to lack of HCV testing but rather to delayed reportability or delayed reporting of cases to the Public Health Agency of Canada. To adjust for this, missing data from several provinces and one territory was imputed based on the proportion of cases in years when reporting appeared more complete.

Table 8b presents the adjusted number of hepatitis C cases reported in Canada from 1991 to 2007. Cumulatively, 221,198 cases were reported in Canada during this period. The number of reported cases peaked in 1998 when 20,280 HCV cases were reported. A decreasing trend has been observed since then; 12,007 new cases were reported in 2006 and 11,795 in 2007. Despite this decreasing trend, this large number of cases in recent years compared to the likely fewer than 2,000 incident cases reported in the year they occur suggests that a substantial proportion of reported cases are “prevalent” infections and the reservoir of undiagnosed infections is not close to being exhausted.

Table 8a Number of HCV cases reported to the Public Health Agency of Canada by year of report and province / territory*, unadjusted, Canada, 1991- 2007

	Province/Territory													
Year of report	British Columbia	Alberta	Saskatch-ewan	Manitoba	Ontario	Quebec	New Brunswick	Nova Scotia	PEI	Newfound-land	Yukon	NWT	Nunavut	Total
1991	316	19	25	-	-	-	-	-	2	-	-	-	-	**362**
1992	936	44	74	-	1,721	1	-	-	1	-	-	-	-	**2,777**
1993	1,005	62	343	-	2,557	4	93	-	1	2	-	-	-	**4,067**
1994	1,902	61	556	-	3,628	2	62	-	3	19	10	-	-	**6,243**
1995	4,648	102	583	-	7,318	2	143	-	-	41	44	-	-	**12,881**
1996	6,140	103	524	-	7,782	51	160	336	-	36	67	-	-	**15,199**
1997	7,728	127	604	-	6,458	1,687	177	528	-	43	69	-	-	**17,421**
1998	6,267	1,506	917	-	7,045	3,070	218	429	59	46	57	-	-	**19,614**
1999	4,999	2,333	537	573	6,458	3,288	186	305	26	46	35	29	6	**18,821**
2000	4,385	2,123	720	505	5,755	3,671	211	254	11	43	45	29	6	**17,758**
2001	4,370	2,128	684	656	5,502	2,961	179	195	27	46	45	38	12	**16,843**
2002	4,533	1,862	735	449	5,390	2,422	149	257	38	39	44	33	6	**15,957**
2003	3,602	1,574	643	451	5,329	2,570	214	256	38	57	41	26	5	**14,806**
2004	3,061	1,504	807	423	5,265	2,928	202	242	31	78	24	37	5	**14,607**
2005	2,856	1,435	666	419	4,494	2,455	272	254	43	84	37	21	7	**13,043**
2006	2,853	1,183	595	320	4,221	2,242	140	259	33	100	38	20	3	**12,007**
2007	2,873	513	380	174	4,333	1,823	90	-	50	90	31	17	2	**10,376**
Total	**62,474**	**16,679**	**9,393**	**3,970**	**83,256**	**29,177**	**2,496**	**3,315**	**363**	**770**	**587**	**250**	**52**	**212,782**

**Reflects data reported to the Public Health Agency of Canada as of September 30, 2008. Variability may exist between data reported by the provinces/territories and the Public Health Agency of Canada. Provincial/territorial data are definitive should a discrepancy exist*

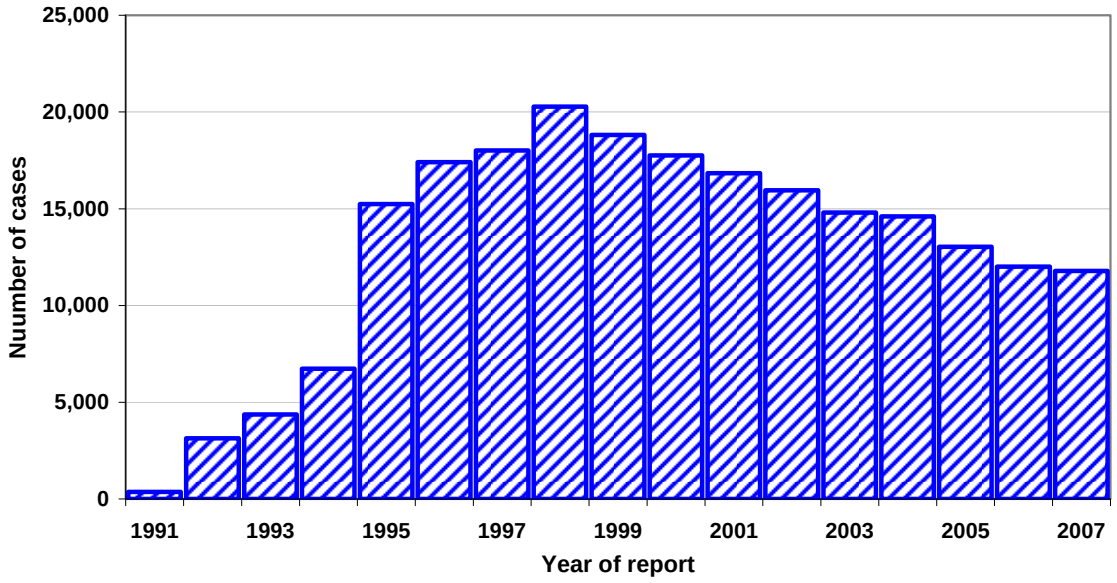
Table 8b Number of HCV cases reported to the Public Health Agency of Canada by year of report and province / territory, adjusted*, Canada, 1991- 2007

	Province/Territory													
Year of report	British Columbia	Alberta	Saskatch-ewan	Manitoba	Ontario	Quebec	New Brunswick	Nova Scotia	PEI	Newfound-land	Yukon	NWT	Nunavut	Total
1991	316	19	25	-	-	-	-	-	2	-	-	-	-	**362**
1992	936	44	74	60	1,721	169	82	34	1	10	7	-	-	**3,138**
1993	1,005	62	343	68	2,557	190	93	39	1	11	8	-	-	**4,377**
1994	1,902	61	556	114	3,628	323	62	65	3	19	10	-	-	**6,743**
1995	4,648	102	583	535	7,318	1,518	143	305	-	41	44	-	-	**15,237**
1996	6,140	103	524	588	7,782	1,670	160	336	-	36	67	-	-	**17,406**
1997	7,728	127	604	597	6,458	1,687	177	528	-	43	69	-	-	**18,018**
1998	6,267	1,506	917	666	7,045	3,070	218	429	59	46	57	-	-	**20,280**
1999	4,999	2,333	537	573	6,458	3,288	186	305	26	46	35	29	6	**18,821**
2000	4,385	2,123	720	505	5,755	3,671	211	254	11	43	45	29	6	**17,758**
2001	4,370	2,128	684	656	5,502	2,961	179	195	27	46	45	38	12	**16,843**
2002	4,533	1,862	735	449	5,390	2,422	149	257	38	39	44	33	6	**15,957**
2003	3,602	1,574	643	451	5,329	2,570	214	256	38	57	41	26	5	**14,806**
2004	3,061	1,504	807	423	5,265	2,928	202	242	31	78	24	37	5	**14,607**
2005	2,856	1,435	666	419	4,494	2,455	272	254	43	84	37	21	7	**13,043**
2006	2,853	1,183	595	320	4,221	2,242	140	259	33	100	38	20	3	**12,007**
2007	2,862	1,290	497	349	4,333	1,849	187	223	49	95	41	16	4	**11,795**
Total	**62,463**	**17,456**	**9,510**	**6,773**	**83,256**	**33,013**	**2,675**	**3,981**	**362**	**794**	**612**	**249**	**54**	**221,198**

**The provincial and territorial estimates of HCV prevalence presented here are based relative weights among the jurisdictions derived from years for which data on reported cases were available to the Public Health Agency of Canada as of September 30, 2008. Provincial/territorial data are definitive should a discrepancy exist.*

Figure 4 shows graphically the annual number of reported HCV cases in Canada from 1991 to 2007.

Figure 4 Number of reported HCV diagnoses by year, adjusted, Canada, 1991-2007



As noted in Section 2.12 above, we wished to estimate the number of diagnosed HCV-infected persons who were still alive as of end 2007 to compare to the number of modeled HCV-infected persons at that time. Table 8c presents the results of this calculation and the comparison. As seen in the third column of data from the left, 192,225 or 87% of the cumulatively diagnosed HCV-infected persons were still alive as of December 2007. Overall, we estimate that 79% of the modeled number of HCV-infected persons living in 2007 have been diagnosed. This varied considerably by province/territory and, with the exception of Nunavut, represented from 44% to 133% of the modeled number of HCV infections.

Table 8c Comparison of modelled* with reported HCV cases surviving to 2007 by province / territory, Canada 2007

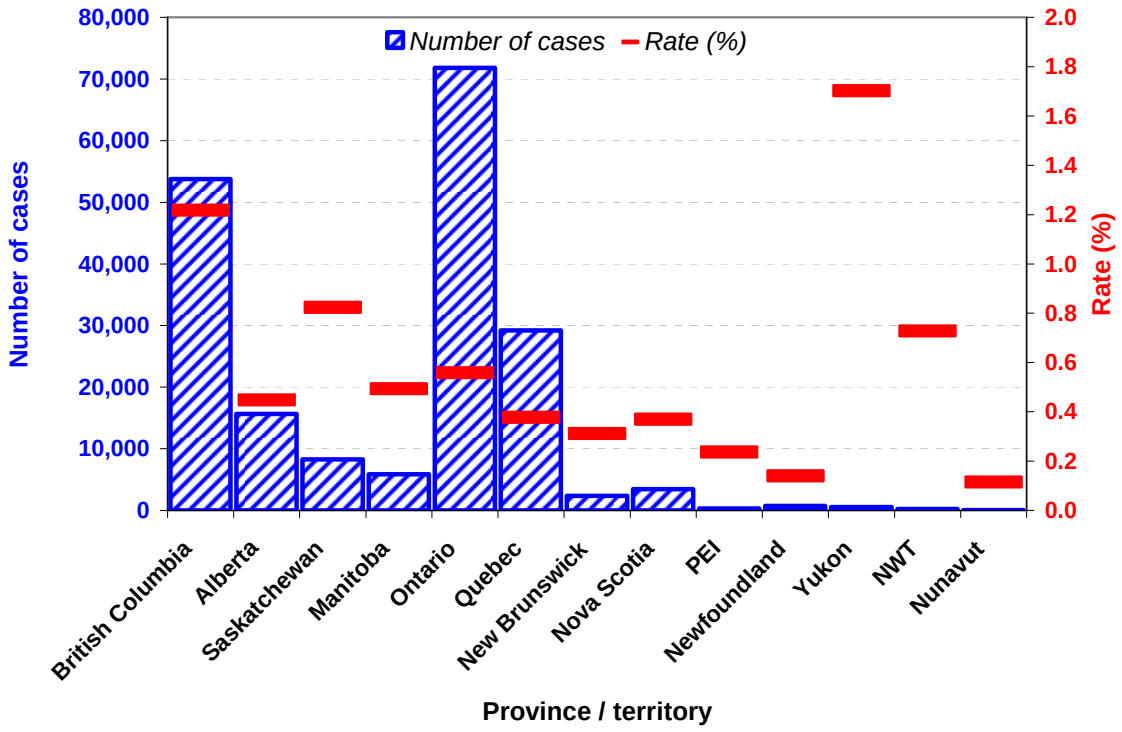
Province / territory	Modeled	Cumulative diagnosed	Cumulative diagnosed, surviving	Proportion diagnosed
British Columbia	53,254	62,463	53,736	101%
Alberta	24,081	17,456	15,666	65%
Saskatchewan	6,234	9,510	8,290	133%
Manitoba	8,401	6,773	5,889	70%
Ontario	102,858	83,256	71,811	70%
Quebec	37,505	33,013	29,179	78%
New Brunswick	2,467	2,675	2,344	95%
Nova Scotia	4,252	3,981	3,460	81%
PEI	602	362	329	55%
Newfoundland	640	794	713	112%
Yukon	1,209	612	532	44%
NWT	243	249	226	93%
Nunavut	778	54	49	6%
Canada	242,521	221,198	192,225	79%

**The provincial and territorial estimates of HCV prevalence presented here are based on an interpolation from national estimates and may be subject to considerable uncertainty.*

Provincial/territorial data are definitive should a discrepancy exist.

Figure 5 shows a graph of the number and rate of persons living with HCV infection by province/territory.

Figure 5 **Prevalence* (number and rate) of surviving reported HCV cases by province / territory, Canada, December 2007**



**The provincial and territorial estimates of HCV prevalence presented here are based on an interpolation from national estimates and may be subject to considerable uncertainty. Provincial/territorial data are definitive should a discrepancy exist.*

4. DISCUSSION

We carried out a modeling study to characterize the epidemiology of hepatitis C infection in Canada in 2007. Specifically, we wished to estimate the incidence and prevalence of hepatitis C infection in Canada from 1967 to 2027 stratified on gender, exposure category and place of birth. We also modeled the prevalence and incidence of serious sequelae of hepatitis C infection for this 60-year period. To accomplish these objectives, we adapted and refined the actuarial model developed for estimating HCV infection in Canada in 2002, which was completed in 2003.

We concluded that, as of December 2007, 242,521 persons in Canada were infected with hepatitis C. HCV infections in Ontario represent approximately 42% of all infections in Canada. The highest HCV prevalence rates were observed in the Yukon, Northwest Territories and British Columbia. With respect to HCV incidence, an estimated 7,945 persons were newly infected in Canada in 2007.

Of the 242,521 HCV-infected persons in Canada, 52,512 (22%) were active IDUs and 87,452 (36%) past IDUs, 25,905 (11%) had been infected through blood transfusion, 861 (0.36%) were hemophilia patients and 75,790 (31%) were infected through other modes of transmission, including sexual, occupational, nosocomial and vertical transmission. Sixty-one percent of HCV-infected persons were male.

We also estimated the prevalence of infection by sex and age group. HCV prevalence was 64% greater in males than in females (0.95% versus to 0.61%). Not surprisingly, HCV prevalence generally, though not always, increased with increasing age. On the other hand, HCV incidence in 2007 was greatest among persons aged 20 to 39 years, with the highest incidence of 0.110% among those 25 to 29 years old. HCV incidence among men overall was 0.034%, almost twice that among females with 0.018%.

We found that HCV prevalence varied considerably by province and territory. The largest number of HCV-infected persons (102,858, or 42%) were residents of Ontario, with the next highest being British Columbia (53,254 or 22%) and Quebec (37,505, or 16%). The highest HCV prevalence rates were observed in the Yukon (3.87%), Northwest Territories (1.83%) and British Columbia (1.21%).

The estimated number of HCV-infected persons in Canada in 2007 was slightly lower than the 251,000 HCV-infected persons we estimated for 2002. The difference is accounted for by more precise estimates of mortality in the five exposure categories examined as well as incorporation of the natural loss of HCV virus and antibody that is not negligible.

The impact of the sequelae of hepatitis C infection on the health of persons in Canada appears to be considerable. In 2007, 15,814 persons were living with cirrhosis, 5,495 were in liver failure, 338 had been diagnosed with hepatocellular carcinoma and 1,187 were post-transplant patients. The annual incidence of new cases of cirrhosis appeared to plateau in 1997 through 2007 but, according to the results of our model, the incidence of the more serious outcomes of HCV infection will continue to rise, at least until 2027, unless modified by treatment. Liver deaths, for example, were estimated to increase from only 24 in 1967 to 613 in 2027, increasing approximately 27% from 2007 to 2027.

Overall, a cumulative total of 221,198 cases of hepatitis C have been diagnosed and reported in Canada, with the time trend of HCV reported cases suggesting we are probably not close to

"exhausting the prevalent pool" of HCV-infected persons. Our estimate of the proportion of HCV diagnosed is subject to uncertainty. Applying annual mortality rates from 1991 to 2007, we estimated that 192,225 of these diagnosed cases were still alive as of December 2007. This represents 79% of modeled HCV infections, though the proportion varied considerably by province/territory.

We were unable to determine to what extent there may be residual duplicates in the national database. If there were significant numbers of unrecognized duplicates in the database, the proportion of HCV infections that have been diagnosed would be lower.

There are several assumptions and limitations to the methods we used in this analysis. With regard to demographic characteristics, data on births, deaths and census populations were relatively precise and therefore not subject to significant uncertainty. Modeled population counts initially agreed very closely with Statistics Canada data in 2001, in part because the model was adjusted to fit known population counts. To determine the prevalence of HCV infection in immigrants, we relied on HCV in the country of origin as reflected by the occurrence of HCV among persons not born in Canada in the EHSSS database. It is unclear how precise the country birth data is in this database.

For the sake of simplicity, we assumed that all hemophilia patients were born in Canada. This was done for two reasons. First, given the limited medical care available in many of the countries from which immigrants come to Canada, many persons with hemophilia may not survive long enough to be able to emigrate to Canada. Also, some hemophilia patients would not be considered eligible for immigration to Canada, given that persons with this condition may incur excessive medical costs. Finally, we do not have data on the distribution of hemophilia patients by country of birth. Thus, it was simpler to model this group entirely within the Canadian-born stratum. Nevertheless, it is likely that at least some of the hemophilia patients categorized as Canadian in our analysis were, in fact, born elsewhere.

The model we developed incorporates assumptions about the likely incidence and prevalence of HCV in key populations. The results of our model are based on data derived from a review of epidemiologic studies and from the EHSSS surveillance project operated by the Public Health Agency of Canada. However, only one reasonably population-based large study on HCV prevalence has been carried out in Canada. This is the study of outpatients attending sentinel hospitals in Quebec in 1990-92 <16>. The EHSSS also has limitations related to incomplete and biased data. These are discussed more fully in the report of our study of HCV infection in Canada in 2002 <2>. Risk factor data was not available from cases routinely reported for surveillance purposes, which would have helped to assess indirectly the relative infection rates in the principal groups at risk for HCV.

In the present study, we also reviewed published studies to identify additional information on the parameters to quantify progression of hepatitis C through its clinical stages and incorporated updated data into our Markov model. Nevertheless, there are substantial uncertainties about the values of these parameters. First, there was considerable variation in the parameters found in different studies and this was only partly controlled by stratification by HIV status and gender. It is unclear to what extent these parameters are applicable to the Canadian population; therefore, the estimates of the incidence and prevalence of HCV sequelae are subject to uncertainty.

We determined the prevalence of hepatitis C infection in each province/territory by using reported cases of hepatitis C as weights and interpolating the HCV infections for each province/territory from the Canadian total using these weights. This approach assumes that the

diagnosis and reporting of hepatitis C infection is similar in all jurisdictions in Canada; this may not be the case. It is difficult to determine the strength of direction of biases that may have been introduced by differential testing and reporting.

In this study, we examined HCV prevalence among two key populations, namely incarcerated individuals and the Aboriginal population. Among incarcerated populations, we were able to obtain information from several studies on the proportion of prisoners who had injected drugs and the prevalence of hepatitis C infection stratified by IDU history.

Nevertheless, the populations studied may not have been representative of all incarcerated populations in Canada, and there are regional and institutional differences in HCV prevalence across Corrections Services Canada <59>. Recent data from Corrections Services Canada suggest that the overall HCV prevalence in federal penitentiaries was approximately 29% in 2005 (slightly higher than our estimate) <60>. Estimated self-reported HCV prevalence among those who do not report a lifetime history of IDU may also be higher than the estimated 1% in this report, as a result of self-reported risk behaviours, including slashing/fighting, sex with an IDU, and sex trade involvement <59>. Prevalence greater than 1% in non-IDUs could also be due, in part, to under-reporting of injection drug use in these studies.

We also examined HCV infection among the Aboriginal population. However lack of data limited the validity of this process. Few studies of hepatitis C infection in this population were available. In fact, few studies of hepatitis C in population-based samples were found. We based our estimate on the relative incidence of AIDS among IDUs in Ontario and incorporated results from Manitoba. Thus, there is considerable uncertainty about our estimate of the 7,200 HCV-infected Aboriginal persons in Ontario. There is uncertainty with respect to the HCV prevalence rate in Aboriginal populations, as it is not clear whether the definition of Aboriginal is the same in different databases. We used the figures for the Aboriginal population from the 2006 Canadian census; however, ethnicity in the census is self-identified and therefore may not conform to other definitions of Aboriginal status, such as those used in epidemiologic studies. An additional source of uncertainty with respect to HCV infection in Aboriginal populations is the observation by Minuk that a higher proportion of persons in this population with anti-HCV antibody may be HCV-RNA negative (i.e. not actively infected) compared to other populations <39>. The reasons for this apparent difference remain unclear.

With regard to active HCV infection status in general, the estimates presented in this report indicate the number of persons who have HCV RNA, HCV Ab or both. In fact, not all of these persons are actively infected. We estimated from an extraction of the model examining only those with HCV RNA, that 205,338, or 85%, of these persons were HCV RNA-positive, that is have active HCV infection. Only these persons can transmit HCV and are candidates for antiviral therapy.

In our model, we found that 31% of prevalent HCV infections were due to modes of transmission other than drug injection, blood transfusion and clotting factors. This is likely to be a substantial overestimate of the importance of other modes of transmission. These other modes of transmission may include sexual, occupational, nosocomial and vertical (i.e. mother to baby), as well as transmissions by unsterile practices in body piercing and tattooing. Though hepatitis C may certainly be transmitted through all these other modalities, it is unlikely that they are highly efficient (and therefore frequent) modes of transmission. The proportion of other modes of transmission is based on data from the EHSSS database. Due to the stigmatization of injection drug use, it is likely that this behavior is underestimated in this surveillance system, thus overestimating the importance of the other modes of transmission. Participation bias may also

result in unrepresentative data. IDU cases are more difficult to reach and many in fact may not be reached. In some EHSSS sites, patient consent is required for interview and IDU may be less likely to consent.

We received and reviewed data on reported cases of hepatitis C in Canada. Nevertheless, as noted above, it is unclear whether a significant number of duplicate cases remained in the database. In addition, it appeared that acute cases were not systematically differentiated from chronic infections nor were risk factor data systematically collected. Ensuring these functions would improve the quality and utility of the hepatitis C surveillance data. It would also be extremely helpful to include enhanced surveillance data from all major cities in Canada.

In our projections of HCV infection and their sequelae to 2027, we did not take into account the possible impact of the expanded use of currently available antiviral medications (e.g. pegylated interferon and ribavirin) nor the potential impact of new, more effective regimens. Both these developments could have considerable impact on our future projections. Also, if new medications are identified that are effective and widely available, this could have a considerable impact on our future projections. Similarly, if effective HCV prevention programs for IDUs, both to reduce transition from non-injection to injection and reduce the extent of sharing of equipment, are developed and widely implemented, the incidence and prevalence of HCV projected to 2027 may be less than that estimated by our model.

APPENDIX

REFINEMENTS, MODIFICATIONS AND UPDATES FOR HCV MODEL CANADA, 2007

Population
Populations updated to 2007 using 2006 census data
Use revised estimations and projections for population, births and immigrants
Adjust demographic model to fit census estimates

Exposure categories
Reworked modeling of hemophilia population to improve stability

Transition probabilities
New literature review and revision of transition parameters

HCV
Transfusion: reduced HCV incidence in response to feedback and new data on residual risk
Hemophilia: reduced HCV incidence in response to new data on HCV risk
Provincial/territorial estimates: Derived weights for interpolating HCV infections to provinces/territories for each exposure category, incorporating 1998 model, population and EHSSS data

HIV
Fit HIV/HCV co-infection to 2001 model carried out for Health Canada

Validation
Obtained new EHSSS data for adjustment of final model

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