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Piecing the puzzle together: foreign-born tuberculosis in an immigrant-receiving country

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ABSTRACT

In major immigrant-receiving countries, annual foreign-born tuberculosis case counts and rates are relatively constant. Why this is so, and who might be a high-yield target for screening for latent tuberculosis infection, remain open questions.

Foreign-born tuberculosis in Canada during 1986-2002 was retrospectively examined using national tuberculosis and immigration data as well as census data. Case counts and rates were analyzed in relation to demographics, immigration period, and time since arrival.

Pre-1986 immigrants (n=3,860,853) and 1986-2002 immigrants (n=3,463,283) contributed 8,662 and 9,613 tuberculosis cases, respectively. Immigrants arriving ≤5 years ago and those arriving >10 years ago contributed almost equally to the annual foreign-born

tuberculosis case count despite a 3.5-fold difference in in-country person-years. Remarkably stable and relatively low tuberculosis incidence was observed among immigrants >10 years post-arrival. Conversely, tuberculosis incidence within 5 years of arrival was dynamic, demonstrating a strong inverse association with time since arrival and higher sensitivity to changes in immigration level than shifts toward higher incidence source countries.

Relative constancy in foreign-born TB incidence is explained by a complex convergence of several factors. Immigrants born in high incidence countries who arrived ≤2 years ago, and who were age 15-35 years upon arrival, constitute high-yield targets for preventive therapy.

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Major immigrant-receiving countries with low tuberculosis (TB) incidence are frequently challenged by TB in their foreign-born people.[1-4] The World Health Organization (WHO) suggests that when foreign-born cases constitute 70% or more of national TB cases, one cannot anticipate more than a 2% decrease in annual national TB rates through the use of regular TB control programs.[5] Under such circumstances, further reductions in national TB incidence and TB elimination require a rethinking of prevailing TB prevention and control strategies.

Canada, with one of the highest levels of immigration per capita internationally,[6] is acutely aware of the increasing burden that TB in the foreign-born represents. Following a shift in immigration pattern from low to high TB incidence countries in the 1960s and a substantial reduction in Canadian-born non-Aboriginal TB incidence, the proportion of foreign-born TB cases increased from 18% in 1970 to 67% in 2007.[2;7-10] In the same period, the foreign-born population nearly doubled, increasing the proportion of the foreign-born Canadian population

from 15% in 1970 to 20% in 2007.[11] Reflecting the WHO's projections, Canada's national TB incidence rate declined by an average of 2% annually between 2001 and 2007.[10]

That a shift in immigration pattern to high incidence countries contributed to an increased proportion of foreign-born cases is a reasonable assumption given that 'country of birth/origin' and 'time since arrival' are key determinants of foreign-born TB incidence.[1;2;12-15] Similarly, an increase in both TB case counts and rates would seem logical following a sustained shift. However, only modest variations in annual foreign-born TB case counts and rates have been reported for several decades (with recent rate reductions being primarily attributed to denominator size).[2;16] This relative stability in foreign-born TB incidence in spite of high levels of immigration from regions of elevated incidence remained unexplained despite similar trends elsewhere.[1;17;18]

There is a general consensus that TB elimination in major immigrant-receiving countries will be contingent on the successful prevention of TB in the foreign-born. However, without a comprehensive understanding of how foreign-born TB incidence is constructed, it will be exceedingly difficult, if not impossible, to effectively design and appropriately target any national TB prevention strategies. To bridge this knowledge gap, this study aimed to deconstruct foreign-born TB incidence in Canada in order to identify relative contributions and trends in TB incidence among immigrant groups. In doing so, it was anticipated that the factors related to the relative constancy in foreign-born TB incidence would be elucidated and high-yield targets for screening and treatment of latent TB infection (LTBI) be identified.

MATERIAL AND METHODS

Study population

The population of foreign-born permanent residents (stock) in Canada from January 1, 1986 through December 31, 2002 ("study period") was divided into two groups:

i. Immigrants who arrived in 1986-2002: Data from Citizenship and Immigration Canada, the federal government department responsible for immigration and settlement, was used to identify immigrants and refugees who were granted permanent residency and arrived in Canada during the study period ("1986-2002 immigrants"). Data abstraction included year of arrival, age-at-arrival, sex and country of birth.

ii. Immigrants who arrived before 1986: Canadian census data was used to estimate the size and age-sex distribution of the foreign-born permanent resident population in 1986.[19;20]

Temporary foreign-born residents (visitors, students, workers, and refugee claimants [whose status remained to be determined] within the refugee determination process) were excluded from the denominator as this information was not maintained by Citizenship and Immigration Canada.

Tuberculosis cases

Foreign-born TB cases diagnosed during the study period were identified from the Canadian Tuberculosis Reporting System (CTBRS), a prospective national TB registry of all active cases. Cases were included in the study if immigration status at the time of diagnosis was reported as 'permanent resident' or if immigration status was unknown. The diagnosis of active TB is based upon positive bacteriology in 80% of cases; in the remainder, it is based upon a standardized case definition.[21]

WHO country groups

Countries of birth for 1986-2002 immigrants were divided into four groups based on the average country-specific WHO estimated incidence rate of smear-positive TB[22] in 1993 through 1995: <15 (Group 1); 15-50 (Group 2); 51-100 (Group 3); and >100 (Group 4) per 100,000 population (see Supplementary Material).

Statistical analysis

'Time since arrival' denotes the number of years between the year of arrival and the year of diagnosis. Cases diagnosed in the calendar year of arrival were categorized as 'year 0' cases (i.e. <1 year since arrival), cases occurring in the calendar year following the year of arrival were 'year 1' cases, etc. Thus, cases diagnosed in year 1 could have been in Canada between one day and two years, or one year on the average.

Incidence rates per 100,000 person-years were calculated overall as well as for sex, age-at-arrival, country group, and time since arrival strata. The calculation of 95% confidence intervals (CIs) for rates assumed a Poisson distribution for case counts. Standardized incidence rates were calculated using the direct method with the age and/or sex distribution of total 1986-2002 immigrants as the standard population. Rates were compared with incidence rate ratios (RR) and 95% CIs. Summary statistics consist of the mean and standard deviation ($\bar{x}$ [SD]), and *P* values were two-sided and considered significant if <0.05.[23]

The size of each annual cohort of immigrants for each year between their arrival and the end of 2002 was estimated with the age-sex-calendar year specific survival rates of the total Canadian population.[24-29] Person-years of observation were obtained by adding annual cohort sizes over the total or partial observation period or across cohorts for a specific year. This was also done for each sex, age-at-arrival, and country group. In the year of arrival, each 1986-2002

immigrant was assumed to contribute 0.5 person-years. Person-years for pre-1986 immigrants were estimated with the same procedure except that each immigrant was assumed to contribute a whole year of observation in 1986.

The relative contributions of immigrants who had arrived within 0-5, 6-10 and >10 years to the total burden of TB was assessed for those who arrived in 1986-2002 and for all immigrants. Of necessity, the latter group was limited to data from the 1995-2002 period, as 1995 was the earliest year in which all pre-1986 immigrants resided in Canada for >10 years after the arrival year.

Among 1986-2002 immigrants, the potential impact of prevalent active but unrecognized disease upon arrival on TB incidence rates in year 0-2 was explored with sensitivity analysis. Based on the assumption that a proportion of year 0-1 cases were "actually" active upon arrival (by inference to have developed TB between the date of the immigration medical examination [IME] and date of arrival), the absolute number of cases in year 0-1 were incrementally reduced until statistically insignificant RRs (year 0-2 compared to year 3-5) were observed.

Stata/IC 11.1 for Windows (StataCorp, College Station, TX) was used for data analysis.

Ethics approval was not required as anonymous and routinely collected surveillance data were used.

RESULTS

The CTBRS received notification of 18,524 foreign-born TB cases during the study period. After excluding 1.3% of cases due to record errors, 18,275 were analyzed; 8,662 (47.4%) among pre-1986 immigrants and 9,613 (52.6%) in 1986-2002 immigrants.

Tuberculosis among pre-1986 immigrants

There were 3,860,853 immigrants who resided in Canada before 1986.[19] During the study period, the TB rate in this group was 14.2/100,000 person-years. Higher rates were associated with males and those aged >64 years (Table 1).

Tuberculosis among 1986-2002 immigrants

There were 3,436,283 individuals who immigrated during the study period. Average annual immigration was 202,134 (SD 30,418) individuals, ranging from 113,513 in 1986 to 245,927 in 1990. The majority of immigrants (49.1%) were born in countries with TB incidence rates of 15-50/100,000 population. Nonetheless, a shift in immigration pattern to higher incidence countries of birth was evident and primarily involved a progressive increase in the proportion of immigrants from WHO Group 3 (51-100/100,000 population) (Figure 1), from 17.1% in 1986-1990 to 24.9% in 1998-2002.

The overall rate of TB among 1986-2002 immigrants was 34.3/100,000 person-years, i.e. 2.4 (95%CI: 2.4, 2.5) times that of pre-1986 immigrants. Males and those aged >64 years at arrival also had the highest TB rates (Table 1).

Rates varied substantially by WHO country group and progressively increased from Group 1 (<15/100,000 population) to Group 4 (>100/100,000 population) (Table 2). As a result, countries of birth within Groups 3-4 (>51/100,000 population) were associated with two-thirds of TB cases and only one-third of arrivals.

Tuberculosis rates generally decreased with increased time since arrival (Figure 2a) and this association persisted in stratified analyses (sex, Figure 2b; age-arrival, Figure 2c; and WHO Group, Figure 3). Consequently, the most critical period for TB incidence was between 0-2

years (Table 3). Moreover, the rate in year 0-2 was 2.1 (95%CI: 2.0, 2.2), 3.0 (2.8, 3.2) and 4.6 (4.2, 5.1) times higher than that of year 3-5, 6-10, and 11-16, respectively. Sensitivity analysis revealed that TB rates in year 0-2 remained significantly higher than those of year 3-5 until the year 0-1 case count was reduced by >60%.

It is also noteworthy that immigrants aged >64 years at arrival maintained higher rates than younger arrivals throughout the post-arrival period (Figure 2c).

The overall TB rate of 1986-2002 immigrants did not fall below 15/100,000 person-years until >10 years after the year of arrival (Table 3). Still, immigrants aged ≥35 years at arrival and those from WHO country groups 3-4 (>51/100,000 population) continued to have rates in excess of 15/100,000 person-years.

Deconstruction of total foreign-born TB incidence in Canada

Among combined pre-1986 and 1986-2002 immigrants, those ≤5 years after the year of arrival (year 0-5) contributed an average of 41.8% (SD 4.0%) of total foreign-born TB cases annually in 1995-2002. This proportion was remarkably similar to that of immigrants >10 years post-arrival (mean 41.1% [SD 4.7%]) despite a 3.5-fold difference in the average annual person-years of observation (1,132,351 versus 3,910,130 person-years in year 0-5 and year >10, respectively).

Cases were stratified into four groups (Figure 4 and 5). Group 'A' (pre-1986 immigrants) exemplifies what would have happened to foreign-born TB incidence if immigration was halted in 1986. As per Figure 5, the rate in 'A' would have decreased significantly between the beginning and end of the follow-up period [RR 0.59 (95%CI: 0.52, 0.66); P <0.0001]. Of note, however, is the relative stability in TB incidence in 'A' after 10 years (Figure 4 and 5).

The three remaining groups, composed of immigrant arrivals in 1986-2002, illustrate that newly arriving groups accounted for an increasing proportion of total cases (Figure 4). Specifically, the absolute number of cases contributed by 'B' (1986-1990 immigrants) progressively increased during the 5 years in which new members entered the cohort ("intake years") and then progressively decreased once 'B' was closed to additional arrivals. As with 'A', the incidence in 'B' was relatively stable once 'B' became composed exclusively of immigrants >10 years since the arrival year (Figures 4 and 5).

Group 'C' (1991-1995 immigrants) and 'D' (1996-2002 immigrants) had similar incidence patterns as 'B' (Figures 4 and 5). Relative to 'B' however, the case count during the intake years of 'C' was 45.3% higher than that of 'B' (Figure 4). This coincided with an 11.5% increase in immigration levels in 'C'. Similarly, 'D' had a simultaneous 6.4% decrease in immigration level and 17.4% decrease in case count within its intake years compared to 'C'.

The proportion of immigrants from WHO Groups 3-4 (>50/100,000 population) increased by 1.7% and 6.0% between 'B-C' and 'C-D', respectively. While these shifts to higher incidence countries of birth coincided with progressively increased rates in year 1 (Figure 5), they appeared to have less of an influence on case counts than changes in immigration level.

DISCUSSION

In the present analysis of foreign-born TB incidence in Canada, immigrants' greatest risk for active TB was within the first few years of arrival. Despite a 3.5 fold difference in annual person-years of observation, the pool of immigrants arrived ≤5 years ago and those arrived >10 years ago contributed almost equally to the annual foreign-born TB case count (42% and 41%,

respectively). Clearly, events preceding and immediately following arrival of the foreign-born are critical for TB prevention and control.

As demonstrated in this study and others, there is a characteristic inverse relationship between foreign-born TB rates and increased time since arrival that persists regardless of demographic or country group.[13-15] The interval between the arrival year and the second year following the year of arrival (year 0-2) is of particular importance given a TB rate that is 2 to 3 times that of year 3-5 despite completion of immigration medical screening for pulmonary disease within a year of departure. Before permission for arrival is granted, all foreign nationals ≥11 years of age applying for permanent residency must undergo radiographic screening for pulmonary disease as part of the Canadian immigration medical screening process. Medical decisions rendered on the basis of the examination are valid for a period of 12 months, after which a repeat examination is required.[21]

Although the existence of prevalent active disease upon arrival (and before departure) may contribute to high TB rates shortly after arrival, sensitivity analysis indicates that the TB rate in year 0-2 would remain significantly higher than that of year 3-5 even if only 40% of cases in the year of arrival and the year following the year of arrival were incidence cases. Similarly, it is unlikely that the described incidence trends were significantly altered by referral of high-risk immigrants (i.e. those diagnosed with inactive pulmonary TB during the IME) to medical surveillance programs due to the limited effectiveness of such programs in preventing future TB cases.[30;31]

In contrast to TB incidence among immigrants arrived ≤5 years ago, TB incidence among those arrived >10 years ago is characterized by remarkably stable and relatively low TB case

counts and rates (14/100,000 person-years). Nevertheless, these immigrants have a rate of TB that is 20 times that of Canadian-born non-Aboriginal persons.[10]

Immigration is a dynamic process, with host countries frequently adjusting annual immigration targets and source countries of new immigrants in response to political, social and international factors.[7] In the current study, shifts in immigration pattern had a more subtle influence on TB incidence than that of changing immigration levels. That shifts in immigration pattern only had a minimal impact on TB rates after the arrival year presumably relates to the majority (>60%) of immigrants in Canada being born in countries with relatively low TB incidence (≤50/100,000 population). With continued shifts to higher incidence source countries and immigration projected to represent an increasing proportion of population growth for the foreseeable future,[6;32] it is speculated that more marked increases in foreign-born TB case counts and rates are imminent.

That immigrants aged >64 years at arrival maintained substantially higher TB rates than younger arrivals throughout the post-arrival period is reasonably explained by aging. In sub-group analyses, TB rates of pre-1986 immigrants aged >64 years in 1986 and 1986-2002 immigrants aged >64 years at arrival were found to progressively increase with each consecutive 5-year increase in age (data not shown). The increasing likelihood of TB with the aging of older arrivals emphasizes the need for timely screening for LTBI, especially when immigrants originate from high incidence countries and/or have other high risk factors for the development of active disease.

The relative constancy seen in foreign-born TB incidence in Canada is the result of the convergence of all the factors discussed above. Clearly, strategies designed to reduce LTBI prevalence in the foreign-born will be critical to address the burden of TB within this vulnerable

population given this complex interplay of factors and previous findings suggesting that the majority of foreign-born TB cases in low incidence countries result from reactivation of LTBI.[33-35] Although routine screening and treatment for LTBI in the foreign-born was previously discouraged due to poor cost-effectiveness,[36] this strategy may emerge as a high priority and cost-effective reality in the near future due to technological advances. In particular, interferon-gamma release assays, which add specificity to the tuberculin skin test,[37;38] have recently received approval in national guidelines and promising short-course LTBI treatment regimens on the horizon offer to improve acceptance and completion of treatment of LTBI.[39-42]

Presumably, the cost-effectiveness of routine screening for LTBI is increased by targeting those at highest risk for TB. This study identified the highest-yield targets as being permanent residents ≤2 years post-arrival who were aged 15-35 years at arrival and born within countries with TB incidence rates >50/100,000 population. Although arrivals >64 years old are at higher risk, they are not ideal targets for systematic screening due to higher rates of serious adverse effects of standard treatment for LTBI (9 months of daily isoniazid).[21;43;44] Current guidelines for systematic screening of LTBI in the foreign-born should also be maintained to ensure that other high-risk, albeit lower-yielding, groups are appropriately managed. In Canada, this includes arrivals referred for medical surveillance by immigration authorities, children <15 years who are ≤2 years post-arrival from high incidence countries (>15/100,000 population), and foreign-born with high risk medical conditions.[21]

Should expanded LTBI screening and local public health responsibility emerge as a critical component of foreign-born TB control, it should not be undertaken to the exclusion of strategies aimed at reducing TB incidence in source countries. Enhanced national TB control programs not only constitute the most cost-effective health intervention in resource limited

settings,[45] but modelling also demonstrates that high-income countries can achieve cost-effective reductions in foreign-born TB morbidity and mortality by funding efforts to expand TB control in selected high-incidence countries.[46]

The methodological strength of this study was the use of data from national TB and immigration databases. This methodology provided precise denominator and demographic information on a large study population over a prolonged period. Additionally, it eliminated the impact of post-immigration (secondary) migration within Canada and other jurisdictional limitations encountered with province-specific studies,[14;33;47;48] making it the most comprehensive report of foreign-born TB incidence in Canada to date.

This study had some limitations. Availability of year of arrival only, without day and month, for 59% of 1986-2002 immigrants necessitated an assumption about the person-years contributed. The resulting assumption of each immigrant contributing 0.5 person-years in the year of arrival reflects the distribution of arrivals with complete date of arrival information. Rate calculations may have been limited by mortality estimates and the assumption of no out-migration from Canada. An evaluation of TB among temporary foreign-born residents was beyond the scope of this study as the study population was limited to foreign-born permanent residents. This notwithstanding, incomplete data on immigration status within the CTBRS may have resulted in the inclusion of TB cases among temporary foreign-born residents. The overestimation in rates from such inclusions would be negligible, however, as temporary foreign-born residents account for only 5-9% of total foreign-born TB cases as per national[10] and province-specific data (Database Manager, Alberta Health Services, personal communication, 2010).

An area for future study is the potential impact of migrant type (economic, family reunification, refugee, skilled worker, etc.) on the distribution of TB in foreign-born populations. Immigration to highly developed economies is a dynamic process and migrants may not equally reflect the TB incidence rates of their place of origin.

With immigration being the single most important determinant of TB dynamics within high-income countries[5] and a demonstrated inability to make substantive reductions in foreign-born TB incidence using current guidelines,[2;9;10;16] the status quo is no longer acceptable if progress toward TB elimination is to be made in major immigrant-receiving countries.

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FIGURE LEGENDS

Figure 1. Percentage of foreign-born permanent residents arriving annually in Canada by the WHO estimated TB incidence rate in the country of birth, 1986-2002. Countries of birth were grouped according to the country-specific WHO estimated incidence rates of smear positive TB per 100,000 population at mid-study period (3-year average): Group 1, <15/100,000 population (*black bars*); Group 2, 15-50/100,000 population (*dark gray bars*); Group 3, 51-100/100,000 population (*light gray bars*); and Group 4, >100/100,000 population (*white bars*).

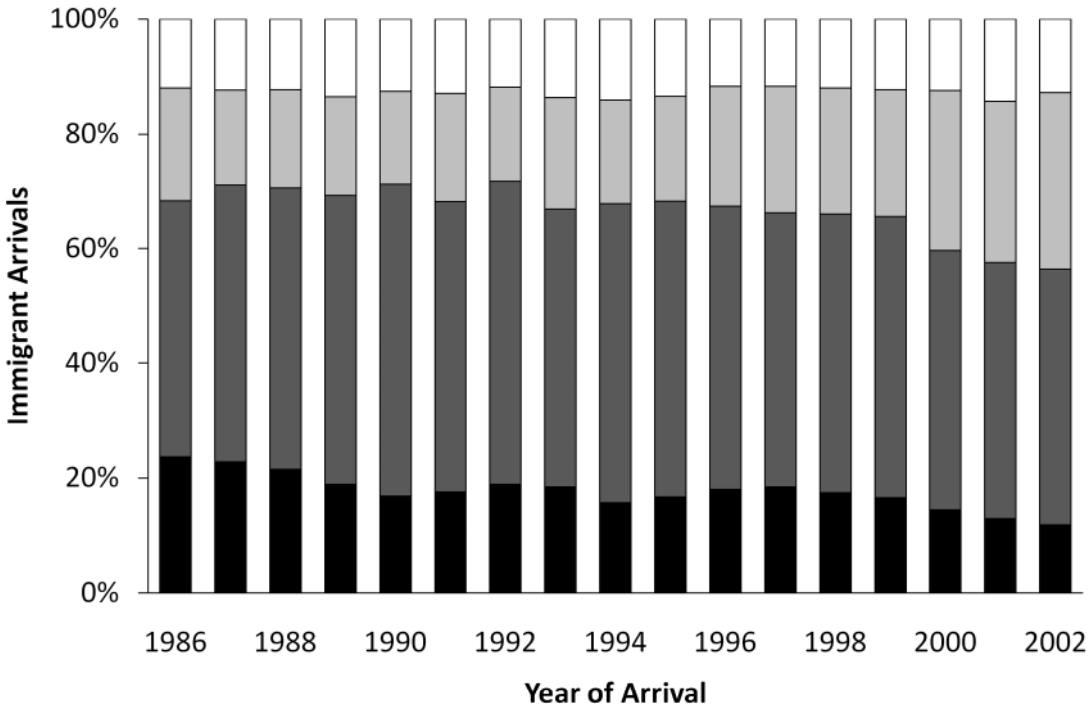

Figure 2. Tuberculosis incidence rates by time since arrival among foreign-born permanent residents who both arrived in Canada and were diagnosed with TB in 1986-2002. *(a)* Crude TB incidence rates. *(b)* Sex-specific TB incidence rates. *(c)* Rates stratified by age-at-arrival (years).

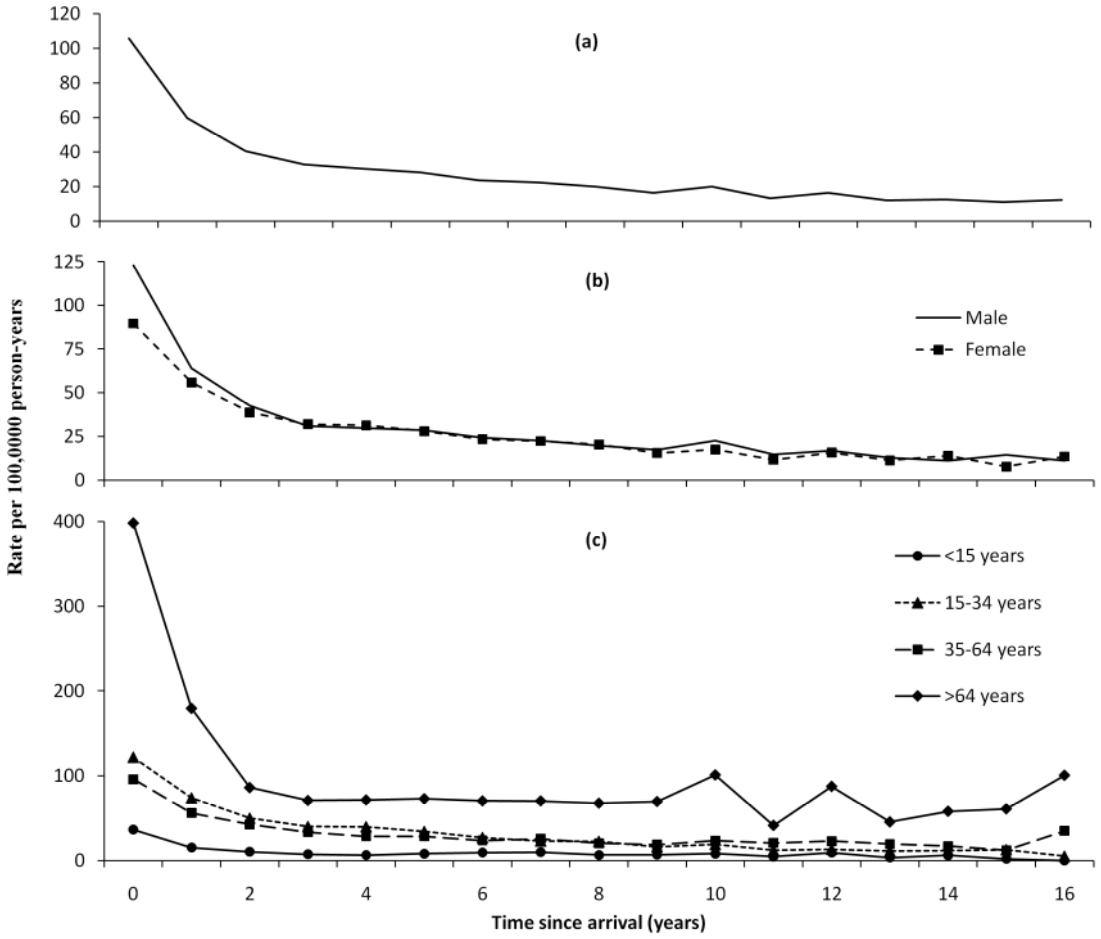

Figure 3. Tuberculosis incidence rates among foreign-born permanent residents who both arrived in Canada and were diagnosed with TB in 1986-2002 by time since arrival and country of birth group. Countries of birth were grouped according to the country-specific WHO estimated incidence rates of smear positive TB per 100,000 population at mid-study period (3-year

average): Group 1, <15/100,000 population; Group 2, 15-50/100,000 population; Group 3, 51-100/100,000 population; and Group 4, >100/100,000 population.

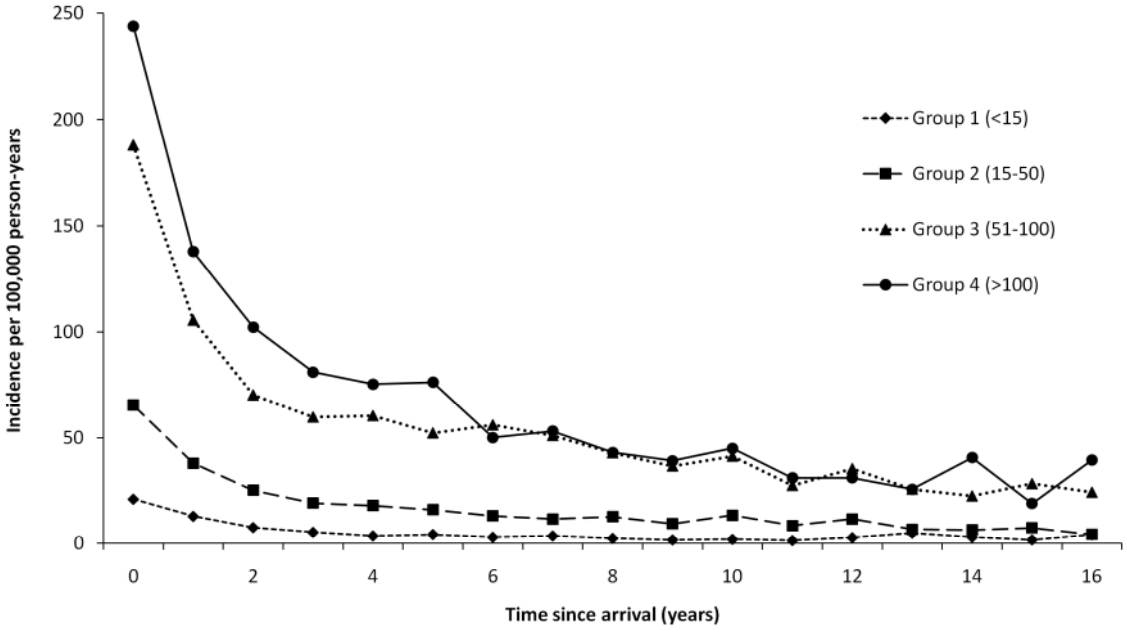

Figure 4. Annual TB case counts among foreign-born permanent residents in Canada by period of arrival, 1986-2002. Foreign-born permanent residents arrived prior to 1986 (*black bars);* those arrived in 1986-1990 (*dark gray bars)*; those arrived in 1991-1995 (*light gray bars)*; and those arrived in 1996-2002 (*white bars)*.

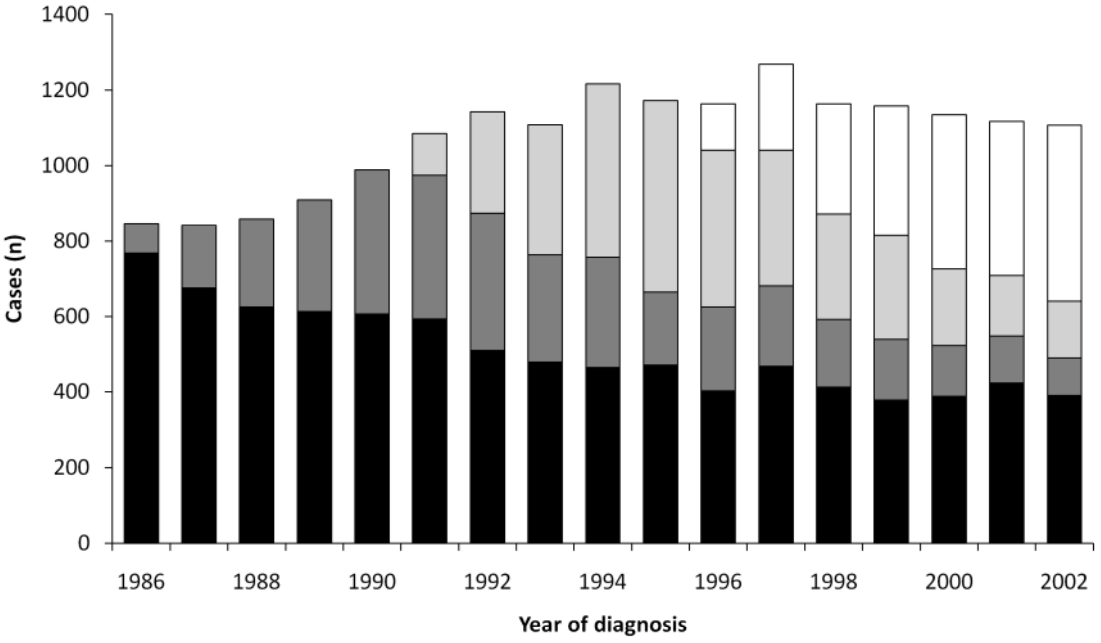

Figure 5. Annual TB incidence rates among foreign-born permanent residents in Canada by period of arrival and time since arrival, 1986-2002. Foreign-born permanent residents arrived prior to 1986 (line *A);* those arrived in 1986-1990 (line *B)*; those arrived in 1991-1995 (line *C)*; and those arrived in 1996-2002 (line *D)*.

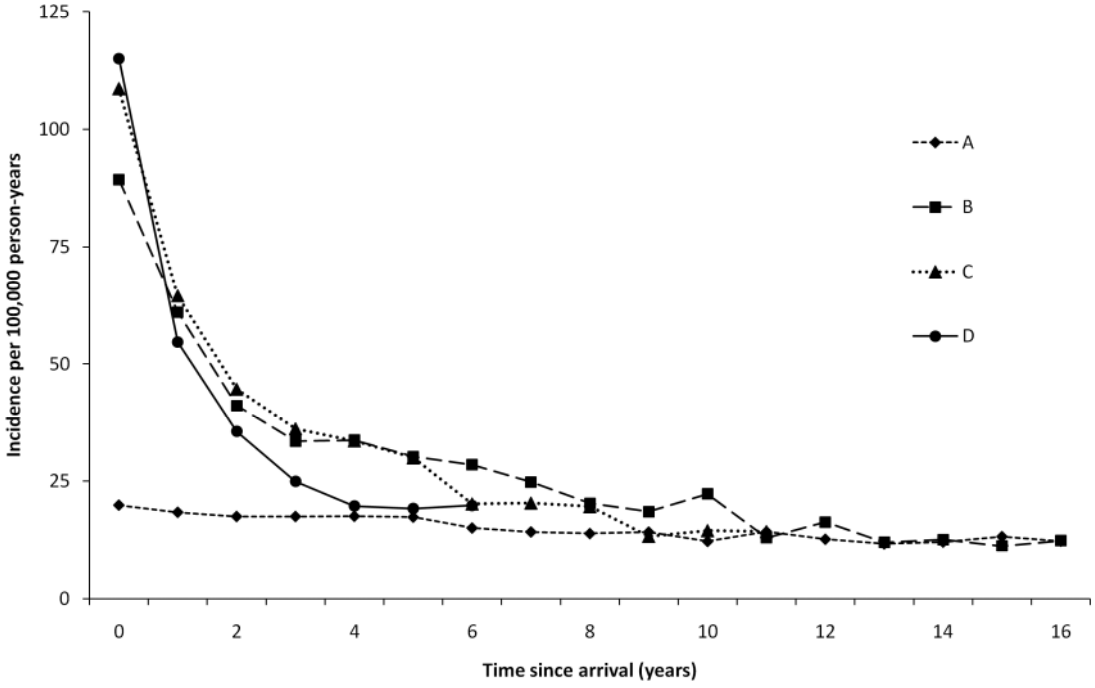
125
100
75
50
25
0
Incidence per 100,000 person-years
0
2
4
6
8
10
12
14
16
Time since arrival (years)
A
B
C
D

Table 1. Tuberculosis Incidence Among Permanent Residents in Canada, 1986-2002

Characteristic	Cases (%)	Immigrants in 1000s	PYrs	Rate[a]	95% CI	Adjusted Rate[b]	95% CI	RR[c]	95% CI	*P* value
Pre-1986 Immigrants										
Sex										
Female	4,088 (47.2)	1,972.5	314.2	13.0	12.6, 13.4	12.8	12.4, 13.2	1.0		
Male	4,574 (52.8)	1,888.4	297.8	15.4	14.9, 15.8	13.9	13.5, 14.3	1.1	1.0, 1.1	0.0004
Age in 1986 (years)										
<15	316 (3.6)	180.5	30.6	10.3	9.2, 11.5	10.4	9.3, 11.6	1.0		
15-34	2,560 (29.6)	1,000.4	169.1	15.1	14.6, 15.7	15.1	14.6, 15.7	1.5	1.3, 1.6	<0.0001
35-64	3,714 (42.9)	2,018.5	331.9	11.2	10.8, 11.6	11.2	10.8, 11.5	1.1	1.0, 1.2	0.194
>64	2,072 (23.9)	661.5	80.5	25.7	24.6, 26.9	26.9	25.8, 28.0	2.6	2.3, 2.9	<0.0001
Sub-total	8,662 (100.0)	3,860.9	612.1	14.2	13.9, 14.5	13.3	13.0, 13.6			

1986-2002 Immigrants										
Sex										
Female	4,651 (48.4)	1,750.3	142.8	32.6	31.7, 33.5	31.9	31.0, 32.9	1.00		
Male	4,962 (51.6)	1,686.0	137.2	36.2	35.2, 37.2	37.5	36.5, 38.6	1.2	1.1, 1.2	<0.0001
Age-at-arrival (years)										
<15	616 (6.4)	738.2	59.5	10.4	9.6, 11.2	10.4	9.6, 11.3	1.00		
15-34	5,300 (55.1)	1,578.7	134.6	39.4	38.3, 40.5	39.4	38.4, 40.5	3.8	3.5, 4.1	<0.0001
35-64	2,723 (28.3)	993.7	77.0	35.4	34.1, 36.7	35.4	34.1, 36.8	3.4	3.1, 3.7	<0.0001
>64	974 (10.1)	125.6	8.9	109.2	102.5, 116.3	114.8	107.9, 122.1	11.0	10.0, 12.2	<0.0001
Sub-total	9,613 (100.0)	3,436.3	279.9	34.3	33.7, 35.0	34.3	33.7, 35.0			
Total	18,275		892.0	20.5	20.2, 20.8	19.9	19.6, 20.2			

Abbreviations: PYrs, person-years of observation (100,000s); CI, confidence interval; RR, rate ratio

P values are two-sided

[a] Incidence rate per 100,000 person-years

[b] Rates per 100,000 person-years were standardized to the distribution of the 1986-2002 immigrant population. Rates were age-adjusted for the characteristic 'sex', sex-adjusted for the characteristics 'age in 1986' (pre-1986 immigrants) and 'age-at-arrival' (1986-2002 immigrants), and age-sex- adjusted for the subtotals and total.

[c] Adjusted rates were used for incidence rate ratios (RR) calculations.

Table 2. Association of Tuberculosis Incidence and WHO Country Group Among Permanent Residents Who Arrived in Canada During the Study Period, 1986-2002.

WHO Country Group[a]	Cases (%)	Immigrants in 1,000s (%)	Person-Years in 100,000s	Crude Rate[b]	95% CI	Adjusted Rate[c]	95% CI
1 (<15)	304 (3.2)	600.9 (17.5)	52.6	5.8	5.2, 6.5	6.1	5.5, 6.8
2 (15-50)	2,898 (30.1)	1,685.8 (49.1)	139.7	20.7	20.0, 21.5	20.8	20.1, 21.6
3 (51-100)	3,494 (36.3)	5,711.2 (20.7)	51.9	67.3	65.1, 69.6	63.6	61.4, 65.8
4 (>100)	2,917(30.3)	438.4 (12.8)	35.7	81.8	78.9, 84.8	84.2	81.2, 87.2
Total	9,613 (100.0)	3,436.3 (100.0)	279.9	34.3	33.7, 35.0		

Abbreviations: WHO, World Health Organization; CI, confidence interval.

[a] Country of birth groupings based on the WHO's estimated incidence of smear positive TB per 100,000 population at mid-study period: <15 (Group 1); 15-50 (Group 2); 51-100 (Group 3); and >100 (Group 4).

[b] Crude incidence rate per 100,000 person-years

[c] Rates were standardized to the sex and 5-year age group distribution of total permanent resident arrivals in 1986 through 2002 as

included in this study.

Table 3. Association Between Tuberculosis Incidence Rates and Time Since Arrival Among Permanent Residents Who Arrived in Canada in 1986-2002

Group	Interval Between Year of Arrival and Year of Diagnosis[a]								≤ 2 yrs : 3-5 yrs	
	≤ 2 yrs		3-5 yrs		6-10 yrs		11-16 yrs			
	Cases	Rate	Cases	Rate	Cases	Rate	Cases	Rate	RR	95% CI
Sex										
Female	2,291	56.6	1,227	30.9	908	20.2	225	12.7	1.83	1.71, 1.97
Male	2,666	68.6	1,125	29.7	919	21.4	252	14.3	2.31	2.15, 2.48
Age-at-arrival (years)										
<15	305	17.9	119	7.2	151	8.2	41	5.5	2.50	2.01, 3.11
15-34	2,755	75.0	1,381	38.0	944	22.0	220	11.9	1.97	1.85, 2.11
35-64	1,357	59.6	662	30.1	532	22.5	172	20.3	1.98	1.80, 2.18
>64	540	192.7	190	71.6	200	73.6	44	58.7	2.69	2.28, 3.19
WHO Country Group[b]										
1	178	12.5	63	4.4	43	2.6	20	2.7	2.87	2.14, 3.89
2	1,530	39.0	689	17.7	532	12.0	147	8.5	2.20	2.01, 2.41
3	1,761	111.1	834	57.8	725	46.8	174	28.4	1.92	1.77, 2.09
4	1,488	147.5	766	77.7	527	46.8	136	30.6	1.90	1.74, 2.07

Total	4,957	62.5	2,352	30.3	1,827	20.8	477	13.5	2.06	1.96, 2.17

Abbreviations: yrs, years; RR, incidence rate ratio; CI, 95% confidence interval; WHO, World Health Organization.

[a] Time since arrival represents the maximum number of years between an immigrant's year of arrival and year of diagnosis. Rates are per 100,000 person-years.

[b] Based on the WHO's estimated incidence of smear positive TB per 100,000 population at mid-study period (3-year average), the country of birth groups are: <15 (Group 1); 15-50 (Group 2); 51-100 (Group 3); and >100 (Group 4).