

HIV Transmission Rates in the United States, 2006-2008

David R. Holtgrave^{*,1}, H. Irene Hall² and Joseph Prejean²

¹Department of Health, Behavior & Society, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD 21205, USA

²Division of HIV/AIDS Prevention, National Center for HIV/AIDS, Viral Hepatitis, STD, and TB Prevention, Centers for Disease Control and Prevention, USA

Abstract: National HIV incidence for a given year x $[I(x)]$ equals prevalence $[P(x)]$ times the transmission rate $[T(x)]$. Or, simply rearranging the terms, $T(x) = [I(x)/P(x)]*100$ (where $T(x)$ is the number of HIV transmissions per 100 persons living with HIV in a given year). The transmission rate is an underutilized measure of the speed at which the epidemic is spreading. Here, we utilize recently updated information about HIV incidence and prevalence in the U.S. to estimate the national HIV transmission rate for 2006 through 2008, and present a novel method to express the level of uncertainty in these estimates. Transmission rate estimates for 2006 through 2008 are as follows (respectively): 4.39 (4.01 to 4.73); 4.90 (4.49 to 5.28); and 4.06 (3.70 to 4.38). Although there are methodological challenges inherent in making these estimates, they do give some indications that the U.S. HIV transmission rate is at a historically low level.

Keywords: HIV, transmission rate, epidemiology, mathematical modeling, United States, evaluation.

INTRODUCTION

Fundamentally, at a national level, HIV incidence for a given year x $[I(x)]$ equals prevalence $[P(x)]$ times the transmission rate $[T(x)]$. Or, simply rearranging the terms, $T(x) = [I(x)/P(x)]*100$ (where $T(x)$ is easily interpreted as the number of HIV transmissions per 100 persons living with HIV in a given year) [1-6].

Despite the central role that $T(x)$ plays in the epidemiology of HIV, there has been relatively scant attention paid in the literature to its calculation [1-6]. We previously estimated the HIV transmission rate for the U.S. for 1977 through 2006 based on extended backcalculation estimates for $I(x)$ and $P(x)$ [6]. For the year 2006, we estimated that $T(x)$ was 5.0 in the U.S. (i.e., that there were approximately 5.0 HIV transmissions to HIV seronegative persons for every 100 persons living with HIV in that year) [6]. However, the attention being given to the HIV transmission rate is increasing since last year's release of the National HIV/AIDS Strategy which set major national goals of reducing HIV incidence by 25% and reducing $T(x)$ by 30% between 2010 and 2015 [7].

Very recently, CDC updated its estimates of $I(x)$ and $P(x)$ for 2006, and added new estimates for 2007 and 2008 [8, 9]. $P(x)$ estimates for 2006 through 2008 are still based on extended backcalculation methodology [9]. $I(x)$ estimates for these three years, however, are based on a stratified extrapolation approach (SEA) for HIV incidence estimation based on a biological marker of recent HIV infection, the BED HIV-1 Capture EIA (BED), that classifies a diagnosed

HIV infection as either of recent (on average within 162 days) [10] or long-standing duration. Incidence is estimated using the SEA by assigning a weight (based on the probability that an individual of similar demographic and risk behavior characteristics would have an HIV test in his/her recency period) to each diagnosis deemed a recent infection, and summing these weights [8, 11]. By using the SEA, annual HIV incidence estimates can be calculated to provide the most up to date information on the burden of HIV infection. $I(x)$ and $P(x)$ base case, lower bound and upper bound estimates published by CDC are presented in Table 1.

To calculate $T(2006)$, $T(2007)$ and $T(2008)$ we must use a BED-based estimate for the numerator and an extended backcalculation estimate for the denominator as there are no published $I(x)$ and $P(x)$ pairs based on the same methodology for these three years. This reflects CDC's position that these methods are the best available to estimate incidence, and prevalence respectively. It is instructive to make these calculations to gauge the approximate transmission rate for the U.S. based on the best available incidence and prevalence estimates in the U.S. even though there are methodological differences. Table 1 displays the results of these calculations. We had previously estimated $T(2006)$ to be 5.0; the updated estimate for $T(2006)$ is 4.39 (Table 1); this difference is simply the result of using different methodologies to estimate $I(x)$. $T(2007)$ and $T(2008)$ estimates are 4.90 and 4.06, respectively. Such estimates would indicate that over 95% of persons living with HIV do not transmit the virus to a seronegative person in a given year (and that percentage is even higher to the extent that there is clustering of HIV transmission; ie, one person infecting more than one person).

Of course, there is clearly uncertainty in these estimates of $T(x)$. One way to explore this uncertainty is to consider the 95% confidence intervals around $I(x)$ and $P(x)$. The

*Address correspondence to this author at the Department of Health, Behavior & Society, Johns Hopkins Bloomberg School of Public Health, 624 N Broadway, Suite 280, Baltimore, MD 21205, USA; Tel: 410 502 4076; E-mail: dholtgrave@jhsph.edu

Table 1. Annual HIV Transmission Rates per 100 Persons Living with HIV [T(x)], 2006-2008

Year (x)	HIV	Lower	Upper	HIV	Lower	Upper	Deaths	HIV
	Incidence	Bound	Bound	Prevalence	Bound	Bound	Implied By I(x),	Transmission Rate
	I(x)	I(x)	I(x)	P(x)	P(x)	P(x)	P(x), & P(x-1)*	T(x)=[I(x)/P(x)]*100
Base Case								
2006	48,600	NA	NA	1,106,400	NA	NA	NA	4.39
2007	56,000	NA	NA	1,142,400	NA	NA	20,000	4.90
2008	47,800	NA	NA	1,178,350	NA	NA	11,850	4.06
"Lower Bound"								
2006	NA	42,400	NA	NA	1,056,400	NA	NA	4.01
2007	NA	49,100	NA	NA	1,092,400	NA	13,100	4.49
2008	NA	41,800	NA	NA	1,128,350	NA	5,850	3.70
"Upper Bound"								
2006	NA	NA	54,700	NA	NA	1,156,400	NA	4.73
2007	NA	NA	62,900	NA	NA	1,192,400	26,900	5.28
2008	NA	NA	53,800	NA	NA	1,228,350	17,850	4.38

*Note: These figures can be compared to CDC's reported (and estimated) deaths for persons living with HIV in years 2006, 2007 and 2008 which are 15,074 (16,319), 14,162 (16,297) and 12,875 (16,769), respectively [12].

original confidence intervals for I(x) and P(x) are provided in Table 1, and the reader is referred to the original sources for a complete discussion of their derivation [8, 9]. For instance, one might estimate a lower bound for T(x) by dividing the lower bound estimate of I(x) by the lower bound estimate of P(x), and an upper bound estimate for T(x) by dividing the upper bound estimate of I(x) by the upper bound estimate of P(x). The results of these calculations are displayed in Table 1, and would indicate lower and upper bounds of less than 9% variance from the base case estimates of T(x).

Although a variance of less than 9% from base case is a rather narrow range, there is some evidence that even this range is possibly too wide. This evidence comes from comparing CDC's previous estimates of deaths among persons living with HIV (given in the footnote of Table 1) [12] to the number of deaths implied by I(x), P(x) and P(x-1) (calculated in Table 1). That is, if we take published estimates of P(x) and I(x) [8, 9], we can calculate the number of implied deaths by using the formula,

$$\text{Implied Deaths (x)} = P(x) - [P(x-1) + I(x)].$$

In the base case calculations for T(2007) and T(2008) we see that the number of implied deaths are 20,000 and 11,850, respectively (with a two year average of 15,925). Given CDC's previously published estimates of deaths among persons living with HIV in 40 states (16,297 for 2007, 16,769 for 2008, and a two year average of 16,533) [12], the implied deaths are a bit too low for 2008 and the two year average. The latest data available on deaths are from the 40 states that have had confidential, name-based HIV infection reporting for a sufficient length of time to adjust for reporting delays.

Examining the lower bound calculations from Table 1 we see that the implied deaths are substantially too low. For 2008, the implied deaths may also be too low in the higher bound calculations given that CDC's published death estimates are for 40 states only. These observations about observed and implied numbers of deaths might suggest that the T(x) bounds calculated in Table 1 are somewhat too wide (however, this assertion is not definitive because the driver of the implied deaths discrepancy from previously estimated deaths could be a function of uncertainty in I(x), P(x) or some combination of the two). We include this tentative discussion of implied deaths simply to highlight that the amount of uncertainty implied in Table 1 about T(x) may well be too high rather than too low.

It is important to note that we did not attempt to calculate the HIV transmission rate for specific subpopulations such as African-American communities and men who have sex with men. To do so would be to imply that all incidence occurs within particular communities and there is no sexual or injection equipment sharing across subpopulations; clearly this is a problematic assumption to make.

Of much policy and programmatic interest is whether there is a discernable upward or downward trend in the transmission rate from year to year. The T(2006-2008) estimates calculated in this report do not indicate an obvious trend in either direction, although further years of data are needed. This result might indicate relatively overall stability in the T(x) for these three years. If stability is a reasonable description of T(x) for this time period, then taking the arithmetic average of T(x) for 2006-2008 would be an appropriate calculation. The unweighted average of T(2006), T(2007) and T(2008) is 4.45 in the base case, 4.07 in the "lower bound" case, and 4.80 in the "upper bound" case.

It is important to routinely update the best available estimates of $T(x)$ for several reasons (even if there are clear methodological challenges and uncertainty in calculating $T(x)$). First, $T(x)$ plays a key role in the National HIV/AIDS Strategy (NHAS) and it is critical to continually refine methods for estimating $T(x)$ so that as soon as possible an estimate for $T(2010)$ can be made to set a baseline for the NHAS [7]. Second, even if somewhat imprecise, the estimates of $T(x)$ can provide some insights into how much progress HIV prevention efforts have made in the U.S., and how much work remains to be done [5, 13, 14]. For instance, Hall *et al.* used transmission rate modeling to project the course of the HIV epidemic in the U.S. for the next decade and to assess the possible impact of various scenarios for scaling up HIV prevention efforts [5].

Also, we can compare the U.S. transmission rate to the lowest regional rates from across the globe. For 2007, it has been estimated that the Western/Central Europe HIV transmission rate is approximately 3.7 (the overall global transmission for that year is approximately 8.2) [13]. For 2005, it has been estimated that the HIV transmission rate for Thailand (a country widely acknowledged to have a highly successful HIV prevention program) is 2.9 [14]. While there are many methodological challenges in comparing the U.S. $T(x)$ to those for Europe, Thailand, and even the entire globe, doing so does give some crude sense that the U.S. is closer to the lower end of the observed continuum than to the higher end. This would suggest that continued improvements in $T(x)$ for the U.S. are very much needed but also could be progressively harder to achieve.

ACKNOWLEDGEMENTS

The authors sincerely thank Dr. Phil Rhodes for provision of confidence intervals estimates utilized in this analysis.

DISCLAIMER

The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the Centers for Disease Control and Prevention.

CONFLICT OF INTEREST

Declared none.

REFERENCES

- [1] Holtgrave DR. Estimation of annual HIV transmission rates in the United States, 1978-2000. *J Acquir Immune Defic Syndr* 2004; 35: 89-92.
- [2] Holtgrave DR, Anderson T. Utilizing HIV transmission rates to assist in prioritizing HIV prevention services. *Int J STD AIDS* 2004; 15: 789-92.
- [3] Farnham PG, Holtgrave DR, Sansom SL, Hall HI. Medical costs averted by HIV prevention efforts in the United States, 1991-2006. *J Acquir Immune Defic Syndr* 2010; 54: 565-7.
- [4] Holtgrave DR. Is the elimination of HIV infection within reach in the United States? Lessons from an epidemiological transmission model. *Public Health Rep* 2010; 125: 372-6.
- [5] Hall HI, Green TA, Wolitski RJ, *et al.* Estimated future HIV prevalence, incidence, and potential infections averted in the United States: A multiple scenario analysis. *J Acquir Immune Defic Syndr* 2010; 55: 271-76.
- [6] Holtgrave DR, Hall HI, Rhodes PH, Wolitski RJ. Updated annual HIV transmission rates in the United States, 1977-2006. *J Acquir Immune Defic Syndr* 2009; 50: 236-8.
- [7] The White House Office of National AIDS Policy. National HIV/AIDS Strategy for the United States. Washington: White House, July 13, 2010.
- [8] Prejean, J, Song, R, Hernandez, A, *et al.* Estimated HIV Incidence in the United States, 2006–2009. *PLoS ONE* 2011; 6(8): e17502.
- [9] Torian L, Rhodes P, Hall HI. HIV Surveillance - United States, 1981-2008. *Morb Mort Wkly Rep* June 3, 2011; 60: 689-93.
- [10] Parekh, BS, Hanson, DL, Hargrove, J, *et al.* Determination of mean recency period for estimation of incidence with the BED-capture EIA in persons infected with diverse HIV-1 subtypes. *AIDS Res Hum Retrov* 2010; (DOI: 10.1089/aid.2010.0159).
- [11] Karon JM, Song R, Brookmeyer R, *et al.* Estimating HIV incidence in the United States from HIV/AIDS surveillance data and biomarker HIV test results. *Stat Med* 2008; 27(23): 4617-33.
- [12] Centers for Disease Control and Prevention. HIV Surveillance Report 2009; vol. 21. <http://www.cdc.gov/hiv/topics/surveillance/resources/reports/>. Published February 2011 (Accessed July 10, 2011).
- [13] Holtgrave DR. Apparent declines in the global HIV transmission rate. *Int J STD AIDS* 2009; 20: 876-8.
- [14] Park LS, Siraprasiri T, Peerapatanapokin W, Manne J, Niccolai L, Kunanusont C. HIV transmission rates in Thailand: Evidence of HIV prevention and transmission decline. *J Acquir Immune Defic Syndr* 2010; 54: 430-6.

Received: November 16, 2011

Revised: January 12, 2012

Accepted: January 17, 2012

© Holtgrave *et al.*; Licensee *Bentham Open*.

This is an open access article licensed under the terms of the Creative Commons Attribution Non-Commercial License (<http://creativecommons.org/licenses/by-nc/3.0/>) which permits unrestricted, non-commercial use, distribution and reproduction in any medium, provided the work is properly cited.