

**Modelling the expected short-term distribution  
of incidence of HIV infections by exposure  
group**

UNAIDS

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## **Acknowledgements**

The spreadsheet was developed by Geoff Garnett and Peter White (Imperial College) in collaboration with Neff Walker and Peter Ghys (UNAIDS), John Stover (TFGI), Tim Brown (East West Centre) & Elizabeth Pisanie (FHI) in 2002, Bangkok; and revised by Peter White and Eleanor Gouws in 2005.

The model is based on formulae of Weinstein et al and employed in the model Avert.

## **AIM**

The aim of the spreadsheet is to calculate the expected number of new infections over the coming year on the basis of a description of the current distribution of infections and patterns of risk within the population. The model serves firstly to explore the user's knowledge of the influences on the pattern of infection in the population of interest, and secondly to identify exposure / risk groups where estimates of new infections can be expected to help plan interventions.

## **Methods**

The spreadsheet uses

- (i) the current prevalence of HIV infection,
- (ii) numbers of individuals with particular exposures, and
- (iii) the rates of these exposures

to calculate the *expected incidence of HIV infection* over the coming year.

The user of the spreadsheet has to supply biological and behavioural surveillance data to inform the values in the cells for the spreadsheet. Some of these may be reasonably well estimated, whereas others may be poorly specified. Estimates of transmission probability per contact are derived from published literature, but can also be specified by the user.

The population can be divided into groups with particular risks of acquiring HIV (see below). By estimating the size of these risk groups and their exposure to HIV infection (i.e. the extent of behaviours which allow for the transmission of HIV and the prevalence of HIV infection in their contacts) we can identify where most new HIV infections will occur and the sensible focus of interventions.

## **Note of caution**

The model uses crude groupings of the population according to their main exposure to HIV infection. The results are only as good as the data entered to estimate the size of the group, the current distribution of HIV and other sexually transmitted infections,

and the risk behaviours of those within these groups. Even with reliable estimates the model does not take account of the distribution of behaviours within the risk groups, the patterns of mixing by demographic, social, geographic and economic variables and the influence of specific sexually transmitted diseases. It can therefore not be used to generate accurate predictions without a full description of these many complexities. Nonetheless, it does allow the user to identify where most of the new HIV infections will be found and the relative orders of magnitude of the incident infections possible within risk groups. Further, it allows programmes to see the type of data required, even for crude predictions. The coverage and focus of the interventions can also be explored and the benefits of both increased coverage and efficacy can be illustrated.

## **Instructions**

### **Data required:**

The model categorizes the population into groups according to their main source of exposure to HIV. Children are not included in this spreadsheet. The risk groups are defined as:

- Row 4        Injecting drug users (IDU)
- Row 5        The sex partners of IDU
- Row 6        Sex workers
- Row 7        Clients of sex workers
- Row 8        The other (non-commercial) sex partners of clients of sex workers
- Row 9        Men who have sex with men (MSM)
- Row 10       Female sex partners of those MSM who also have sex with women
- Row 11       Those who have ‘casual’ heterosexual sex (e.g., more than one partner or premarital sex)
- Row 12       The regular sex partners of those who have casual heterosexual sex
- Row 13       Adults with low-risk behaviour (including those of former high-risk behaviour)
- Row 14       Adults at no risk of HIV (those that do not inject drugs and are not involved in any sexual activity)
- Row 15       Adults who receive medical injections (assumed to include the total population)
- Row 16       Adults who receive a blood transfusion

	B	C	D	E	F	G	H	I	J	K	L	M	
	Percent with risk behaviour	Number with risk behaviour	Prevalence of HIV	Prevalence of STI	Number of partners per year	Number of acts of exposure per partner per year	Percentage of acts protected	Transmission probability per risky exposure act		Incidence	% of incidence	Incidence per 100,000	
								with STI	No STI				
Adult Risk Behaviour													
Injecting Drug Use (IDU)	0.14%	22'901	30.0%	3.5%	1	50	50%	Not applicable	0.01	1'069	1.05	4'666	
Partners IDU	0.06%	9'815	12.0%	Not applicable	1	70	10%	0.006	0.002	325	0.32	3'310	
Sex workers	0.50%	81'790	27.0%	65.0%	158	4	40%	0.006	0.002	8'194	8.06	10'018	
Clients	2.50%	408'950	15.0%	15.0%	16	8	40%	0.003	0.001	16'132	15.87	3'945	
Partners of Clients	1.20%	196'296	9.0%	Not applicable	1	50	13%	0.006	0.002	2'825	2.78	1'439	
MSM	0.50%	81'790	30.0%	15.0%	3	10	30%	0.03	0.01	4'345	4.27	5'312	
Female partners of MSM	0.40%	65'432	15.0%	Not applicable	1	50	13%	0.006	0.002	1'759	1.73	2'689	
Casual heterosexual sex	29.00%	4'743'820	9.0%	7.0%	2	30	30%	0.0045	0.0015	27'297	26.85	575	
Partners CHS	19.00%	3'108'020	7.0%	Not applicable	1	52	13%	0.0045	0.0015	19'245	18.93	619	
Low-risk heterosexual sex	36.70%	6'003'386	5.0%	3.5%	1	52	13%	0.0045	0.0015	19'909	19.58	332	
No risk	10.00%	1'635'800	0.0%	0.0%	0	0				0	0.00	0	
Medical injections		16'358'000	5.0%	Not applicable	2.2	1	80%	Not applicable	0.001	398	0.39	2	
Blood transfusions	0.50%	81'790	5.0%	Not applicable	1	1	96%	Not applicable	0.9	173	0.17	211	
<b>TOTAL ADULT POPULATION</b>	<b>100%</b>	<b>16'358'000</b>	<b>6.65%</b>							Total incidence	101'671	622	
										Total incidence in partners of high-risk individuals	24'155	23.758	715
Cells that have to be filled in are denoted:													
NB The prevalence of STD in the group with the risk behaviour is used for STD prevalence of the spillover group													

Figure 1. Spreadsheet for estimating incidence of HIV infection by ‘risk’ group.

For each risk group a number of variables are required (columns B to J), as shown in figure 1.

User-specified inputs are required for the cells with a blue background while the contents of the cells in orange should not to be changed. The steps to follow are explained below.

### 1. Specify the size of the risk groups (cells B4 to B16 and C4 to C16)

- The ‘risk groups’ are defined according to the main source of exposure to HIV. For medical injections, it is assumed that the entire population is “exposed”.
- If a risk group does not apply to your population then set its size to zero.
- Please check that the total population size (cell C17) is correct and that it is equal to the sum of the population sizes in the risk groups specified in cells C4 to C14.
- Potential data sources are summarized in table 1.

**2. Specify the current HIV prevalence in those risk groups (cells D4 to D16)**

- If a risk group does not apply to your population then set its HIV prevalence to zero.
- Please check that the total population HIV prevalence (cell D17) is correct – if not then you should adjust the HIV prevalence of one or more of your risk groups. (The adult prevalence in D17 is the weighted average of the prevalences in the risk groups, cells D4 to D14).

**3. Specify the prevalence of sexually-transmitted infections (STI) in the risk groups (cells E4 to E16)**

- Risk groups that do not require this information are:  
partners of IDU, partners of sex-work clients, female partners of MSM, regular partners of those who have casual heterosexual sex partners, those who receive medical injections, and those who receive blood transfusions.

**4. Specify the (average) number of partners per year (cells F4 to F16)**

- For most risk groups – all except IDU, medical injections and blood transfusions – this is the average number of sexual partners they have per year.
- For injecting drug users, this is the average number of needle-sharing partners they have per year.
- For medical injections and blood transfusions, this is the number of injections or transfusions received: each one is counted as a ‘partner’.

**5. Specify the (average) number of acts of potential HIV risk exposure per partner per year (cells G4 to G16)**

- For most risk groups – all except IDU, medical injections and blood transfusions – the mode of HIV transmission is sexual, and the number of acts of exposure per partner per year is the average number of sex acts with each partner per year.
- For the IDU risk group, it is the average number of acts of needle sharing with each injecting partner per year.
- For medical injections and blood transfusions, the number of acts of exposure per ‘partner’ is fixed at one, because each blood transfusion or injection ‘counts’ as having a new ‘partner’.

**6. Specify the (average) percentage of acts of exposure that is ‘protected’ (cells H4 to H16)**

- For most risk groups – all except IDU, medical injections and blood transfusions – the mode of HIV transmission is sexual, and the percentage of acts that is protected is the percentage of sex acts in which condoms are used correctly. Remember that this percentage is the average over all partnerships.
- For the IDU risk group, it is the average percentage of injection events that involve safe needle use. Again, remember that this percentage is the average over all partnerships.
- For the medical injections risk group, the percentage of acts of exposure that is ‘protected’ is the proportion of injections that involve safe needle use.
- For the blood transfusions risk group, it is the percentage of units of blood that are screened effectively: this is the percentage of units that are tested, multiplied by the % sensitivity of the test used (i.e. the proportion of HIV+ blood units that are detected as being HIV+ and so not used).

**7. Optional: Specify the transmission probability per risky exposure act (cells I4 to I16 & J4 to J16)**

*It is recommended that the default values (based on a literature review) are used. However, you can also input your own data, if available.*

In this spreadsheet, the transmission probability for each risk group represents the average infectivity of HIV+ partners to whom they are exposed. For example, the transmission probability for IDU represents HIV infectivity of sharing needles with other IDU, whilst the transmission probability for sexual partners of IDU represents HIV infectivity of sexual contact.

HIV+ individuals who are also infected with a (non-HIV) sexually-transmitted infection (STI) are more likely to transmit HIV during sexual contact than HIV+ individuals who do not have an STI. This is why there are two transmission probabilities for each risk group (except for the IDU, blood transfusions and medical injections risk groups, because for those groups HIV transmission is not sexual). Cells I5 to I14 contain the transmission

probabilities for sexual transmission of HIV from HIV+ individuals who have an STI, and cells J5 to J14 contain the transmission probabilities for sexual transmission of HIV from HIV+ individuals who do not have an STI. Cell J4 contains the transmission probability for HIV transmission amongst injecting drug users; cell J15 contains the transmission probability for unsafe medical injections; and cell J16 contains the transmission probability for blood transfusions (which is very high).

**8. Examine the resulting incidence pattern (red cells K4 to M17 and charts)**

- The resulting pattern of incidence by risk behaviour is shown in columns K to M and in the charts. The incidence, defined as the cumulative number of cases of HIV infection over one year in each ‘risk group’, is shown in cells K4 to K16, along with the total incidence in K17 and the total incidence amongst ‘partners’ (i.e. partners of IDU + partners of sex-work clients + female partners of MSM + regular partners of those who have casual heterosexual sex) in cell K18.
- Cells L4 to L16, and L18, show the percentage of the total incidence that occurs in each risk group. The contents of cells L4 to L16 are shown graphically on the charts (figure 2).
- Finally, cells K4 to K16 show the incidence in each risk group per 100,000 of that risk group.

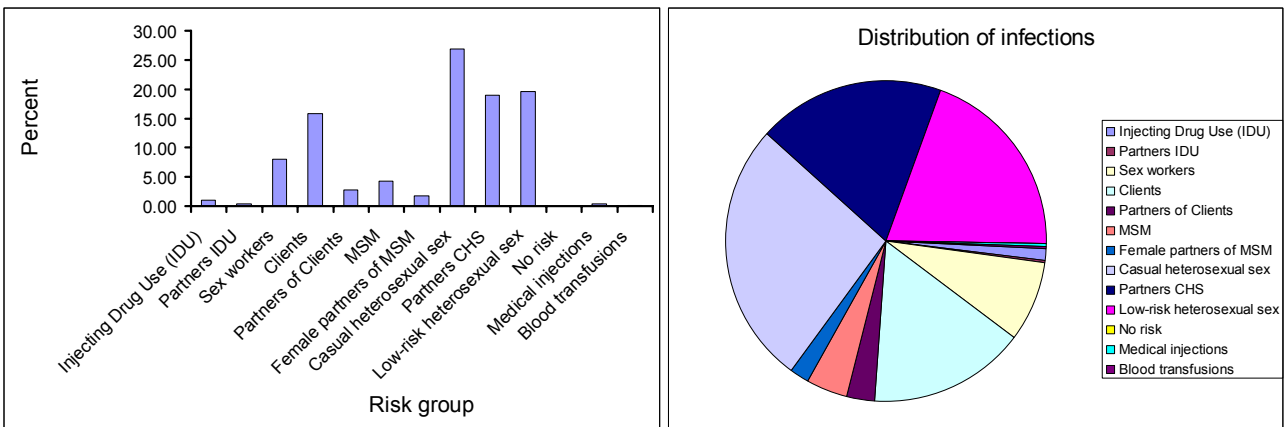


Figure 2. Percentage of total incidence by risk group



## Summary of data required

A summary of the data required for each risk groups, and potential sources of data, is provided in table 1.

Table 1: Data required and possible sources of information

Data required for each risk groups	Potential sources of data
Number (or percentage) of individuals in risk group	Surveillance (HIV, STI, Behavioural), Population based surveys (e.g., DHS), other published reports/papers. In countries with DHS reports, data can be found in the chapter on “ <i>HIV/AIDS-related Knowledge, attitudes and behaviour</i> ”  Medical Injections : See Hutin et al. <sup>1</sup> Blood transfusions: See Rapiti et al. <sup>2</sup> tables (Appendix 2)
HIV prevalence in risk group	HIV surveillance, Population based surveys, UNAIDS/WHO Epi Fact sheets In countries with DHS reports, data can be found in the chapter on “ <i>HIV Prevalence and associated factors</i> ”
Prevalence of STI	Surveillance (Behavioural and biomedical) and special studies. In countries with DHS reports, data on self-reporting of STIs can be found in the chapter on “ <i>HIV/AIDS-related Knowledge, attitudes and behaviour</i> ”
Average number of partners per year	Behavioural surveillance, population based surveys, published papers/reports In countries with DHS reports, data can be found in the chapter on “ <i>HIV/AIDS-related Knowledge, attitudes and behaviour</i> ”  Blood transfusions and Medical injections: Number received should be reported (usually 1 per year)
Number of acts per partner per year	Behavioural surveillance, population based surveys, published papers/reports In countries with DHS reports, data can be found in the chapter on “ <i>HIV/AIDS-related Knowledge, attitudes and behaviour</i> ”  Blood transfusions and Medical injections: Fixed at 1
Percentage of potential exposure acts protected	Behavioural surveillance, population based surveys, published papers/reports Medical Injections : See Hutin et al. <sup>1</sup> Blood transfusions: See Rapiti et al. <sup>2</sup> tables (Appendix 2)
Transmission probability per act of exposure with and without STIs	Recommended to use default values that are derived from published literature

<sup>1</sup> Hutin YJF, Hauri AM, Armstrong GL. Use of injections in healthcare settings worldwide, 2000: literature review and regional estimates. *BMJ* 2003; 327: 1075 (Review)

<sup>2</sup> Rapiti E, Hutin Y, Dhingra N. The global burden of HBV, HCV and HIV infections attributable to unsafe blood transfusions. Unpublished report

**Box 1. Definitions**

1. Size of risk behaviour groups: The number of people who engage in the risk behaviour and for whom this is their main source of HIV infection risk. People can only be 'counted' in one risk group, even though they may have several different means of exposure (except in the medical injections and blood transfusions groups, which are counted independently).
2. HIV prevalence by risk group: the percentage of people in the particular risk group who are infected with HIV.
3. STI prevalence by risk group: the percentage of people in the particular risk group who have a sexually transmitted infection.
4. Number of partners per year: the number of different partners per year. Note that for blood transfusions, each donor counts as a 'partner' and for medical injections, each unsafe use of a needle counts as having a 'partner'.
5. Number of acts of exposure per partner per year: the number of contacts per partner per year. For blood transfusions and unsafe medical injections there is one 'act' per 'partnership'.
6. Percentage of acts protected: The fraction of acts that are protected by condom use / safe needle use / screening of blood used for transfusions.

## Appendix 1

### ***Model assumptions:***

If we assume that the risk of infection in a susceptible individual is a simple binomial function of their number of partners and number of sex acts with each partner we can derive a risk per susceptible which depends upon the current prevalence of infection within their contacts. We can further take account of the different transmission probabilities when another STI is or is not present. If we multiply this by the number of susceptibles at risk in the population we get an expected incidence for the coming year using the following equation:

$$I = S \left[ 1 - \left\{ p \left( B(1 - \beta'(1 - v))^a + (1 - B)(1 - \beta)^{a(1-v)} \right) + (1 - p) \right\}^n \right]$$

where  $I$  is the incidence of HIV in the target population, which depends upon the number susceptible,  $S$ , and the HIV prevalence in the partner population,  $p$ . The variable  $B$  is prevalence of STIs in the target or partner population, whichever is higher,  $\beta'$  and  $\beta$  represent the probability of transmission of HIV during a single contact in the presence or absence of an STI (in the case of transmission by needle-sharing  $\beta' = \beta$ ),  $v$  is the proportion of acts currently protected by effective condom use or the use of sterile needles,  $a$  is the number of contacts per partner and  $n$  is the number of partners (figure 1).

**Appendix 2:**

**Table 2: Blood transfusions per person and per year and data sources used, by region, 2000**

(Source: Rapiti E, Hutin Y, Dhingra N. The global burden of HBV, HCV and HIV infections attributable to unsafe blood transfusions. Unpublished report)

	AFR D	AFR E	AMR A	AMR B	AMR D	EMR B	EMR D	EUR A	EUR B	EUR C	SEAR B	SEAR D	WPR A	WPR B
Number of blood transfusions per 1000 persons and per year	4	5	43	11	7	18	4	57	11	20	5	4	36	15
Countries for which age-specific estimates of transfusion frequency were used	Cam Eron	Cote d'Ivoire Congo Kenia Mozambique Tanzania Zambia	USA	NA	NA	NA	NA	France	NA	NA	NA	India	NA	NA
Use of other regions' age-specific estimates											SEAR D		AMR A	SEAR D

**Table 3: Estimates of the proportion of blood donations screened for HBV, HCV and HIV according to (a) the Global Database on Blood Safety and (b) the “worse-case scenario”, (c) published studies review by region, 2000** (Source, Rapiti E, Hutin Y, Dhingra N. The global burden of HBV, HCV and HIV infections attributable to unsafe blood transfusions. Unpublished report)

	AFR D	AFR E	AMR A	AMR B	AMR D	EMR B	EMR D	EUR A	EUR B	EUR C	SEAR B	SEAR D	WPR A	WPR B
Proportion of screening HBV	76.9%	70.0%	100%	91.3%	61.2%	100%	94.0%	100%	97.3%	100%	100%	78.0%	100%	94.0%
Worse-case scenario	50%	50%	100%	50%	50%	50%	50%	100%	80%	80%	50%	50%	100%	50%
Published studies	-	-	100%	93.9% (84-100)	78.1% (60-95.5)	-	95%	100%	-	-	-	-	100%	-
Proportion of screening HCV	11.8%	32%	100%	77.9%	46.6%	90%	29%	100%	89.2%	100%	45%	34%	100%	48%
Worse-case scenario	11.8%	32%	100%	50%	46.6%	50%	29%	100%	80%	80%	45%	34%	100%	48%
Published studies	-	-	100%	66.7% (14.8-100)	43.6% (37.2-53)	-	17%	100%	-	-	-	25%	100%	-
Proportion of screening HIV	92.8%	96%	100%	92%	67%	100%	97%	100%	97.8%	100%	100%	74%	100%	94%
Worse-case scenario	50%	50%	100%	50%	50%	50%	50%	100%	80%*	80%	50%	50%	100%	50%
Published studies	-	82.5% (72-93)	100%	95.9% (85-100)	81.8% (60-100)	-	52%	100%	-	-	-	-	100%	-

\*For the age-groups 0-4 and 5-14 years the worse-case scenario was set up to 90% of screening for both genders.

## Regions for which the burden of infections has been estimated

<b>REGION</b>	<b>COUNTRIES</b>
<b>AFR D</b>	Algeria, Angola, Benin, Burkina Faso, Cameroon, Cape Verde, Chad, Comoros, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea-Bissau, Liberia, Madagascar, Mali, Mauritania, Mauritius, Niger, Nigeria, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Togo
<b>AFR E</b>	Botswana, Burundi, Central African Republic, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Eritrea, Ethiopia, Kenya, Lesotho, Malawi, Mozambique, Namibia, Rwanda, South Africa, Swaziland, Uganda, United Republic of Tanzania, Zambia, Zimbabwe
<b>AMR A</b>	Canada, Cuba, United States of America
<b>AMR B</b>	Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Brazil, Chile, Colombia, Costa Rica, Dominica, Dominican Republic, El Salvador, Grenada, Guyana, Honduras, Jamaica, Mexico, Panama, Paraguay, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Uruguay, Venezuela
<b>AMR D</b>	Bolivia, Ecuador, Guatemala, Haiti, Nicaragua, Peru
<b>EMR B</b>	Bahrain, Cyprus, Iran (Islamic Republic of), Jordan, Kuwait, Lebanon, Libyan Arab Jamahiriya, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, Tunisia, United Arab Emirates
<b>EMR D</b>	Afghanistan, Djibouti, Egypt, Iraq, Morocco, Pakistan, Somalia, Sudan, Yemen
<b>EUR A</b>	Andorra, Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Luxembourg, Malta, Monaco, Netherlands, Norway, Portugal, San Marino, Slovenia, Spain, Sweden, Switzerland, United Kingdom
<b>EUR B</b>	Albania, Armenia, Azerbaijan, Bosnia and Herzegovina, Bulgaria, Georgia, Kyrgyzstan, Poland, Romania, Slovakia, Tajikistan, The Former Yugoslav Republic of Macedonia, Turkey, Turkmenistan, Uzbekistan, Yugoslavia
<b>EUR C</b>	Belarus, Estonia, Hungary, Kazakhstan, Latvia, Lithuania, Republic of Moldova, Russian Federation, Ukraine
<b>SEAR B</b>	Indonesia, Sri Lanka, Thailand
<b>SEAR D</b>	Bangladesh, Bhutan, Democratic People's Republic of Korea, India, Maldives, Myanmar, Nepal
<b>WPR A</b>	Australia, Brunei Darussalam, Japan, New Zealand, Singapore
<b>WPR B</b>	Cambodia, China, Cook Islands, Fiji, Kribati, Lao People's Democratic Republic, Malaysia, Marshall Islands, Micronesia (Federated States of), Mongolia, Nauru, Niue, Palau, Papua New Guinea, Philippines, Republic of Korea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu, Viet Nam