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Sharps injuries

Global burden of disease from sharps injuries to health-care workers

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Preface

Health-care workers are at increased risk of infection with bloodborne pathogens because of occupational exposure to blood and other body fluids (Gerberding, 1990; Mangione et al., 1991). Most exposures among health-care workers are caused by percutaneous injuries with sharp objects contaminated with blood or body fluids (Romea et al., 1995; EPINet, 1998; NaSH, 1999; CCOHS, 2000; Puro et al., 2001). These sharps include needles, scalpels, lancets and broken glass. The pathogens most commonly transmitted to health-care workers in occupational settings are the hepatitis B and C viruses (HBV, HCV) and the human immunodeficiency virus (HIV) (Sepkowitz, 1996a). Health-care workers may also acquire other infections from bloodborne pathogens (e.g. Creutzfeld-Jakob disease), airborne pathogens (e.g. tuberculosis, varicella, influenza) or faecal-oral pathogens (e.g. hepatitis A, salmonellosis) (CDC, 1995; Sepkowitz, 1996a,b). However, the risk of infection from these pathogens is either lower than that from HBV, HCV and HIV, or has only been poorly estimated.

The risk of infection of health-care workers from contaminated sharps should be considered part of a larger risk-factor group called "unsafe injections" (Hutin & Chen, 1999). A safe injection is defined as one that does not harm the recipient, the provider or the community. Thus, unsafe injections include those that lead to infections in injection recipients (Hauri et al., 2003), or in providers before, during or after injections, as well as injections by contaminated sharps that have been improperly disposed of in the community and that lead to infection. Although the impact of unsafe injections is far greater among recipients, the bloodborne pathogens introduced by contaminated needle-sticks nevertheless cause a high burden of death and disability among health-care workers. Because of their effect on health-care workers, unsafe injections may also have indirect consequences on health-care delivery, particularly in regions where the qualified work force is small compared to the disease burdens in the population.

Occupational percutaneous exposures to bloodborne pathogens can be prevented by strategies that include: immunization against HBV; procedures to prevent percutaneous injuries; and postexposure prophylaxis (PEP) to prevent the development of disease. But in many countries, it has not been possible to implement such strategies because no supporting estimates of the disease burden associated with occupational exposure to bloodborne pathogens have been available.

A separate guide is being prepared to help countries assess the national or local disease burden from sharps injuries in health-care workers (Rapiti et al., 2003). The guide will provide a practical step-by-step approach, using numerical examples, and can be adapted to local circumstances and data availability.

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Summary

Background

Although the occupational transmission of hepatitis B virus (HBV), hepatitis C virus (HCV) and human immunodeficiency virus (HIV) has been documented in health-care personnel, and a number of countries have national surveillance programmes for occupational infections, the burden of disease from such infections has not yet been estimated at the global level.

Methods

We modelled the incidence and fraction of HBV, HCV and HIV infections that were attributable to a workplace percutaneous injury with a needle or sharp contaminated with bloodborne pathogens. The model was based on probabilities for the occurrence of joint events or states, including the probability of injury, the prevalence of active infection in the population, the susceptibility of the worker, and the percutaneous transmission potential. The model assumed that the risk of infection increased almost proportionally to the number of infectious individuals in the population, and was applied to 14 geographical regions, grouped on the basis of the WHO Region and mortality strata (Annex). For developed regions, the effects of PEP for HBV and HIV were included in the model.

Results

The proportion of health-care workers in the general population varied substantially by region (0.2%–2.5%), as did the average number of injuries per health-care worker (0.2–4.7 sharps injuries per year). The annual proportions of health-care workers exposed to bloodborne pathogens was 2.6% for HCV, 5.9% for HBV and 0.5% for HIV, corresponding to about 16 000 HCV infections and 66 000 HBV infections in health-care workers worldwide. According to the model, 200–5000 HIV infections would also be caused (with an expected value of 1000 HIV infections). In developing regions, 40%–65% of HBV and HCV infections in health-care workers were attributable to percutaneous occupational exposure. In developed regions, by contrast, the attributable fraction for HCV was only 8%–27%, and that for HBV was less than 10%, largely because of immunization and PEP. The attributable fraction for HIV in the various regions ranged between 0.5%–11%.

Conclusions

Health-care workers are frequently exposed to percutaneous injuries with contaminated sharps, which cause a large proportion of all HCV, HBV and HIV infections in this group. These infections could largely be prevented, as shown by the lower numbers of infections in regions where efforts have been made to reduce such exposures.

1. Introduction

The World Health Organization estimated the global disease burden from contaminated sharps injuries to health-care workers at the workplace by analysing 25 risk factors that covered occupation, environment, lifestyle, diet, health practices and substance abuse (WHO, 2002). For additional information on the methods and results see: WHO (2002) and Ezzati et al. (2003). We estimated the incidence of occupational infections with HBV, HCV and HIV that were attributable to sharps injuries, using the format proposed by WHO's Comparative Risk Assessment project (WHO, 2002). The estimates are therefore based on methods comparable to those used for other risk factors. The disease burden was then estimated from the incidence data for each of 14 regions based on WHO region and mortality strata (Annex), for gender, and for the age groups 15–29, 30–44, 45–59 and 60–69 years. The model we used was similar to that used to estimate the incidence of bloodborne pathogens in the general population after source individuals became infected from contaminated needles (Aylward et al., 1995; Kane et al., 1999; Hauri et al., 2003).

1.1 Study population

The study population was defined as workers at risk of sharps injuries. This included health-care workers, such as physicians, dentists, nurses, midwives, laboratory technicians, nursing aids, medical assistants, traditional health professionals and acupuncturists. In principle, it also included non-health-care workers, such as laundry workers and cleaners, who could not be quantified in this study.

1.2 Exposed population

The exposed population was defined as health-care and other workers who had at least one injury with sharps contaminated with HBV, HCV or HIV during the past year. Contaminated sharps were defined as sharps that had been used on an infected person. The exposed population was modelled on the basis of observed parameters. For further details see section 2.4 *Exposed population*.

1.3 Exposure variable

Occupational exposure to bloodborne pathogens among health-care workers includes percutaneous exposures to needles and other sharp objects, and mucocutaneous exposure (i.e., contact with intact or nonintact skin, and contact with mucous membranes). In this study, only percutaneous exposures (i.e., sharps injuries) were considered, because such exposures were associated with the highest risk of transmission and they accounted for the largest proportion of reported exposures. In Canada, Italy, Spain and the United States of America, for example, percutaneous exposures accounted for 66%–95% of all occupational exposures to bloodborne pathogens and, of these, needle-stick injuries accounted for 62%–91% (Romea et al., 1995; EPINet, 1998; NaSH, 1999; CCOHS, 2000; Puro et al., 2001). Also, only the risks associated with injuries by contaminated sharps were included in the present study, as injuries with noncontaminated objects were not considered to bear specific risks.

The average risk of transmission of HIV, HCV and HBV, following percutaneous exposure to a sharp used on an infected source-patient, was estimated from a number of cohort studies of health-care workers (Mitsui et al., 1992; Ippolito et al., 1993; Gerberding, 1995; Bell, 1997; Puro et al., 2001).
The average risk of infection with HIV following a mucous exposure to a contaminated substance was estimated from a review of six studies and found to be 0.09% (Ippolito et al., 1993). No estimates were available for HCV or HBV. Also, the risk of transmission of HBV, HCV or HIV following exposure to intact skin has not been estimated.

Percutaneous transmission of other diseases, such as tuberculosis, diphtheria, herpes, malaria, B virus infection, Ebola virus infection and Epstein-Barr virus infection have been documented (Collins & Kennedy, 1987; Sepkowitz, 1996a), but the diseases caused by the three viruses studied here (HBV, HCV, HIV) are likely to be the only ones of global importance. It should also be noted that certain diseases can be transmitted to health-care workers by other pathways, for example through the faecal-oral route (e.g. salmonellosis, hepatitis A), or by airborne transmission (e.g. tuberculosis, measles) (Sepkowitz, 1996a,b).

1.4 Minimum exposure

To estimate by how much the disease burden would be reduced by lowering the risk factors associated with sharps injuries, the disease burden from contaminated sharps injuries in a study population can be compared with the disease burdens in populations where exposure rates to sharps have already been lowered, or in populations that use alternative technologies.

Some regions (e.g. Amr A) have made considerable efforts to reduce the risk of infection from sharps injuries by phasing in alternative technologies and training programmes for health-care workers (Panlilio et al., 2000). Considering that further efforts are under way in Amr A and other “A” regions (listed in Annex), we assumed the theoretical minimum exposure to be an absence of occupational injuries with contaminated sharps.

2. Estimating risk factors

Parameters used to estimate risk included the number of health-care workers and other workers at risk, the annual number of sharps injuries, and the prevalence of active infection in the population. In addition, among health-care workers at risk, only a small fraction were not susceptible to HBV, HCV and HIV infection. The proportion of susceptible health-care workers depended upon past infection and on immunization (in the case of HBV).

2.1 Number of health-care workers exposed to contaminated sharps

To estimate the population of health-care workers at risk from contaminated sharps, we combined the following information sources:

- The WHO Statistical Information System, WHOSIS (WHO, 2001a). This provided the size of four professional health-care worker groups (physicians, dentists, nurses and midwives) in more than 150 countries.
- The International Labour Organization (ILO) database (ILO, 1994). This provided the number of workers in all health-care worker categories in 11 countries.
- The ILO database and the ILO Yearbook of Labour Statistics (ILO, 2000). These provided the health-care worker population, by gender.

WHOSIS compiled estimates of the number of physicians, dentists, nurses and midwives for more than 150 countries for the years 1992–1998. However, health-care workers not listed in WHOSIS may also be exposed to sharps injuries. Such workers included laboratory technicians, nursing aids, medical assistants, traditional health professionals and acupuncturists. Although WHOSIS covered the majority of countries, the database included only selected categories of health-care worker. On the other hand, the ILO database covered all categories of health-care worker, but for only 11 countries. To estimate the global population of health-care workers, we therefore multiplied the numbers of nurses and midwives for all countries (from the WHOSIS database) by the proportion of nurses and midwives in the health-care workers (from the ILO database). Pharmacists, veterinarians, occupational therapists, dieticians, opticians, faith healers, chiropractors, masseurs and similar occupations do not generally have occupational exposures to sharps and were excluded in this analysis. In addition, other workers at risk of sharps injuries, including hospital cleaners, laundry workers, waste workers, nursing students, medical students, corrections workers, policemen and emergency response personnel were excluded because we could not estimate their population size.

The proportion of nurses among all health-care workers at risk in the ILO database was generally between 35%–50% (Table 1). To obtain a conservative estimate of health-care workers at risk, we assumed that the proportion of nurses among health-care workers was 50%, and doubled the number of nurses and midwives reported by WHOSIS. However, for China, a proportion of 64% was taken as the total of both nurses and physicians, since health-care workers were organized differently in China compared to most other regions. For some countries, the number of health-care workers estimated in this way was lower than the reported number of physicians, nurses, midwives and dentists in the WHOSIS database. To account for other health-care workers at risk in these countries, we increased by 20% the number of physicians, nurses, midwives and dentists reported in WHOSIS, because we estimated there would be at least an additional 20% of health-care workers not covered by those categories. Overall, the number of health-care workers at risk worldwide was calculated to be 35 702 000 (Table 2).

Table 1 Proportion of professional nurses and midwifes among all health-care workers at risk[a]

Country	Proportion of nurses and midwives among all health-care workers at risk (%)
Australia	51
Bahrain	66
Canada	42
China[b]	64
Finland	49
France	35
Japan	47
Kuwait	49
Netherlands	35
Senegal	44
USA	38

[a] Source: data are mainly from ILO (1994).
[b] Proportion of nurses and physicians among all health-care workers.

Table 2 Number of health-care workers at risk[a]

Region	Health-care workers (*N*)	Proportion of health-care workers in total population (%)
Afr D	611 000	0.21
Afr E	1 011 000	0.30
Amr A	7 696 000	2.47
Amr B	1 518 000	0.35
Amr D	176 000	0.25
Emr B	739 000	0.55
Emr D	782 000	0.24
Eur A	5 773 000	1.41
Eur B	2 255 000	1.04
Eur C	4 222 000	1.69
Sear B	488 000	0.17
Sear D	1 395 000	0.11
Wpr A	2 351 000	1.55
Wpr B	6 685 000	0.44
Total	35 702 000	Mean value 0.59

[a] see Annex for regional groupings

The WHOSIS database was compiled from country reports to the WHO Regional Offices on the numbers of health-care workers (WHO, 2001a). Potential sources of error included the definitions of health-care worker categories (e.g., nurses, midwives), and the methods of assessment, which may differ from country to country. These uncertainties may lead to an under- or overestimation of the data.

2.2 Distribution of health-care workers at risk, by gender

In the ILO database, there were large regional differences in the proportion of males among health-care workers at risk (Table 3). In addition, the ILO Yearbook of Labour Statistics (ILO, 2000) reported estimates of the proportion of males among "health and social workers" for a number of Latin American and European countries. While this latter category corresponded to a broader category than health-care workers, the proportions of males in the two categories were comparable in countries for which both estimates were available (e.g. Finland, France; Table 3). Thus, for Regions where the proportion of males among health-care workers was unknown, we assumed that it was identical to the proportion of males among "health and social workers".

Table 3 Proportion of males among "health-care workers" and "health and social workers", selected countries

Region	Country	Proportion of males (%)		
		Among health-care workers[a]	**Among health and social workers[b]**	**Other sources**
Afr D	Senegal	57	-	-
	Mauritius	49	-	-
Amr A	USA	21	-	-
	Canada	19	16	-
Amr B	Argentina	-	30	-
	Costa Rica	37	-	-
	Mexico	-	32	-
Amr D	Bolivia	-	37	-
	Peru	-	30	-
Emr B	Bahrain	33	-	-
	Kuwait	40	-	-
	Tunisia	60	-	-
Emr D	Egypt	52	-	-
Eur A	Austria	26	-	-
	Finland	12	11	-
	France	26	23	-
	Netherlands	22	-	-
	UK	18	21	-
Eur B	Bulgaria	-	20	-
	Poland	-	17	-
	Romania	-	21	-
Eur C	Estonia	-	14	-
	Hungary	21	-	-
	Kazakhstan	-	19	-
	Latvia	-	16	-
	Lithuania	-	15	-
Sear D	India	-	-	32[c]
Wpr A	Australia	21	-	-
	Japan	27	-	-
Wpr B	China	32	-	-
	Korea, Rep.	-	32	-

[a] Data from the ILO database (ILO, 1994).; [b]Data from the ILO Yearbook (ILO, 2000).
[c] Mean established on the basis of Indiastat, Registered Nursing and Midwifery, and Village Health Guides (Indiastat, 2001).

We calculated regional estimates of the proportion of males among health-care workers at risk using country values that were weighted by the country's population of workers (Table 4). For regions where values from more than one country were available, we used data from the ILO database (ILO, 1994), rather than the ILO Yearbook statistics (ILO, 2000), because the former source provided a more accurate description of worker category. Estimates for Afr D,E; Amr B,D; and Emr B,D were pooled (Table 4), because fewer than three national estimates were available, or because none of the countries in the region with dominant populations were assessed (e.g. China, India). These regions were considered jointly because it was assumed that practices in the health-care system, and the staff social structure, were similar.

Table 4 Proportion of males among at-risk health-care workers

Region	Proportion of males among health-care workers at risk (%)	Method of estimation
Afr D and E	56	Weighted average for available values for Afr D (from ILO for health-care workers), applied to Afr D and Afr E.
Amr A	21	Weighted average, ILO values for health-care workers for Amr A.
Amr B and D	32	Weighted average for Amr B and D, ILO values for health-care workers and "health and social workers", for the five country data in Amr B and D.
Emr B and D	54	Weighted average, ILO values for health-care workers, combined for Emr B and D.
Eur A	22	Weighted average, ILO values for health-care workers based on the five country data of Eur A.
Eur B	19	Weighted average, ILO values for health and social workers based on Bulgaria, Poland and Romania.
Eur C	18	Weighted average, ILO values for health-care workers and health and social workers based on the five country data of Eur C.
Sear B	32	Same as Sear D.
Sear D	32	Mean value for Registered Nursing and Midwifery, and Village health guides[a].
Wpr A	26	Weighted average, ILO values for health-care workers based on Australia and Japan.
Wpr B	32	ILO values for China, health-care workers.

[a] Source: Indiastat (2001).

2.3 Age distribution of health-care workers

Little information was available on the distribution of health-care workers by age groups. In addition, health-care workers at risk included heterogeneous occupational subgroups (nurses, technicians, physicians etc.). Thus, we assumed that the age distribution of health-care workers at risk was similar to that of the general population between the ages of 20–64 years old, and used data from the United Nations World Population Prospects (UN, 1998).

2.4 Exposed population

The exposed population was defined as workers at risk who had at least one injury with a sharp object contaminated with HBV, HCV or HIV. To estimate the size of the exposed population, we first calculated the average annual number of contaminated sharps injuries (n_c) by multiplying the average annual number of sharps injuries per health-care worker (n) by the prevalence of active infection in the population (p_v).

$$n_c = p_v * n \qquad (1)$$

The prevalence of active infection in the population (p_v) differed for HBV, HCV and HIV, but the annual number of injuries per person (n) remained constant.

To estimate the number of infections from contaminated injuries, we needed to estimate the probability of having at least one contaminated infection (since individuals could have more than one contaminated injury). If the average number of contaminated sharps injuries is relatively small, and injuries are independent events, a Poisson distribution can be assumed. For a Poisson distribution, the probability of no contaminated injury is:

$$p(0) = e^{-nc} \qquad (2)$$

Consequently, the probability of receiving at least one contaminated injury (p_c) is:

$$p_c = 1 - e^{-nc} \qquad (3)$$

When n_c is small, p_c is approximately equal to n_c and each exposed person will experience an average of only one contaminated injury per year. In most other situations, p_c will be slightly smaller than $n_{c.}$

Finally, the number of exposed health-care workers ($N_{exp,\ HCW}$) was calculated by multiplying the number of health-care workers at risk (N_{HCW}) by the probability of at least one injury with a contaminated sharps (p_c), as p_c represents the proportion of health-care workers that will be exposed:

$$N_{exp\ HCW} = N_{HCW} * p_c \qquad (4)$$

2.5 Estimating the number of sharps injuries

We considered health-care workers to be exposed if they had at least one contaminated sharps injury in the previous year. Health-care workers were considered to be unexposed if they had not experienced contaminated sharps injury in the previous year. Different levels of exposure were not assessed.

Sources of information used to estimate the number of percutaneous exposures included surveys on sharps injuries conducted among health-care workers, and data from national or local occupational injuries surveillance systems. The most common definition of accident reported from the reviewed literature was a cut/injury contaminated with blood or body fluid.

We conducted an electronic literature search in MEDLINE and the WHO regional libraries, including AIM (African Index Medicus), IMEMR (Index Medicus for the Eastern Mediterranean Region), IMSEAR (Index Medicus for the South-East Asian Region) and LILACS (Latin American and Caribbean Information System of Health Science for the PAHO). Searches used the MeSH terms “viral infection”, “hepatitis”, “hepatitis B virus”, “hepatitis infection”, “hepatitis C”, “AIDS virus”, “HIV”, combined with “needle-stick injury”, “percutaneous exposure”, “occupational exposure”, “occupational disease”, “health-care worker”, “health-care personnel”, “employee health” and “accident prevention”. We limited the search to articles that primarily studied human subjects, were published between 1985–2001, and included a full text or an abstract in English, French, Spanish, Portuguese, Italian or German. We checked the reference list of identified articles and reviews to identify other relevant articles.

After combining search results and eliminating duplicates, the search yielded over 700 references. We retrieved for review articles published in peer-reviewed scientific journals that reported observational studies of health-care workers exposed to sharps injuries during the course of their occupation, or that reported retrospective or prospective analyses of occupational exposures, or literature reviews that addressed the subject. In addition, we reviewed surveys of injection safety since 2000 that used WHO standardized assessment tools (WHO, 2000a, 2001b). To obtain an annual estimate (where applicable), data on the number of needle-stick or sharps injuries were entered into a database after processing. We excluded studies that did not report the data in the required format, or that reported the data in a format that could not be converted. For example, when an average incidence for all health-care workers was not presented and could not be calculated; or the total number of injuries was reported, but the baseline population was not provided; or no quantified results were provided.

There were major differences in the reported incidence of sharps injuries within and between regions (Table 5). Therefore, we averaged survey results for each region, and applied the average value to all age and gender categories for the region. The sources of information used to generate the estimates, as well as the regional estimates obtained, are shown in Table 5. Estimates for the two African subregions (Afr D and Afr E) were pooled because of assumed similarities in practice, and no systematic differences in socioeconomic conditions. No quantitative data were available for the Amr D region, and estimates for this region were therefore extrapolated from Amr B, assuming similarities in practices and socioeconomic conditions.

Table 5 Annual incidence of sharps injuries

Comments	Region													
	Afr D[a]	**Afr E[a]**	**Amr A**	**Amr B**	**Amr D**	**Emr B**	**Emr D**	**Eur A**	**Eur B[a]**	**Eur C[a]**	**Sear B**	**Sear D**	**Wpr A**	**Wpr B**
Mean number of sharps injuries per health-care worker per year	2.10	2.10	0.18	2.53	2.53	1.06	4.68	0.64	0.93	0.93	2.08	2.27	0.74	1.30
Countries for which sharps injuries surveys or review of surveillance systems were used	Nigeria[3]	South Africa[4]	USA[6]	Brazil[7] Chile[8] Jamaica[9]	Extrapolated from AMR B	Saudi Arabia[10]	Egypt[11] Pakistan[12]	Denmark[13] France[14] Greece[15] Spain[16,17] Switzerland[18] UK[19]	NA[b]	NA	Thailand[21]	NA	Australia[23] New Zealand[24]	China[25]
Countries for which rapid assessment surveys were used	NA	Tanzania[5]	NA	NA	NA	NA	NA	NA	Uzbekistan[20]	NA	NA	India[22]	NA	Mongolia[26]
Countries for which tool C surveys[1,2] were used	Burkina Faso Chad Gambia Niger	Ethiopia	NA	NA	NA	Syria	Egypt Morocco	NA	Kyrgystan	Moldova	NA	NA	NA	NA

[a]Pooled for analysis of the two regions; [b]NA = not available; [1]WHO (2001b); [2]J. Fitzner, unpublished data, 2001; [3]Adegboye et al. (1994); [4]Karstaedt & Pantanowitz (2001); [5]Gumodoka et al. (1997); [6] J. Jagger, unpublished data, 2002; [7]Costa et al. (1997); [8]Wolff & Hildalgo (1992); [9]Figueroa et al. (1994); [10]al-Turki & Abu-Gad (2000); [11]M. Talaat, unpublished data, 2001; [12]Mujeeb, Khatri & Khanani (1998); [13]Nelsing et al. (1993); [14]Abiteboul et al. (1992); [15]Pournaras et al. (1999); [16]Failde et al. (1998); [17]Benitez et al. (1999); [18]Luthi et al. (1998); [19]Williams et al. (1993); [20]R. Kammerlander & J. P. Stamm, unpublished data, 2001; [21]Danchaivijitr et al. (1995); [22]S. Vishnu-Priva & C. Lee, unpublished data, 2001; [23]McCall et al. (1999); [24]Lum et al. (1997); [25]Guo et al. (1999); [26] S. Logez, unpublished data, 2001.

The annual incidence of sharps injuries in the A countries of the regions are the lowest (0.18, 0.64 and 0.74 per person per year, respectively for Amr, Eur and Wpr). In the USA, special efforts to raise awareness and to promote the safety of health-care workers, including early adoption of policies, have been undertaken for more than a decade. Universal precautions (CDC, 1987) were formulated and regulations, including the Bloodborne Pathogens Standard (OSHA, 1991), were issued. The large number of injuries in Emr D is in line with the large number of injections (Hauri et al., 2003), since the more frequent use of injections means that more people handle needles, thereby increasing the risk of injuries. The estimated annual incidence of sharps injuries was relatively low for Eur B and Eur C. For three reasons, these incidences may have been underestimated: data for Eur B and Eur C were based on three surveys with a limited sample size; the frequency of injections per capita in Eur B and Eur C is one of the highest in the world (Hauri et al., 2003); and sharps waste-collection practices are commonly unsafe in Eur B and Eur C (WHO, 1999; R. Kammerlander & J.P. Stamm, unpublished data, 2001).

The percentages of the regional populations that were covered by studies on sharps injuries are given in Table 6. To estimate the percent coverage for a region, we divided the sum of all the country populations in a region for which coverage data were available by the total population for the region. For example, the region Amr A is composed of Canada, Cuba and the United States of America. However, data were only available for the United States of America, which makes up 87% of the population of the Amr A region. Consequently, the coverage for the Amr A region is given as 87% in Table 6.

Table 6 Country populations covered by injury studies

Region	Proportion of population studied (%)
Afr D	49
Afr E	43
Total Afr D + Afr E	48
Amr A	87
Amr B	44
Amr D	0
Emr B	27
Emr D	68
Eur A	44
Eur B	13
Eur C	2
Sear B	21
Sear D	82
Total Sear B + Sear D	70
Wpr A	15
Wpr B	84

In addition to the best estimates obtained as described above, we generated lower and upper estimates, as the compiled surveys contained a number of potential biases. For example, the available studies and surveys focused mainly on hospital settings, and other health-care settings were not well represented. Also, most of the reviewed studies estimated the incidence of sharps injuries retrospectively, on the basis of self-reports by health-care workers. The quality of these estimates may have been affected by a number of factors, including data collection procedures (interviews or anonymous mailed questionnaire), sample size, response rate and recall period. As the studies did not generally provide confidence intervals, we evaluated them from the average deviation of the coverage rates for all the regions shown in Table 6. We therefore estimated the lower and upper bounds to be ±65% of the best coverage estimate reported by a study. Using Equation 4, this allowed us to obtain the annual numbers (Table 7) and proportions (Table 8) of health-care workers exposed to an injury with a sharp object contaminated with HCV, HBV or HIV.

Table 7 Health-care workers exposed to at least one percutaneous injury with a sharp object contaminated with HBV, HCV and HIV

Region	**Health-care workers exposed annually (*N*)[a]**		
	HCV	**HBV**	**HIV**
Afr D	33 000 (12 000–53 000)	131 000 (50 000–201 000)	33 000 (5 900–144 000)
Afr E	57 000 (20 000–92 000)	223 000 (84 000–340 000)	194 000 (37 000–652 000)
Amr A	22 000 (14 000–31 000)	7 100 (4 300–10 000)	8 000 (2 500–33 000)
Amr B	57 000 (20 000–93 000)	61 000 (22 000–99 000)	23 000 (4 100–109 000)
Amr D	10 000 (3 700–17 000)	8 700 (3 100–14 000)	4 500 (800–21 000)
Emr B	18 000 (6 300–29 000)	43 000 (15 000–70 000)	170 (30–840)
Emr D	178 000 (68 000–272 000)	143 000 (53 000–222 000)	2 200 (380–11 000)
Eur A	16 000 (5 700–27 000)	43 000 (15 000–71 000)	9 400 (1 700–46 000)
Eur B	39 000 (14 000–64 000)	113 000 (40 000–183 000)	420 (70–2 000)
Eur C	94 000 (33 00–156 000)	148 000 (52 000–241 000)	12 500 (2 000–61 000)
Sear B	28 000 (10 000–46 000)	83 000 (31 000–130 000)	5 600 (1 000–27 000)
Sear D	57 000 (20 000–93 000)	109 000 (39 000–75 000)	23 000 (4 000–107 000)
Wpr A	47 000 (17 000–77 000)	34 000 (12 000–56 000)	670 (120–3 000)
Wpr B	269 000 (96 000–439 000)	953 000 (350 000–1 498 000)	10 400 (1 800–51 000)
Totals	926 000 (340 000–1 490 000)	2 100 000 (770 000–3 300 000)	327 000 (61 000–1 300 000)

[a] Corresponding lower and upper estimates are given in parentheses.

Table 8 Proportions of health-care workers exposed to contaminated sharps injuries per year

Region	Proportion of exposed health-care workers per year[a] (%)		
	HCV	**HBV**	**HIV**
Afr D	5.4 (1.9–8.7)	21 (8.1–32.9)	5.4 (1.0–23)
Afr E	5.6 (2.0–9.1)	22 (8.3–34)	19 (3.7–65)
Amr A	0.3 (0.2–0.4)	0.09 (0.06–0.13)	0.1 (0.03–0.4)
Amr B	3.7 (1.3–6.1)	4.0 (1.4–6.5)	1.5 (0.3–7.1)
Amr D	5.9 (2.1–9.5)	5.0 (1.8–8.0)	2.5 (0.5–12)
Emr B	2.4 (0.8–3.9)	5.9 (2.1–9.5)	0.02 (0.004–0.1)
Emr D	23 (8.7–34.7)	18 (6.8–28)	0.3 (0.03–1.4)
Eur A	0.3 (0.1–0.5)	0.7 (0.3–1.2)	0.2 (0.003–0.8)
Eur B	1.7 (0.6–2.8)	5.0 (1.8–8.1)	0.02 (0.003–0.09)
Eur C	2.2 (0.8–3.7)	3.5 (1.2–5.7)	0.3 (0.1–1.4)
Sear B	5.8 (2.1–9.4)	17 (6.3–27)	1.2 (0.2–5.5)
Sear D	4.1 (1.5–6.7)	7.8 (2.8–13)	1.6 (0.3–7.6)
Wpr A	2.0 (0.7–3.3)	1.5 (0.5–2.4)	0.03 (0.005–0.1)
Wpr B	4.0 (1.4–6.6)	14.3 (5.2–22.4)	0.16 (0.03–0.8)
Mean values:	2.6 (1.0–4.2)	5.9 (2.2–9.3)	0.9 (0.3–1.4)

[a] Corresponding lower and upper estimates are given in parentheses.

Worldwide, it was estimated that more than three million health-care workers will be exposed to a sharp object contaminated with HCV, HBV or HIV every year. This corresponds to almost one health-care worker out of ten.

2.6 Estimating hepatitis B vaccine coverage among health-care workers

Regional estimates of hepatitis B vaccine coverage among health-care workers were needed to calculate the proportion of health-care workers susceptible to HBV infection. We searched MEDLINE and the WHO regional libraries AIM, IMEMR, IMSEAR and LILACS to collect information on immunization coverage among health-care workers. Additional sources of information were obtained by reviewing references cited in studies of sharps injuries. We calculated regional estimates of the hepatitis B vaccine coverage among health-care workers by averaging the estimates available from the countries in the region, and then applying the estimate to all age and gender categories (Table 9). The susceptibility rate of health-care workers to HBV in the first age group was assumed to be the same as in the general population. In the absence of data, we extrapolated estimates for Eur B, Eur C, Sear B and Wpr B from Amr B and Emr D. Estimates of the Afr region were extrapolated to Sear D on the basis of comparable immunization coverage among children (WHO Expanded Programme on Immunization, unpublished data).

2.7 Prevalence of infection with HBV, HCV and HIV in the general population

We obtained country-specific estimates of the proportion of the population infected with HBV, HCV and HIV (P_v) from the WHO programmes on immunization against hepatitis B (WHO, Vaccines and Biologicals Department, unpublished data, 1996) and hepatitis C (WHO, Communicable Disease Surveillance and Response, unpublished data, 2001), and from the Joint United Nations Programme of HIV/AIDS (UNAIDS, 2000; 2001).

Table 9 Hepatitis B vaccine coverage among health-care workers

	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
Mean immunization rate of health-care workers for HBV	18%	18%	67%	39%	39%	39%	39%	71%	29%	29%	39%	18%	77%	39%
Source of data	Immunization surveys	Extrapolated from AFR D	Estimated from survey	Immunization surveys	Extrapolated from AMR B	Immunization surveys	Immunization surveys	Immunizations, surveys; review of sharps incidents	Tool C (draft)	Extrapolated from Eur B	Extrapolated from AMR B	Extrapolated from AFR D	Immunization surveys	Extrapolated from AMR B
Countries for which immunization rate was available	Nigeria[1,2]	NA	USA[3]	Brazil[4] Jamaica[5]	NA	Saudi Arabia[6,7] Egypt[8] Pakistan[9,10]	NA	Czech Republic[11] Denmark[12] Italy[13] UK[14-16]	Romania[17]	NA	NA	NA	Australia[18] New Zealand[19]	NA

[a]NA = not available; [1]Omokhodion (1998); [2]Olubuyde et al. (1997); [3]Mahoney et al. (1997); [4]Costa et al. (1997); [5]Figueroa et al. (1994); [6]Shanks & al-Kalai (1995); [7]al-Turki et al. (2000); [8]M. Talaat, unpublished data, 2001); [9]Nasir et al. (2000); [10]Mujeeb et al. (1998); [11]Helcl et al. (2000); [12]Nelsing et al. (1993); [13]Stroffolini et al. (1998); [14]Alzahrani et al. (2000); [15]Gyawali et al. (1998); [16]William et al. (1993); [17]C. Dentinger, unpublished data, 2001); [18]McCall et al. (1999); [19]Lum et al. (1997).

3. The relationship between risk factor and disease

3.1 Model

Using Equation 5, we modelled the incidence of HBV, HCV and HIV infections from sharps injuries among health-care workers, by calculating the probability that a health-care worker would be exposed at least once. The equation relates the probability of at least one "success" (infection of a health-care worker, in our case), to the number of events needed for an infection to occur, *n*, and the probability, *p*, that an event will occur (Snedecor & Cochran, 1989). Equation 5 has also been used to model the incidence of communicable disease.

$$P_{\text{(at least one infection)}} = 1 - (1 - p)^n \qquad (5)$$

In our model, *p* represents the probability of all events that need to occur jointly for an injury with a contaminated sharp object to result in an infection. This probability is based on the multiplication of a series of probabilities of independent events:

$$p = p_v * p_t * p_s \qquad (6)$$

where:

p_v is the prevalence of active infection in the patient population. The greater the prevalence, the greater the probability that the injuring sharp will be contaminated with bloodborne pathogens;
p_t is the probability of infection following percutaneous exposure with a sharp that had been used on an infected source patient;
p_s is the proportion of the population of health-care workers susceptible to infection (in most cases, 1 – prevalence).

Probability, *p*, is based on the assumption that the risk of infection increases in proportion to the number of infectious individuals in the population. As a result, the incidence of infection caused by sharps injuries, I_n, can be expressed as:[1]

$$I_n = 1 - (1 - p_s * p_t * p_v)^n \qquad (7)$$

The fraction of all infections in health-care workers that can be attributed to occupational exposure to sharps can then be estimated as follows:

$$AF_{(HCW)} = \frac{N_{n\,(HCW)}}{N_{n\,(HCW)} + N_{b\,(HCW)}} = \frac{I_{n\,(HCW)}}{I_{n\,(HCW)} + I_{b\,(HCW)}} \qquad (8)$$

where:

$AF_{(HCW)}$ is the attributable fraction among health-care workers;

[1] This equation can be applied to a population group provided that the probability, *p*, remains relatively low, which was the case for all groups considered in this analysis.

$N_{n\ (HCW)}$ is the number of infections due to sharps injuries among health-care workers;
$N_{b\ (HCW)}$ is the number of baseline infections among health-care workers;
$I_{n\ (HCW)}$ is the incidence of infection due to sharps injuries among health-care workers;
$I_{b\ (HCW)}$ is the baseline incidence among health-care workers.

The number of infections due to sharps injuries $(N_{n\ (HCW)})$ is simply the product of the incidence of disease due to sharps injuries, and the total number of health-care workers at risk of a sharps injury. The baseline incidence among health-care workers (i.e. infections not due to occupational exposure), $I_{b\ (HCW)}$, is equal to the incidence of the disease among susceptibles in the general population, $I_{bs(GP)}$, multiplied by the proportion of health-care workers susceptible to the disease, p_s:

$$I_{b(HCW)} = I_{bs(GP)} * p_s \quad (9)$$

Based upon estimates of the risk of infection following exposure to a contaminated sharp in a health-care setting, we assumed the probability of transmission, $p_t = 0.018$ for HCV (CDC, 1997a) and 0.003 for HIV (Cardo et al., 1997). For HBV, we assumed $p_t = 0.18$, calculated as an average of the 0.06 estimated for source patients hepatitis B e-antigen (HBeAg)-negative, and the 0.3 for source patients HBeAg-positive (Seeff et al., 1978). The transmission potential may vary according to the delay between the contamination of the sharp and the injury, and other parameters, such as the titre of virus in the contaminant; the type of needle used; the depth of needle penetration; the volume of blood involved; the host defence system. The estimated transmission probabilities, to some extent, accounted for these parameters.

3.2. Estimating contamination rates from disease prevalences

To estimate contamination rates for HCV and HCB, we used the disease prevalences in the general population. We would have preferred to use disease prevalences for the patient population, but at global level only general population data were available. A review of the literature has shown that there may be significant differences between general and patient populations in disease prevalence (Table 10). The prevalence data for the general population are the same as those used in Section 3.1 to calculate infection rates from sharps injuries.

Table 10 Prevalence of HBV, HCV and HIV among hospital patients and the general population

Country	HCV prevalence (%)			HBV prevalence (%)			HIV prevalence (%)			Origin of patient sample	Size of patient sample	Reference
	Hosp[a]	GP[b]	Ratio[c]	Hosp	GP	Ratio	Hosp	GP	Ratio			
Algeria	0.19	0.20	1.00	1.60	5.00	0.30	-	-	-	Obstetric clinic	715	Ayed et al. (1995)
Brazil	1.50	2.60	0.60	-	-	-	-	-	-	Obstetric clinic	6 995	Lima et al. (2000)
Brazil	0.80	2.60	0.30	0.80	2.00	0.80	0.60	0.57	1.10	Obstetric clinic	1 502;1 006;1 473	Reiche et al. (2000)
China[d]	12.70	3.00	4.20	16.70	12.00	1.40	0.80	0.07	11.40	All wards	1 805	Shiao et al. (2002)
Congo	-	-	-	46.00	12.00	3.80	-	-	-	Gastroenterology & Internal Medicine dept	139	Ibara et al. (1991)
Denmark	1.50	0.20	7.50	0.85	0.30	2.80	-	-	-	All wards	466	Nelsing et al. (1995)
Egypt	19.00	18.10	1.00	-	-	-	-	-	-	Obstetric clinic	100	Kassem et al. (2000)
Greece[e]	4.75	1.50	3.20	2.66	3.00	0.90	-	-	-	"High risk" patients	46 901	Koulentaki et al. (2001)
Italy	2.36	0.44	5.40	0.90	3.00	0.30	-	-	-	Dermatology dept	677	Bongiorno et al. (2002)
Italy	1.70	0.50	3.40	-	-	-	-	-	-	Obstetric clinic	1 700	Floreani et al. (1996)
Mexico	0.53	0.70	0.80	0.30	1.00	0.30	-	-	-	Perinatal care	1 500	Ortiz-Ibarra et al. (1996)
Mongolia	48.00	10.70	4.50	28.70	14.00	2.10	-	-	-	All wards (outpatients)	150	Fujioka et al. (1998)
Poland	22.30	1.40	15.90	-	-	-	-	-	-	All wards	980	(Polz et al. (1995)
Spain	1.40	0.70	2.00	-	-	-	-	-	-	Obstetric clinic	2 615	Munoz-Almagro et al. (2002)
South Africa	-	-	-	-	-	-	54.00	19.94	2.70	All wards	535	Colvin et al. (2001)
Sudan	3.00	3.20	0.90	26.00	10.00	2.60	-	-	-	All wards (outpatients)	651	McCarthy et al. (1994)
Tanzania	-	-	-	-	-	-	32.80	8.09	4.10	All wards	1 422	Kwesigabo et al. (1999)
Uganda[e]	-	-	-	-	-	-	58.00	8.30	7.00	Suspected immunosuppressed patients	8 000	Muller et al. (1990)
USA	11.70	1.80	6.50	-	-	-	-	-	-	3 samples: random, elective surgery, gastrointestinal dept	530	Austin et al. (2000)
USA	-	-	-	-	-	-	6.00	0.61	9.80	Emergency dept	2 544	Kelen et al. (1989)
USA	-	-	-	-	-	-	4.70	0.61	7.70	20 acute care hospitals	195 829	Janssen et al. (1992)
UK	0.80	0.02	40.00	-	-	-	-	-	-	Antenatal clinic	4 729	Ward et al. (2000)
UK	-	-	-	-	-	-	1.30	0.11	11.80	Accidents & Emergency dept	922	Poznasky et al. (1994)
UK	0.14	0.02	7.00	0.56	0.30	1.90	-	-	-	Antenatal clinic	3 522	Boxall et al. (1994)
Median	-	-	3.40	-	-	1.90	-	-	5.90			

[a] Hospital sample. [b] General population. [c] Ratio of the prevalences of the hospital sample and the general population.

[d] The estimate was extrapolated from the data for Taiwan. The Taiwan population may not be representative of the population of China, and the ratio was not included in the median calculation.

[e] Patients included in these studies were “high risk” patients and were not representative of the patients of the ward. Consequently, the ratio was not included in the median calculation.

As can be seen from Table 10, the ratios of disease prevalence in the patient and general populations can vary substantially, depending on the type of infection, the country, and the hospital or ward from which the patient sample is taken. Overall, the median ratios were: 1.9, 3.4 and 5.9, for HBV, HCV and HIV, respectively. While most of the studies show higher prevalences in patients than in the general population, we point out the following qualifications: the patient samples often represented high-risk patient groups and were therefore not representative of all patients; the data were incomplete for most of the regions; most studies we examined were carried out in urban settings, where disease prevalence is generally higher and not necessarily reflective of national averages; there was no consideration of patients outside hospital settings; and higher patient prevalences may not be expected in all wards. For HBV and HCV, the range of ratios was large and different ratios may be expected between the various wards. We therefore decided not to adjust for differences between estimates of HBV and HCV prevalence for patients, but rather to consider the differences as uncertainty in the estimates (see section 3.4). For HIV, prevalences were more consistent between studies, except those from obstetric clinics which generally reflected prevalences of the general population, rather than those of patients. As most of the studies were performed in acute-care hospitals or emergency departments (which were expected to have higher patient prevalences than average), and to account for patients outside the hospitals, we conservatively estimated the patient prevalence of such populations to be twice that of the general population. Again, the factor 5.9 was considered in the uncertainty analysis for the upper estimate.

3.3 Postexposure prophylaxis

Recommendations for HBV PEP with hepatitis B immunoglobulin (HB-Ig) and/or hepatitis B vaccine for occupational exposures have been adopted in many industrialized countries. These require that the surface antigen status of the source, and the vaccination and vaccine-response status of the exposed person, first be evaluated. In perinatal settings, combining HB-Ig and the hepatitis B vaccine series is 85%–95% effective in preventing HBV infection (Beasley et al., 1983; Stevens et al., 1985). Although the postexposure efficacy of the combined PEP has not been evaluated in occupational settings, it is assumed to be as efficacious under such settings (CDC, 2001a).

In industrialized countries, PEP with antiretroviral agents after occupational exposure to HIV is also recommended (Rey et al., 2000; CDC, 2001a). When zidovudine was used for PEP treatment of HIV in a case-control study of health-care workers, the risk of HIV infection was reduced by approximately 81% (95% CI = 48%–94%; Cardo et al., 1997). Following exposure to a known/suspected HIV-seropositive source, PEP is usually offered after a risk assessment. Acceptance of PEP among health-care workers varies between 40%–79% (Puro et al., 2000; Russi et al., 2000; Grime et al., 2001). Also, PEP was interrupted because of side-effects in 12%–33% of individuals (Parkin, 2000; Puro et al., 2000, Wang et al., 2000).

The potential impact of PEP in reducing the risk of HBV and HIV infections from sharps injuries was estimated for the attributable fraction for the A regions, whose countries were more likely to have implemented PEP recommendations. In developing countries, the proportion of health-care workers offered PEP after a sharps injury was poorly documented, and we assumed that the proportion was negligible at regional level. In the A regions, we assumed that all injured workers were offered PEP, as information on injuries reporting and on the uptake/interruption of PEP was scarce. For HBV and HIV, therefore, average PEP efficacies of 90% and 81%, respectively, were applied to the incidences of HBV and HIV infections due to sharps injuries (obtained from the model described above).

3.4 Estimation of the number of deaths

HBV, HCV and HIV infections attributable to sharps injuries are converted into resulting deaths using theoretical cohorts followed for (i) background mortality and (ii) deaths from acute hepatitis, hepatocellular hepatitis, end-stage liver disease and AIDS (Hauri et al. 2003). Further details on the natural history parameters, including the rate of progression to chronic infection, mortality rates associated with chronic liver infection and risk of fulminant hepatitis are outlined in Hauri et al. (2003).

3.5 Uncertainty analysis

We considered the main sources of uncertainty to be:

- estimates of the annual incidence of sharps injuries;
- estimates of hepatitis B immunization coverage;
- estimates of the prevalence of disease among hospital populations, compared to the general population;
- estimates of the number of health-care, or other, workers at risk of a contaminated sharps injury.

We obtained lower and upper uncertainty intervals both for the incidence of infections due to sharps injuries and for the attributable fraction, by introducing into the model the lower and upper bounds values for the annual incidence of sharps injuries, the HBV immunization rates, and an estimate of the upper boundary for prevalence in hospital patients. This does not constitute a proper uncertainty analysis, but in the absence of more accurate information on the uncertainty of individual input parameters, this approach does provide a description of the lower and upper values the results may take.

The average number of sharps injuries was estimated from regional estimates. Upper and lower bounds were estimated to be ±65% (the mean average deviation around the actual figure). For the HBV immunization rate, the lower and upper bounds of A regions were estimated by proportionally applying the confidence interval of the main study performed in Amr A (Mahoney et al., 1997). For the other regions, the lower bound was arbitrarily fixed at 5% and the upper bound was taken as 30% above the reported figure. Median values for disease prevalences in hospital patients were used to estimate the upper uncertainty boundary (i.e. 3.4 for HCV, 1.9 for HBV and 5.9 for HIV; Table 10).

We did not attempt to estimate lower and upper bounds for the number of health-care and other workers at risk, as the main uncertainties were likely to be included in the parameters mentioned above. Rather, we acknowledge that we have only attempted to quantify occupational infections for health-care workers.

At national level, estimates of the sharps-related disease burden could be improved by increasing the accuracy of input parameters, such as by measuring prevalences in patients, rather than using general population measures.

4. Results

We estimated the number of HBV, HCV and HIV sharps-associated infections in health-care workers worldwide (Table 11). The data were grouped into 14 regions of countries with similar vital statistics and socioeconomic/cultural conditions. For the calculations, we divided the populations into four age groups (that included the adult population in the work force), and sorted the data by gender. For simplicity, however, the figures in Table 11 are reported as single values, rather than as the disaggregated data.

Table 11 Sharps-associated infections in health-care workers[a]

Region	Number of infections among health-care workers attributable to sharps injuries[b]		
	HCV infections	**HBV infections**	**HIV infections**
Afr D	580 (200–3 100)	3 600 (1 300–10 900)	100 (20–510)
Afr E	1 000 (350–5 400)	6 200 (2 200–18 800)	620 (110–3 000)
Amr A	390 (240–1 800)	40 (20–120)	5 (1–20)
Amr B	1 000 (360–5 500)	6 000 (1 800–25 100)	70 (13–360)
Amr D	180 (60–980)	760 (230–3 200)	14 (3–70)
Emr B	310 (110–1 700)	2 300 (680–9 600)	1 (0–3)
Emr D	3 200 (1 200–14 900)	6 800 (2 200–25 000)	7 (1–30)
Eur A	290 (100–1 600)	210 (60–730)	6 (1–30)
Eur B	690 (240–3 800)	6 400 (2 100–23 000)	1 (0–7)
Eur C	1 700 (590–9 100)	8 200 (2 600–29 800)	40 (7–200)
Sear B	500 (180–2 700)	1 500 (480–6 100)	20 (3–90)
Sear D	1 000 (360–5 500)	7 300 (2 600–22 000)	70 (13–350)
Wpr A	830 (290–4 500)	110 (30–400)	0 (0–2)
Wpr B	4 700 (1 700–25 400)	16 000 (5 100–63 500)	30 (6–160)
Totals (rounded)	16 400 (5 900–86 000)	65 600 (2 400–240 000)	1 000 (200–5 000)

[a] Average values for ages 20–65 years. Lower and upper estimates are given in parentheses.
[b] PEP applied to A regions for HBV and HIV.

Globally, health-care workers suffer about 16 000 (uncertainty range: 5 900–86 000) HCV infections, and 66 000 (2 400–240 000) HBV infections owing to their occupation. As a group, they may also suffer a further 200–5 000 HIV infections from sharps injuries worldwide, with the most likely estimate being 1 000 HIV infections worldwide. An idea of the potential benefits of applying PEP to this group can be seen by comparing the numbers in Table 11 with those calculated assuming PEP was not used (Table 12).

Table 12 Sharps-associated HBV and HIV infections in health-care workers without PEP[a]

	HBV infections (*N*)	**HIV infections (*N*)**
Amr A	400 (70–1 100)	26 (8–105)
Eur A	2 100 (210–6 400)	30 (5–150)
Wpr A	1 100 (100–3 500)	2 (0–10)

[a] The data are average values for health-care workers aged 20–65 in A regions for the year 2000. Lower and upper estimates are shown in parentheses.

The proportion of HBV, HCV and HIV infections among health-care workers that could be attributed occupational sharps injuries was high in most regions (Table 13). For example, the attributable fraction of HBV and HCV in developing regions generally varied between 40%–65%. In developed regions, the corresponding fraction for HCV ranged between 8%–27%, while the HBV fraction remained under 10%, largely because of immunization and PEP. The attributable fractions for HIV ranged between 0.5%–10%, depending on the region. When the proportions of HBV, HCV and HIV infections were converted into fractions attributable to the risk factor in the general population, the resulting values were small, because this health-care workers constitute only 0.1%–2.5% of the total population (estimates not presented here).

Between 2000-2030, we estimate that 16 000 HCV infections attributable to sharps injuries will result in 142 (51-749) early deaths. Similarly, the 66 000 HBV infections will lead to 261 (86-923) early deaths, and about 736 (129-3578) health-care workers will die prematurely from 1000 HIV infections.

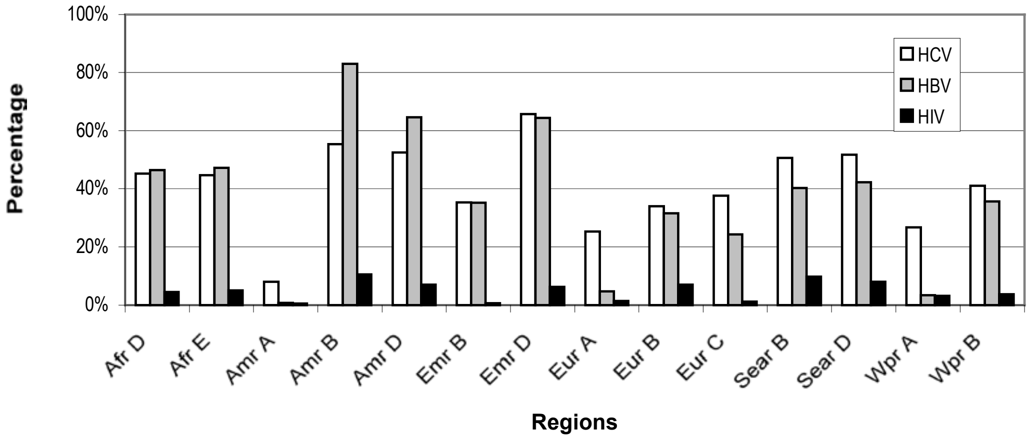
Table 13 Fraction of HCV, HBV and HIV infections in health-care workers attributable to contaminated sharps[a]

Region	Attributable fraction (%)		
	HCV	HBV	HIV
Afr D	45 (22–82)	46 (23–73)	4.5 (0.8–19)
Afr E	45 (22–82)	47 (24–73)	5.0 (0.9–20)
Amr A	8 (5–29)	1 (1–3)	0.5 (0.2–2)
Amr B	55 (30–87)	83 (63–94)	11 (2.0–37)
Amr D	52 (28–86)	65 (39–85)	7 (1.3–27)
Emr B	35 (16–75)	35 (16–63)	0.6 (0.1–3)
Emr D	66 (40–91)	64 (39–85)	6.2 (1.1–24)
Eur A	25 (11–65)	8 (3–22)	1.4 (0.3–7)
Eur B	34 (15–74)	32 (14–59)	7.0 (1.3–27)
Eur C	38 (17–77)	24 (10–50)	1.2 (0.2–6)
Sear B	51 (26–85)	40 (19–68)	9.8 (1.9–35)
Sear D	52 (27–86)	42 (20–70)	7.9 (1.5–29)
Wpr A	27 (11–67)	5 (2–14)	3.1 (0.6–14)
Wpr B	41 (20–80)	36 (16–63)	3.7 (0.7–16)
Mean values:	39 (19–78)	37 (18–65)	4.4 (0.8–18.5)

[a] Average value for health-care workers aged 20–65 years are shown. Lower and upper estimates are given in parentheses.

The results in Table 13 are shown graphically in Figure 1.

Figure 1 Fraction of HCV, HBV and HIV infections in health-care workers attributable to contaminated sharps[a]



[a] Data taken from Table 13.

Globally, occupational infections with HBV and HCV accounted for about 37% and 39%, respectively, of all HBV and HCV infections in health-care workers. An exception was Amr A, which had much lower injury rates from sharps. For example, the attributable fraction of HIV due to sharps injuries ranged between 1%–18%, with a most likely expected value of about 4%.

5. Discussion

5.1 Sharps injuries and HCV

Sharps injuries are a major source of HCV infection among health-care workers, causing approximately 39% of the HCV infections globally that occur in this group every year. This amounts to 16 000 infections caused by sharps injuries, which result in 142 deaths. This global average can be misleading, since there was significant variation in attribution fractions. In Emr D, for example, where HCV is endemic (WHO, 2000b) and sharps waste-collection practices unsafe (WHO, 2001b), sharps injuries were estimated to cause two-thirds of new infections.

Occupational infections with HCV occur during adulthood, an age at which the risk of severe long-term liver damage, including cirrhosis and hepatocarcinoma, is highest (G. Dore, unpublished data, 2001). In recent decades, too, HCV prevalence has reached alarming levels in a number of countries of the Emr and Afr regions (Khan et al., 2000; WHO, 2000b; Frank et al., 2000). Thus, in the future, the long-term consequences of HCV infection might emerge as a major cause of disability and death among senior health-care workers in these regions.

Secondary prevention of HCV infection among health-care workers who experienced a sharps injury from an infected source patient is not currently recommended, but patients should be followed and monitored, so that chronic disease can be identified early and treatment options evaluated. This management approach would be feasible in regions, such as Amr A, where occupational sharps injuries only account for 6% of new cases of HCV infection among health-care workers, or where the incidence of HCV infection is low (Armstrong et al., 2000) and where low-cost primary prevention efforts have already brought this public health issue under control.

5.2 Sharps injuries and HBV

To a large extent, HBV infections among health-care workers are also driven by occupational exposures to contaminated sharps, with an attributable fraction (37%) comparable to that calculated for HCV. However, the global incidence of HBV infection is higher than that of HCV infection, with contaminated sharps causing 66 000 cases of HBV infections and 261 deaths annually among health-care workers, versus 16 000 cases of HCV infection.

For adults, the long-term consequences of HBV infection are less severe than for HCV, and health-care workers infected with HBV may have a more favourable prognosis than those infected with HCV. HBV can also be prevented at low cost by immunization (Mahoney et al., 1997) and efforts should be made to vaccinate health-care workers as early as possible in their career. In addition, if a system to manage exposure is feasible, immunization against hepatitis B can also be used as a highly efficacious PEP measure. Our model estimated there would be 400 (70–1 100) HBV infections for the Amr A region in the year 2000 without PEP (Table 12), but only 40 infections with PEP. Similarly, PEP could ultimately reduce the number of infections in other A regions, from 2100 to 210 in Eur A, and from 1100 to 110 in Wpr A, provided that PEP is applied after every contaminated injury.

5.3 Sharps injuries and HIV

Occupational acquisition of HIV represents the worst possible consequence of sharps injuries and is associated with a high fatality rate. According to our model, most of the expected 1 000 cases of sharps injuries that lead to HIV infections annually occur in Afr E, and 736 of these cases will result in death over the next 30 years. These occupational HIV infections are likely to be overlooked among health-care workers who, like other adults in the general population, may also report sexual exposures. Our model estimated that, worldwide, about 4% of HIV infections among health-care workers may be attributable to occupational sharps injuries. In industrialized countries, PEP has considerably reduced the risk of HIV infection among health-care workers who were injured with contaminated sharps. As a result, we estimated that PEP reduced the total number of HIV infections in the A regions from about 58 to 10. However, it is costly to manage occupational exposures to HIV with PEP, and it requires a responsive health system. The required resources are most likely to be present only in countries that have an efficient primary prevention system.

Between 1985–1999, 56 documented and 136 possible cases of occupational HIV transmission were reported in US health-care workers (CDC, 1999a), implying a mean of 13 cases per year. During the last four years, about one documented and two possible occupational HIV infections in health-care workers were reported yearly in the USA (CDC, 1997b; 1998; 1999a,b; 2001b). By modelling, we estimated there were about 5 (1–20) cases of sharps-associated HIV infections per year in Amr A. Accounting for possible additional cases in other Amr A countries, as well as underreporting, the model estimates fit well with the surveillance data. In Europe, 96 confirmed and possible occupationally-acquired cases were recorded until 1997 (Eurosurveillance, 1999). For comparison, the model estimate for the year 2000 was about 6 (1–28) HIV infections. This situation is similar to that in the USA. Considering the sharply rising proportion of people (and thus patients) living with HIV/AIDS, and the progressive introduction of PEP, our model estimates are comparable with the surveillance data. This suggests that the results obtained with our model are consistent with those developed through other methods.

5.4 Limitations to the study

For a number of regions, the annual number of sharps injuries was not well documented. Reliable information on the frequency of sharps injuries was difficult to find and was mostly limited to hospital settings and selected categories of workers (where data were reported as mean values for all health-care workers). Estimates for regions with incomplete data were extrapolated from hospital data to cover the region as a whole. Similarly, data for health-care workers were extrapolated to cover all workers, regardless of work setting.

Also, the transmission potentials used to estimate sharps-associated infections were developed with data for developed countries, and it was unclear if such potentials were applicable to developing countries, where different medical practices could influence the transmission potentials. This limitation likely leads to an underestimate of the number of sharps-associated infections.

Our study population was limited to physicians, dentists, nurses, midwives, laboratory technicians, nursing aids, medical assistants, traditional health professionals and acupuncturists. We could not study other workers at high risk of sharps injuries, such as cleaners, laundry workers and waste handlers, because there were no population data, and only limited information on the frequencies of injuries in these groups. Nevertheless, these people are at high risk of sharps injuries and work in settings where contaminated sharps are not handled safely (Hersey & Martin, 1994; Luthi et al., 1998; Pournaras et al., 1999). Our inability to account for them likely means we have underestimated the burden of disease from such injuries.

We also limited our study to sharps injuries, since they account for the largest proportion of occupational exposures to bloodborne pathogens and are associated with the highest risk of infection. However, not including mucocutaneous and skin exposures in our study may have led to an underestimate of the attributable fractions. In the US, for example, up to 15% of documented infections resulted from mucocutaneous exposure (J. Jagger, unpublished data, 2002).

Finally, estimates of source prevalence for HBV and HCV were based on their prevalences in the general population. But health-care workers were exposed to patient populations that may have significantly higher prevalences. Again, this could lead to an underestimate of occupational infections. For HIV, a difference in prevalence between patients and the general population was taken into account, but the model may still have underestimated the number of resulting infections, as this difference in prevalence may be greater than that assumed in the model.

The model and estimates of occupational infections in health-care workers are based on several important assumptions. Therefore, the estimates should be considered the best current estimates, in acknowledgement that they could change as additional evidence and information become available.

5.5 Prevention

In industrialized countries, the first reported case of HIV infection caused by a needle-stick injury to a health-care worker caused tremendous concern and led to the implementation of efficient strategies to protect health-care workers. In the North American region (Amr A) and in Europe, for example, occupational infections from sharps injuries to health-care workers are monitored. The USA hepatitis surveillance programme reported that 800 health-care workers became infected with hepatitis B in 1995, but a comparison with previous years indicated that such infections were in a sharp decline (CDC, 2001a). Our model estimated there would be only 400 (70–1100) HBV infections for the entire Amr A region in the year 2000 (assuming no PEP; Table 12).

In developing and transitional countries, by contrast, bloodborne pathogens are commonly transmitted to health-care workers. Several factors contribute to this large-scale transmission, including: a higher prevalence of infection with bloodborne pathogens; unnecessary injections; limited vaccination of public and health-care workers against HBV; a lack of engineering controls and personal protective equipment; and unsafe work practices, including improper management of sharps waste. To a large extent these infections are preventable, as demonstrated by the effectiveness of vaccination and PEP interventions in A regions. In many cases, for example, the injuries arise because systems for managing percutaneous exposures are nonexistent in the country. The infections have a substantial impact on health-care workers, causing illness, disability and death which, in turn, may impact the quality of health-care provided to a population. The delivery of health-care services could be further compromised, if health-care workers become afraid of acquiring these infections while taking care of patients. To date, however, few prevention efforts have been initiated to protect health-care workers in developing countries.

While secondary prevention of HCV and HIV infection associated with sharps injuries is expensive and requires a strong health system, simple measures have been effective in the primary prevention of sharps injuries. Some examples are:

- Avoid unnecessary injections. Reducing the number of injections also reduces the opportunities for needle-stick injuries, as fewer sharps are handled.
- Safely manage sharps waste. This includes collecting contaminated sharps waste immediately after use (without recapping the needle), and using puncture-proof sharps containers that will not leak liquids.
- Immunize at-risk health-care workers against Hepatitis B. Immunization of health-care workers at risk of sharps injuries reduces the proportion of workers susceptible to this infection, and thus the number of infections.
- Use engineering controls, such as autodisposable syringes, needle-free devices, and retractable or sheathed needles.
- Provide personal protective equipment, such as gloves, gowns, masks etc.
- Train and inform workers on the risks of transmission of bloodborne pathogens and on safe practices to combat transmission.

Increasingly, the public-health importance of caring for and supporting HIV-infected patients is being recognized. In this context, the successful implementation of the above prevention measures will be all the more important. Yet such measures can only be successfully implemented if the health-care workers can engage in a positive relationship with their patients, without fearing for their health or for the health of their families. Health-care workers are the pillars of the health-care system, and their good health is essential for the system to function well. This is particularly true for countries in which the number of health-care workers per general population is already small, as is the case in many developing countries. Unfortunately, the health-care workers in these countries also have the highest disease burden from exposure to contaminated sharps.

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Annex 1 Country groupings for global assessment (according to WHO Region and mortality strata)[a]

Region		WHO Member States
Afr	**D**	Algeria, Angola, Benin, Burkina Faso, Cameroon, Cape Verde, Chad, Comoros, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Madagascar, Mali, Mauritania, Mauritius, Niger, Nigeria, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Togo.
Afr	**E**	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.
Amr	**A**	Canada, Cuba, United States of America.
Amr	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.
Amr	**D**	Bolivia, Ecuador, Guatemala, Haiti, Nicaragua, Peru.
Emr	**B**	Bahrain, Cyprus, Iran (Islamic Republic of), Jordan, Kuwait, Lebanon, Libyan Arab Jamahiriya, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, Tunisia, United Arab Emirates.
Emr	**D**	Afghanistan, Djibouti, Egypt, Iraq, Morocco, Pakistan, Somalia, Sudan, Yemen.
Eur	**A**	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.
Eur	**B**	Albania, Armenia, Azerbaijan, Bosnia and Herzegovina, Bulgaria, Georgia, Kyrgyzstan, Poland, Romania, Slovakia, Tajikistan, The Former Yugoslav Republic of Macedonia, Turkey, Turkmenistan, Uzbekistan, Yugoslavia.
Eur	**C**	Belarus, Estonia, Hungary, Kazakhstan, Latvia, Lithuania, Republic of Moldova, Russian Federation, Ukraine.
Sear	**B**	Indonesia, Sri Lanka, Thailand.
Sear	**D**	Bangladesh, Bhutan, Democratic People's Republic of Korea, India, Maldives, Myanmar, Nepal.
Wpr	**A**	Australia, Brunei Darussalam, Japan, New Zealand, Singapore.
Wpr	**B**	Cambodia, China, Cook Islands, Fiji, Kiribati, 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.

[a] Source: *World Health Report*. Geneva, World Health Organization, 2001.