Monitoring the HIV epidemic in Ontario: Methods and findings

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Mandate

• Since December 1996, mandated by AIDS Bureau to monitor HIV epidemic
• Ontario HIV Epidemiologic Monitoring Unit (OHEMU) founded in 1997
• Based at Dalla Lana School of Public Health, University of Toronto
• Produces statutory reports and custom analyses
Objectives

• Estimate the size, characteristics and distribution of the at-risk populations
• Estimate HIV incidence and prevalence
  • Crude and stratified
• Evaluate the impact of HIV prevention programs
• Assess the need for HIV-related health services
Data sources, primary

- HIV Laboratory diagnostic database, Public Health Ontario (PHO)
- PHO prenatal screening database
- Reported AIDS cases
- HIV-related deaths
- HIV cases reported to public health units
Data sources, supplementary

- CPARG mother-infant HIV database
- Viral load testing
- Repeat HIV tester analysis
- Epidemiologic studies in Ontario and elsewhere
- Laboratory Enhancement Program (LEP)
  - HIV risk factors
  - HIV testing histories
  - Incidence assay results
Data analyses, overview

- Adjustment of HIV diagnoses
- Descriptive analyses - HIV and AIDS
- Mother-infant – linkage for HIV testing uptake
- HIV incidence from incidence assay
- Ontario HIV model: by exposure category, gender and health region
Reports and outputs

- Annual HIV/AIDS surveillance report
- Special situation reports
- HIV diagnoses, real-time
- HIV testing in pregnancy
- Web site (www.ohemu.utoronto.ca)
- Custom outputs
- Invited presentations
- Community planning initiatives (small area analysis)
Assessment of source databases

HIV serology results (HIV Laboratory)

Strengths

- Comprehensive (~100% coverage)
- Accessible
- No/low cost
- Computerized (LAByrinth/Labware)
- Continuous, long-term

- Captures all HIV-positive results since testing began in 1985 and HIV-negative results since 1992
Assessment of source databases

HIV serology results (HIV Laboratory)

Weaknesses

- Limited number variables
- Missing data (especially risk factors)
- Poor quality patient identifiers (incorrect and non-linkage for repeat testers)
- Data on risk factors not validated
- Incomplete data on place of residence
- Representativeness
- Testing bias following infection (‘motivated testing’)

Ontario
Assessment of source databases

HIV serology results (HIV Laboratory)

Solutions

• Laboratory Enhancement Program (LEP) since 1999
• Questionnaire sent to all physicians prescribing HIV-positive test and ~1:200 random sample of HIV-negative tests
• Three components:
  • High quality risk factor information
  • HIV testing history
  • HIV incidence testing
Assessment of source databases

HIV serology results (HIV Laboratory)
Solutions

• Supplementary data from LEP allows adjustment for missing and misclassified risk factor data
• In January 2009, questionnaire modified:
  • Added data on race-ethnicity and municipality of residence
  • Specific country of birth (as opposed to question on birth in HIV-endemic country) and year of arrival
  • Transgender as option for sex
Exposure category classification according to HIV test requisition, returned questionnaires and modeled distribution, HIV-positives

<table>
<thead>
<tr>
<th>Exposure category</th>
<th>HIV test requisition</th>
<th>Returned questionnaires among NIR</th>
<th>Projected final distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSM</td>
<td>3,347</td>
<td>1,287</td>
<td>5,681</td>
</tr>
<tr>
<td>MSM-IDU</td>
<td>75</td>
<td>69</td>
<td>200</td>
</tr>
<tr>
<td>IDU</td>
<td>472</td>
<td>215</td>
<td>862</td>
</tr>
<tr>
<td>HIV-endemic</td>
<td>351</td>
<td>1,205</td>
<td>2,536</td>
</tr>
<tr>
<td>HR hetero</td>
<td>206</td>
<td>175</td>
<td>523</td>
</tr>
<tr>
<td>LR hetero</td>
<td>1,178</td>
<td>539</td>
<td>2,155</td>
</tr>
<tr>
<td>Other</td>
<td>63</td>
<td>0</td>
<td>63</td>
</tr>
<tr>
<td>NIR</td>
<td>6,329</td>
<td>3,490</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>12,021</td>
<td>3,490</td>
<td>12,021</td>
</tr>
<tr>
<td>% NIR</td>
<td></td>
<td></td>
<td>52.6%</td>
</tr>
</tbody>
</table>
Adjustment procedure for HIV diagnoses

• Allocate unknown health region
• Allocate unknown sex
• Allocate unknown exposure category:
  • Based on LEP HIV risk factors
• Reallocate exposure category:
  • Based on LEP HIV risk factors
  • Mostly from low-risk heterosexual
HIV diagnoses* by sex and proportion female
Ontario, 1985-2011

* Adjusted for unknown sex
Proportion of HIV diagnoses* by sex and exposure category, Ontario, 1985-2011

Male (n=27,397)
- MSM: 70.7%
- MSM-IDU: 6.5%
- IDU: 4.3%
- Clotting factor: 6.2%
- Transfusion: 0.8%
- HIV-endemic: 0.3%
- HR hetero: 1.1%

Female (n=5,145)
- IDU: 43.3%
- Clotting factor: 19.2%
- Transfusion: 14.3%
- HIV-endemic: 14.0%
- HR hetero: 1.8%

* Adjusted for unknown sex, health region and exposure category
HIV diagnoses* by selected exposure category
Ontario 1985-2011

* Adjusted for unknown sex, health region and exposure category
Assessment of source databases

Reported AIDS cases

Strengths

• Serious outcome, most seek care
• Notification mandatory
• Allows comparison over time and place
• Low cost
Assessment of source databases

Reported AIDS cases

Weaknesses

- Under-reporting
- Delayed reporting
- Late manifestation of HIV infection
- Impact of ARVs and interpretation
- iPHIS – especially problem for risk factor data
- Limited political will and resources at PHUs
- Data often not exploited at local level
Reported AIDS cases by sex and proportion female
Ontario, 1981-2011
Proportion of AIDS cases by sex and exposure category, Ontario, 1981-2011

Male (n=8,434)

- MSM: 75.3%
- MSM-IDU: 4.4%
- IDU: 4.7%
- Clotting factor: 5.3%
- Transfusion: 7.2%
- HIV-endemic: 0.3%
- Heterosexual: 0.1%
- MTC: 16.4%
- Other: 0.1%

Female (n=877)

- IDU: 37.5%
- Clotting factor: 34.7%
- Transfusion: 16.4%
- HIV-endemic: 3.6%
- Heterosexual: 6.4%
- MTC: 0.2%
- Other: 1.1%
Assessment of source databases

HIV-related mortality

Strengths

• 100% ascertainment for vital statistics due to legal requirement
• Available at no/low cost
• Indicator of advanced HIV disease
• Allows comparison by gender, age and country of birth
• Can assess impact of improved ARV therapy
Assessment of source databases

Reported HIV-related mortality

Weaknesses

• Delayed availability
• Mechanism for release of data unwieldy
• Coding of death data subject to uncertainty
• HIV as indirect cause of death difficult to capture
Assessment of source databases

Reported HIV-related mortality
Solutions

• Improve mechanisms for access
• Special studies with record linkage
• Evaluation of HIV-related mortality database with focus on challenges to coding
HIV-related deaths, Ontario, 1987-2010

* Adjusted for the comparability ratio of ICD-10 and ICD-9
Uptake of HIV testing in pregnancy

• Prenatal testing records linked to HIV diagnostic database
• Data extracted from LAByrinth/Labware
• Prenatal testing records linked to HIV diagnostic database
• Matching allowed for different spelling and structure of name and reversal of month-day in birthdate
Data management

• Tests aggregated into episode based on gestation period and HIV test uptake analysed by pregnancy
• Current test versus prior test
• Number and proportion of pregnant women tested for HIV by quarter and health region
• Number and rate of HIV-positive results by quarter and health region
Evaluating HIV testing in pregnancy

Strengths

- Provides empiric indicator of success at local level
- Available in real-time (within two months)
- Results posted on OHEMU website
- May be important factor in success of program
Evaluating HIV testing in pregnancy

Weaknesses

• Location is place of testing not residence
• HIV test status based in part (~10% currently) on record linkage to HIV diagnostic testing database
  • Matching (sensitivity and specificity) may not be perfect
  • No patient identifiers for coded and anonymous tests
• Regular outputs to MOH discontinued several years ago due to local concerns
HIV testing among pregnancies by timing of HIV test, Ontario, 1999 Q1 - 2012 Q4
### Proportion of pregnancies tested for HIV by health region, 2012 Q4

<table>
<thead>
<tr>
<th>Region</th>
<th>Number of pregnancies</th>
<th>HIV tested</th>
<th>Proportion tested</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toronto</td>
<td>8,930</td>
<td>8,787</td>
<td>98.4%</td>
</tr>
<tr>
<td>Central East, other</td>
<td>9,637</td>
<td>9,489</td>
<td>98.5%</td>
</tr>
<tr>
<td>Southwest</td>
<td>3,971</td>
<td>3,888</td>
<td>97.9%</td>
</tr>
<tr>
<td>Central West</td>
<td>6,627</td>
<td>6,499</td>
<td>98.1%</td>
</tr>
<tr>
<td>Ottawa</td>
<td>2,418</td>
<td>2,393</td>
<td>99.0%</td>
</tr>
<tr>
<td>Eastern, other</td>
<td>2,195</td>
<td>2,174</td>
<td>99.0%</td>
</tr>
<tr>
<td>Northern</td>
<td>2,130</td>
<td>2,104</td>
<td>98.8%</td>
</tr>
<tr>
<td>N/A or OFP</td>
<td>262</td>
<td>245</td>
<td>93.5%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>36,170</strong></td>
<td><strong>35,579</strong></td>
<td><strong>98.4%</strong></td>
</tr>
</tbody>
</table>
### Number of HIV-positive pregnancies, 1999 Q1-2012 Q4

<table>
<thead>
<tr>
<th>Year</th>
<th>Current</th>
<th>Previous</th>
<th>Prior</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>10</td>
<td>0</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td>2000</td>
<td>24</td>
<td>0</td>
<td>7</td>
<td>31</td>
</tr>
<tr>
<td>2001</td>
<td>29</td>
<td>1</td>
<td>18</td>
<td>48</td>
</tr>
<tr>
<td>2002</td>
<td>23</td>
<td>10</td>
<td>7</td>
<td>40</td>
</tr>
<tr>
<td>2003</td>
<td>35</td>
<td>7</td>
<td>21</td>
<td>63</td>
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<tr>
<td>2004</td>
<td>43</td>
<td>6</td>
<td>20</td>
<td>69</td>
</tr>
<tr>
<td>2005</td>
<td>17</td>
<td>11</td>
<td>30</td>
<td>58</td>
</tr>
<tr>
<td>2006</td>
<td>24</td>
<td>13</td>
<td>24</td>
<td>61</td>
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<tr>
<td>2007</td>
<td>16</td>
<td>13</td>
<td>41</td>
<td>70</td>
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<tr>
<td>2008</td>
<td>15</td>
<td>13</td>
<td>42</td>
<td>70</td>
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<tr>
<td>2009</td>
<td>23</td>
<td>14</td>
<td>26</td>
<td>63</td>
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<tr>
<td>2010</td>
<td>26</td>
<td>16</td>
<td>48</td>
<td>90</td>
</tr>
<tr>
<td>2011</td>
<td>26</td>
<td>17</td>
<td>51</td>
<td>94</td>
</tr>
<tr>
<td>2012</td>
<td>23</td>
<td>12</td>
<td>45</td>
<td>80</td>
</tr>
<tr>
<td>Total</td>
<td>334</td>
<td>133</td>
<td>384</td>
<td>851</td>
</tr>
</tbody>
</table>

- **Current**: Number of women diagnosed with HIV during a pregnancy in this period (i.e. a first positive test in the current pregnancy).
- **Previous**: Number of pregnancies among women who first tested HIV-positive during a previous pregnancy.
- **Prior**: Number of pregnancies among women who first tested HIV-positive before the current pregnancy but not during a pregnancy.
Ontario HIV model

- Use iterative spreadsheet model to ensure internal consistency across multiple data sources (triangulation) and across model parameters
- Based on HIV diagnoses, reported AIDS cases, HIV-related mortality, repeat tester analysis, incidence assay results and epidemiologic studies
- Output: HIV incidence and HIV prevalence by exposure category, sex and health region
Ontario HIV model

- Incidence, cumulative incidence and prevalence of:
  - HIV infection
  - HIV diagnoses
  - AIDS
  - HIV-related mortality (no prevalence, though!)
- Model values adjusted to fit available data on HIV diagnoses, reported AIDS cases and AIDS deaths and results from back-calculations
Model design

- Each exposure category modeled separately
- Stratified on gender (by sex and summed or overall and interpolated)
- Modeled from 1978 to 2009
- Uses spreadsheet with cell values either inputs or calculated from other cells
- Adjusted to achieve best fit
Model parameters

Five categories of parameters:

- Population at risk
- HIV incident infections
- HIV diagnoses
- Reported AIDS cases
- Mortality, HIV-related and other cause
Model parameters: Populations at risk

- Population engaging in at-risk behaviour within defined period (e.g. previous year)
- Based on published studies and surveys (Canada and elsewhere)
- For MSM, rural-to-urban migration taken into account
- Adjusted HIV testing data used to constrain estimate
Inputted model parameters:
Annual HIV incidence

• Use estimated populations at risk and HIV incidence rates to obtain absolute numbers
• Calculation of HIV prevalence rate to validate model
• Sources of data
  • Incidence assay (LEP), raw and adjusted
  • HIV incidence among repeat testers (Polaris from HIV diagnostic data)
  • Incidence from epidemiologic studies in comparable populations
  • Modeled from HIV diagnoses, Ping Yan
Model parameter inputs: Annual HIV diagnoses

- All HIV diagnostic testing in Ontario carried out at Public Health Laboratory
- Data on HIV-positive tests from October 1985 and HIV-negative tests from January 1992
- Use first-time HIV-positive tests by exposure category and year
- Use weights from LEP to assign NIR and re-assign selected exposure categories
- Adjustment for repeat testing using data from LEP
Model parameters inputs:
Annual AIDS incidence

- AIDS using standard case definition and reportable in Ontario since 1981
- Adjusted for under-reporting
  - Evaluation in Ontario and Quebec and published literature
- Adjusted for delayed reporting
  - Weights determined in collaboration with PHAC
Model parameter inputs:
Annual HIV-related mortality

- Carried out in two ways, as follows:
  - Modeled survival following AIDS diagnosis
    - Based on published studies
  - Vital statistics data from ORG
    - Adjusted for under-ascertainment
    - Data from 1987 to 2009
Model parameter inputs:
Annual other-cause mortality

- For most groups, life-table mortality
- For IDUs, include excess mortality due to overdose, trauma and serious infections
- Based on published studies, Canada and elsewhere
Model parameters calculated: HIV infection

- HIV incidence, number = population at risk x incidence density
- Cumulative HIV incidence at end year = sum of annual HIV incidences since 1978
- HIV prevalence at end year = cumulative HIV incidence less cumulative mortality
- Population HIV prevalence rate = HIV prevalence / population at risk
Model parameters calculated: HIV diagnoses, AIDS and deaths

- For HIV diagnoses, AIDS and mortality, cumulative incidence at end year = sum of annual incidences since 1978
- Prevalence at end year = cumulative HIV incidence less cumulative mortality
Model development and validation

• Preliminary data entered to obtain functional model and then refined with adjustments to achieve best fit

• Model also constrained by:
  • HIV prevalence rates from epidemiologic studies, taking into account possible biases
  • Proportion population tested for HIV
Iterative spreadsheet model
Results

- 27,420 HIV-infected persons living in Ontario as of 2009
- 1,540 new HIV infections in 2009
- Most affected groups: MSM 15,175, persons from HIV-endemic regions 5,160, others infected heterosexually 4,305
- Since 2004, HIV prevalence increased by 55% among persons from HIV-endemic regions and 38% among others infected heterosexually
- Overall, ~65% of persons living with HIV have been diagnosed, 35% not yet diagnosed
Modeled HIV incidence among MSM
Ontario, 1977–2009
Modeled HIV prevalence among MSM
Ontario, 1977–2009
Modeled MSM population at risk, HIV prevalence and incidence by health region, Ontario, 2009

<table>
<thead>
<tr>
<th>Health region</th>
<th>Population at risk</th>
<th>HIV prevalent number</th>
<th>HIV prevalence rate (%)</th>
<th>Annual HIV incident number</th>
<th>Annual HIV incidence rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toronto</td>
<td>57,400</td>
<td>10,575</td>
<td>18.4%</td>
<td>485</td>
<td>1.04%</td>
</tr>
<tr>
<td>Ottawa</td>
<td>12,600</td>
<td>1,335</td>
<td>10.6%</td>
<td>70</td>
<td>0.62%</td>
</tr>
<tr>
<td>Central East, other</td>
<td>14,700</td>
<td>895</td>
<td>6.1%</td>
<td>30</td>
<td>0.22%</td>
</tr>
<tr>
<td>Eastern, other</td>
<td>3,300</td>
<td>275</td>
<td>8.3%</td>
<td>15</td>
<td>0.50%</td>
</tr>
<tr>
<td>Central West</td>
<td>9,800</td>
<td>1,060</td>
<td>10.8%</td>
<td>40</td>
<td>0.46%</td>
</tr>
<tr>
<td>Southwest</td>
<td>7,000</td>
<td>805</td>
<td>11.5%</td>
<td>40</td>
<td>0.65%</td>
</tr>
<tr>
<td>Northern</td>
<td>3,300</td>
<td>230</td>
<td>7.0%</td>
<td>10</td>
<td>0.33%</td>
</tr>
<tr>
<td>Ontario, total</td>
<td>108,100</td>
<td>15,175</td>
<td>14.0%</td>
<td>695</td>
<td>0.75%</td>
</tr>
</tbody>
</table>
Modeling HIV incidence and prevalence in Ontario

Strengths

• Model incorporates data from multiple sources adjusted for incomplete data and biases
• Provides detailed outputs by exposure category, gender and year
• Results are plausible:
  • Consistent with data from comparable populations
  • Consistent with new study results as they become available
Modeling HIV incidence and prevalence in Ontario

Weaknesses

• Results subject to uncertainty in source databases
• Methodologic problems with incidence assay:
  • Laboratory test performance, especially with specificity
  • Bias associated with “motivated testing” and correlation of HIV testing frequency with HIV risk
  • Representativeness of “testers”
• Limited empirical data on HIV incidence in most groups
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