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Nosocomial HIV Infection: Epidemiology and Prevention – A Global Perspective

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Abstract

Because, globally, HIV is transmitted mainly by sexual practices and intravenous drug use and because of a long asymptomatic period, healthcare-associated HIV transmission receives little attention even though an estimated 5.4% of global HIV infections result from contaminated injections alone. It is an important personal issue for healthcare workers, especially those who work with unsafe equipment or have insufficient training. They may acquire HIV occupationally or find themselves before courts, facing severe penalties for causing HIV infections. Prevention of blood-borne nosocomial infections such as HIV differs from traditional infection control measures such as hand washing and isolation and requires a multidisciplinary approach.

Since there has not been a review of healthcare-associated HIV contrasting circumstances in poor and rich regions of the world, the aim of this article is to review and compare the epidemiology of HIV in healthcare facilities in such settings, followed by a consideration of general approaches to prevention, specific countermeasures, and a synthesis of approaches used in infection control, injury prevention, and occupational safety.

These actions concentrated on identifying research on specific modes of healthcare-associated HIV transmission and on methods of prevention. Searches included studies in English and Russian cited in PubMed and citations in Google Scholar in any language. MeSH keywords such as nosocomial, hospital-acquired, iatrogenic, healthcare associated, occupationally acquired infection and HIV were used together with mode of transmission, such as "HIV and hemodialysis". References of relevant articles were also reviewed.

The evidence indicates that while occasional incidents of healthcare-related HIV infection in high-income countries continue to be reported, the situation in many low-income countries is alarming, with transmission ranging from frequent to endemic. Viral transmission in health facilities occurs by unexpected and unusual as well as more frequent modes. HIV can be transmitted to patients and to donors of blood products by specific vehicles and vectors during blood transfusion, plasma donation, and artificial insemination, by improperly sterilized sharps, by medical equipment during activities such as dialysis and organ transplantation, and by healthcare workers infected by occupational exposure to hazards such as blood-contaminated sharps. Personal, equipment, and environmental factors predispose to acquisition of nosocomial HIV and all are pertinent for prevention. For infection and injury control, poverty is often an underlying determinant. While sophisticated new tests offer improved HIV detection, increasingly higher marginal costs limit their feasibility in many settings. Modest investment in safer equipment and appropriate integrated training in infection control, injury prevention, and occupational safety should provide greater benefit. **(AIDS Rev. 2008;10:47-61)**

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Key words

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Introduction

Worldwide, about 10% of hospitalized patients develop infections every day, while in low-income countries the rates are as high as 25%[1,2]. Nosocomial infections are defined as those that originate or occur in a hospital or hospital-like setting more than 48-72 hours after admission, and that were not present or incubating when the patient was admitted[1]. The term "nosocomial" derives from the Greek *nosos* (disease) and *komein* (to care for), and later from the Latin for hospital, *nosocomium*[3]. Although difficult to eliminate completely, nosocomial infections can be reduced to a minimal level if healthcare workers (HCWs) are aware of the risk factors, epidemiology, and prevention, and if sufficient resources are allocated for detection and prevention.

Although healthcare-associated HIV infections are frequently associated with hospital admission, such infections can arise after admission or a visit to any healthcare facility. Hence, in this paper the term "healthcare-associated HIV infection" is preferred. HIV is less commonly reported as a healthcare-associated virus than hepatitis B (HBV) or C (HCV) viruses. There are two main reasons for this. First, the lower rate of HIV transmission compared with HBV reflects much lower blood titres of virus. The serum or plasma concentration of HIV is 10^0-10^3 particles in 1 ml versus 10^2-10^8 of HBV[4]. Second, the global burden of HIV is about 40 million people, much less than for HCV (150 million) or HBV (350 million)[4,5].

Certain conditions predispose a patient to acquire HIV in a hospital or other health care setting. In addition to a susceptible host, there should be a human reservoir such as an HIV patient hospitalized or being treated for a particular disease, a blood/sperm/organ donor, or an HIV infected HCW. HIV can be transmitted to patients and to donors of blood products by: improperly sterilised sharps, such as needles, or instruments used in invasive procedures; medical equipment during activities such as dialysis; blood transfusion, plasma donation, organ transplantation and artificial insemination; spread from infected HCWs. Healthcare workers can be infected by occupational exposure to hazards such as blood-contaminated sharps[6]. Transmission of HIV in healthcare settings continues to be reported not only in low-income countries such as Romania, Colombia, and former members of the Soviet Union such as Kazakhstan, but also in high-income developing countries such as Libya and industrialized countries such as the USA, Canada, Australia, France, Denmark, the Netherlands, and Germany. However, because globally HIV is transmitted mainly by sexual practices and intravenous drug use[7], healthcare-associated transmission receives little attention.

Asepsis has been described as the "cornerstone" for prevention of healthcare-associated infections[8]. For HIV the situation differs somewhat since many such infections result from injury by sharps and because both patients and staff are vulnerable. Hence, in addition to the usual measures of asepsis such as hand hygiene, cleaning, disinfection, sterilization, aseptic techniques, epidemiologic methods, and isolation, modern concepts of injury prevention and occupational safety are essential for the control of HIV and other blood-borne nosocomial pathogens[8-10].

There is an overlap in certain priorities for control of healthcare-associated HIV infection between high- and low-income countries. However, since about 1985, major sources of infection have been dealt with in industrialized high-income countries, but remain serious threats in low-income and some mid-to-high-income developing countries. Failure to control healthcare-associated HIV does not always result from an insufficient health budget, but rather from an imbalance between the proportions of financial resources and skilled professionals dedicated to treatment of patients and to prevention of complications of healthcare, such as nosocomial HIV among patients, blood product donors, and HCWs. All health professionals need to be aware of the epidemiology and prevention of healthcare-associated HIV infection since ignorance, lack of training, and unsafe equipment may not be adequate defenses before a court of law, as recently experienced by HCWs in Libya and Kazakhstan[11,12]. In some institutions and countries, while suing and prosecuting HCWs is unfortunate for the individuals involved, it may represent part of the solution if targeted to institutional and countrywide deficiencies. More research on this would be helpful.

We undertook this global review because the last review of healthcare-associated HIV infection was in 1994[6] and was quite short without any conclusions drawn, and because there has never been a review contrasting the circumstances in poor and rich regions of the world. We describe the epidemiology of HIV in healthcare facilities, followed by general approaches to prevention and specific countermeasures. Since nosocomial HIV can be an infection, an injury, an occupational, and a patient safety issue, we review and provide a synthesis of preventive approaches used by experts in infection control, injury prevention, and occupational safety. As far as blood-borne infections are concerned, specialists in these three fields have tended to function in isolation, to the detriment of patients and occupational safety.

Search strategy and selection criteria

We concentrated on identifying research both on specific modes of healthcare-associated HIV transmission and on methods of prevention of such infections, seeking published research from both high- and low-income developed and developing countries. Our searches included studies published in English and Russian and cited in PubMed, together with studies cited in Google Scholar in any language. For the PubMed search, MeSH keywords such as nosocomial infection, hospital-acquired infection, healthcare-associated infection, occupationally acquired infection and HIV were used. Google Scholar was searched using combinations of "HIV" together with major terms such as "nosocomial transmission of HIV", then "occupational transmission of HIV", and then HIV together with the mode of transmission, such as "HIV and hemodialysis". We also searched the references of relevant articles.

Since the review is global and covers many specific modes of infection, we did not do a comprehensive, systematic review of all available material. Hence, the conceptual framework presented here is not based upon a complete review of all cases of healthcare-associated HIV infections reported worldwide, but was developed to emphasize the variety of modes of transmission in healthcare facilities, together with differences and common features in epidemiology and prevention between high- and low-income countries. While we generally use the terms high and low income, at times it was necessary to use the term developing country since, as seen in the recent outbreak in Libya, resource-rich countries do not always allocate sufficient funds to prevention in general, and to prevention of nosocomial blood-borne infections in particular. As a result, some high-income countries may experience a degree of risk similar to their low-income counterparts.

Epidemiology of healthcare-associated HIV infection

The epidemiology of healthcare-associated HIV should include an assessment of incidence and risk factors. Sufficient well-interpreted data are vital to understanding and managing the global problem. The difficulty with this approach is that healthcare-associated HIV transmission has been poorly documented in developing countries, with very little solid epidemiologic data to show how such transmission occurs. Unfortunately, in low-income countries where the incidence is believed to be highest, reporting tends to be confined to large epidemics that cannot be ignored. Unavailability of quality data adversely impacts not only day-to-day prevention, but reduces the feasibility of studies that rely on existing data sources. Although the situation is improving, there is a lack of both cross-sectional and longitudinal studies. Hence, a limitation of our analysis is that the papers upon which it is based mainly report the so-called tip of the iceberg, while the ongoing healthcare-associated HIV epidemic passes largely unreported.

Modes of healthcare-associated HIV transmission

It is helpful to consider the epidemiology of healthcare-associated HIV infection, including modes of transmission, by the income level of countries, and by pre- and post-1985 time periods, remembering that at least a few high-income developing countries may resemble low-income nations in certain respects (Table 1).

For high-income countries, the risk of the main modes of healthcare-associated transmission has decreased greatly since 1985 with the development and implementation of sensitive and specific HIV-antibody tests. For low-income countries, an improvement has been less evident; furthermore, there are important modes of transmission that were never a major source of infection in high-income countries. We now discuss each mode of transmission in greater detail, with trends and examples from high- and low-income countries.

Transfusion of HIV-infected blood and blood products

While blood transfusions and blood products have been and still are the most efficient means of transmitting HIV infection in hospitals, the relative importance of these modes of transmission has declined in high-income developed countries. The frequency of seroconversion after a transfusion of HIV-infected blood is over 90%[12,13]. About 5% of AIDS cases worldwide are estimated to have occurred through blood and blood products; however the proportion may be as high as 10% in low-income countries. The risk of transmitting infection depends upon the type of blood components

Table 1. Epidemiology of nosocomial HIV transmission in high and low-income countries by time period

Mode/source of HIV transmission	Level of risk of nosocomial HIV infection			
	High-income countries		Low-income countries	
	Pre-1985	Post-1985	Pre-1985	Post-1985
Transfusion of blood and blood products	High	Extremely low	High	Still high
Unsafe injections	Low	Extremely low	High	Still high
Other unsafe equipment				
a. Instruments	Low	Extremely low	High	Still high
b. Plasma donation	Low	Extremely low	High	Still high
c. Dialysis	Low	Extremely low	High	Still high
Transplantation	High	Extremely low	High	No information
Artificial insemination	High	Low/extremely low	High	No information
Transmission to and from healthcare workers (HCW)				
a. HCW to patient	Low	Extremely low	Low	Low
b. Patient to HCW	Low	Low	Moderate	Moderate

given. Since cellular products cannot be pasteurized or treated by other virucidal processes, in the absence of rigorous HIV testing they are a source of transmission[14]. In illustration, about 5000 people contracted HIV in France during a tragedy that could have been prevented if a new screening test for blood had been implemented within the country at the time when the test was first released[15]. Similar incidents occurred in many high- and low-income countries during the 1980s and 1990s, including Canada, Italy, Japan, Portugal, Iran, and China; in some countries in the Eastern Mediterranean region, almost 50% of HIV cases were associated with lack of timely screening[16-20].

Although screening of blood donors for HIV has greatly reduced the chance of HIV transmission through transfusions, AIDS due to blood transfusion continues. Errors can occur in HIV testing and some donors may be in the "window" phase, with an acute infection that is not yet serologically recognizable[21-23]. Such was the case of an Australian primary school girl, infected via blood transfusion during surgery[24]. Her father, a surgeon, had volunteered his own blood, but the authorities gave him the impression that it was an "unnecessary hassle", as the risk was estimated at 1:1,200,000. Cases arising from this source can be much more frequent in areas of high incidence. In illustration, in Thailand such risk has been estimated at between 1:3400 to 1:25,000 and in South Africa as between 1:25,641 and 1:90,909[19].

Unusual practices have been reported to have resulted in widespread infection in some low-income countries. By the end of 1990, it had been alleged that 39% of AIDS cases in Romanian children below 13 years old had resulted from unscreened blood transfused to sick and malnourished infants; over 400 children are estimated to have been infected. This was reported to have occurred because some physicians believed that transfusions of whole blood would provide important nutrients and help to stimulate the infants' immune system. Because of the small amount of blood needed for each transfusion, one unit of blood taken from a single HIV-infected adult could infect several infants[20]. Similar incidents involving the inappropriate administration of unscreened blood to multiple recipients by inadequately trained HCWs have been reported from other countries such as Kazakhstan, where 21 HCWs involved in an outbreak of 103 infected children are before the courts[12]. The evidence to support such modes of transmission has been insufficient to convince all who have reviewed it.

Invasive procedures with non-sterile needles and syringes

Recent modeling suggests that, worldwide, unsafe injections cause 80,000-160,000 HIV infections each year[25-26], and an estimated 5.4% of HIV cases worldwide[5]. The efficiency of transmission of HIV from this source has been estimated from seroconversion of HCWs after percutaneous exposures and from documented iatrogenic outbreaks. Case-control data[27] showed an average rate of seroconversion after "deep" injuries, arguably comparable to unsafe injections, of 2.3%[28]. A transmission efficiency of 2-7% was derived using data from an iatrogenic HIV outbreak that infected 628 infants in Romania[20]. Although not all cases have been thoroughly investigated, the outbreak was believed to possibly have resulted from a severe shortage of medical supplies and an inappropriate use of injections, together with inadequate sterilization and disinfection practices due to power shortages.

The above estimates of transmissibility appear low and do not explain the frequency of transmission of HIV among Russian and Libyan children in iatrogenic outbreaks in 1988 and 1998, respectively[29-34]. During 1988-1989 in hospitals in southern Russia, 274 children were infected with HIV during treatment of serious illnesses requiring intensive therapy including catheterization of large central veins[29]. An outbreak of nosocomial HIV at Al-Fateh Children's Hospital in Benghazi, Libya affected 426 children[31-33]. Although documentation and a study of the epidemic were attempted, the exact route of transmission was never definitively established as foreign investigators were unable to conduct an epidemiologic field study. The Libyan representative of the World Health Organization (WHO) asked two university hospitals in Switzerland to perform in-depth investigations on 111 coded plasma samples and on a group of infected children. The nosocomial origin of the HIV infection is supported by the monotypic characteristic of the HIV sequences. Phylogenetic analyses showed that a monophyletic recombinant HIV-1 from CRF02-AG was the agent in all HIV-positive patients[34]. Other arguments support the nosocomial origin of this outbreak: all children attended the same hospital and underwent invasive procedures; the serologic data of a subgroup of parents excluded vertical transmission; and evidence suggested that some children were coinfected with HIV and HCV during the same invasive procedures.

Nosocomial child-to-child transmission of HIV, documented by nucleotide sequencing, was reported in Denmark in 1998; the transmission probably resulted from an unnoticed needlestick injury during an unobserved visit to the room of the child who was the source[35].

In resource-limited countries, health-care related transmission of HIV is still a major public health concern because of high prevalence of the virus, overuse of injections, frequent sharing of syringes, and poor enforcement of safety guidelines. In illustration, a report from Nepal showed that in 28 primary healthcare centers, only 35% of HCWs regularly followed infection-control guidelines, and 72% never used high-level disinfection to eliminate contamination by blood-borne pathogens[36] of instruments and other items. Transmission efficiency in medical settings with grossly insufficient or no cleaning of equipment ranges from 0.5-3% for procedures such as intramuscular injections, to 10-20% or more for higher-risk procedures[37]. In such settings, children specifically are at high risk of exposure because of their frequent use of medical facilities and because of the paucity of symptoms in other patients with acute HIV infection who might be a source of nosocomial infection for children[26,28,39].

Some experts claim that the risk of HIV infection associated with injections by HCWs may have been underestimated in Africa and also Asia[25,26,28,38,39]. It has been suggested that the fact that unsafe injections are frequent in the developing world[25,26,40] affected recent univariate attributable-risk calculations, and that 20-40% of HIV infections are attributable to contaminated injections[41]. Other studies indicate no compelling evidence that unsafe injections are a predominant mode of HIV-1 transmission in sub-Saharan Africa, and that epidemiologic evidence defines sexual transmission as by far the major mode of HIV-1 spread in the region[42-44].

Invasive medical procedures

Transmission of HIV through invasive medical procedures has been long recognized. In industrialized countries, such procedures were routes of HIV spread some decades ago, with occasional cases still reported. In 1989 in Australia, HIV was transmitted among five patients undergoing procedures such as excision of cysts, moles, and other skin lesions at the private surgical consulting rooms of a general surgeon who tested HIV-antibody negative[45]. The mechanism of transmission was unclear. In 1990 in the Netherlands, a patient contracted HIV when unintentionally given an intravenous injection with a syringe containing a minute amount of blood from a man infected with HIV[46]. Six years later in Denmark, a case of horizontal nosocomial HIV transmission was discovered using epidemiologic and phylogenetic analyses. Transmission was strongly linked to the use of multi-dose vials[47]. In France, another patient acquired HIV while having scintigraphy with radiotracer-labeled leukocytes[48]. The most plausible explanation was that he received the leukocyte preparation intended for another patient, who was HIV-infected .

Hemodialysis

Chronic hemodialysis has been associated with a risk of patient-to-patient and patient-to staff transmission of blood-borne pathogens, including HIV, if infection control guidelines are neglected. Epidemic transmission of HIV in renal dialysis centers has been reported in developing countries. In Argentina, unchanged filters and rushed sanitary procedures resulted in nosocomial HIV transmission to 33 patients in 1990, and another 20 in 1993[49,50]. In Colombia during 1992-1993[51], improperly reprocessed patient-care equipment, most probably access needles sterilized in low-level disinfectants, was the likely mechanism of HIV transmission in 13 patients at one dialysis center. Practices that resulted in the sharing of syringes among patients caused two outbreaks in Egypt, one in 1990 in which a total of 82 HIV infections occurred at three dialysis centers, and another in 1993 with 39 patients at two centers infected[52,53].

HIV transmission by organ transplantation

Cases of HIV infection in transplant recipients have been reported both pre- and perioperatively[54-61]. The risk of HIV transmission from an organ donor who tests negative is very low. However, many organ donors are from high-risk population subgroups who, prior to dying from trauma, receive emergency treatment including massive blood transfusions. This dilutes the donor's own blood and can lead to false-negative results in HIV antibody assays[62]. In the case of liver transplantation, large volumes of blood products are required by recipients as compared with transplantation of most other organs[55] and transfusion was the mode of HIV transmission in most incidents. Moreover, since HIV infects Kupffer cells, the viral load in a liver graft may be greater than in other grafted organs, with a higher risk of infection[62].

An incident of multiple nosocomial HIV infections from a single donor of organs and tissues was reported in the USA. The infections resulted because the organs and tissues were procured between the times when the donor became infected and when antibodies appeared. This illustrates that, although rare, HIV transmission by seronegative organ and tissue donors can occur[60]. The donor was a 22-year-old man who died 32 hours after a gunshot wound; he had no known risk factors for HIV infection and was seronegative. The HIV was detected in cultured lymphocytes from the donor. Of the 48 identified recipients, 41 were tested for HIV antibody. All four recipients of organs and all three recipients of unprocessed freshly frozen bone became infected with HIV. Negative tests for HIV antibody were found among 34 other recipients, 25 of whom had received ethanol-treated bone, three lyophilized soft tissue, three gamma-radiation treated dura mater, two corneas, and one marrow-evacuated, freshly frozen bone.

HIV transmission by semen

The early, highly viremic, seronegative stage of HIV infection may carry a high risk of infection by semen because seminal viral load parallels viremia[63]. Transmission of HIV through donor artificial insemination has been documented, with most incidents reported before 1985 when screening of donors for HIV antibodies was introduced. Such HIV infection was first reported in Australia in 1985 in four women who had been inseminated between 1982 and 1984 with semen from an infected donor[64]. In the USA there were several incidents of HIV infection by semen from donors who had not been routinely screened. One woman was inseminated with semen from five HIV-infected donors between 1984 and 1985, another with processed semen from her HIV-infected hemophiliac husband, and seven others were inseminated before 1985 in five infertility clinics[65,66]. Currently, as long as quarantine storage of anonymous sperm donation is not mandatory in all countries, artificial insemination still has to be seen as a possible source of HIV infection. In illustration, as late as 1998 a female HCW in Germany was infected with HIV by artificial insemination with fresh sperm[67].

Plasma donation

Donating plasma for money is an important source of income in some low-income countries[68-71]. The frequency of donation varies from every other day to twice a month. After the plasma is separated from whole blood, blood cells are transfused back into the donor. A healthcare-associated HIV infection outbreak was first reported among male plasma donors in Spain in 1989[70]. Investigations by public health authorities revealed incorrect handling of the equipment used in plasma extraction. The same possibly contaminated material, intravenous lines and blood bottles, had been used several times. The WHO estimated in 2006 that commercial plasma and blood donation was responsible for 69,000 cases of HIV/AIDS in China, 11% of HIV/AIDS cases in China overall; this is clearly an enormous healthcare-related outbreak[72]. Of note, during HIV screening in Wy village in central China, it was found that 41% of HIV-positive individuals had been infected via paid blood and blood products donation.

Furthermore, although in about 50% of other cases the route of infection could not be identified, it is probable, given their history of blood donation, that most were infected via this route[73]. An incident was reported in 1995 of HIV in a mother and two daughters in rural China; the virus probably came from other plasma donors[70].

HIV transmission to patients from infected healthcare workers

Transmission of HIV from infected HCWs is possible by contact when a worker sustains a needlestick or other injury from a sharp device, and then an instrument or gloves contaminated with the HCW's blood enters an open wound. The risk is greatest during exposure-prone invasive procedures when the worker's hands or fingertips may not be completely visible at all times[1]. Patients would not normally be aware of such an exposure unless notified by the HCW, and the HCW may also be unaware of it.

To better quantify the risk for patients of becoming infected with HIV during invasive procedures, several investigations of patients exposed to an infected HCW have been undertaken. In 1995, the U.S. CDC reported that among 22,171 patients tested who had been treated by 51 infected HCWs, there were 113 HIV-positive patients. However, epidemiologic and laboratory follow-up did not show that a HCW was the source of HIV infection for any of these patients[74]. It is estimated that the risk of HIV transmission from surgeon to patient is low. Mathematical models suggest 2-24 infected patients per million procedures performed by an HIV-seropositive surgeon; however, the degree of risk could differ by surgeon and by procedure and the estimated risk might not apply[75].

Six patients became infected with HIV in 1995 in the USA while receiving care from a dentist with HIV[76]. The precise way in which he might have infected his patients was never determined. There had been no other evidence of infection from HCWs until transmission from an orthopedic surgeon with HIV to a patient during a 10-hour procedure was reported in France in 1999[77,78]. The surgeon had been infected with HIV while performing surgery 12 years earlier. Possible transmission was also reported in France in 2000 from an infected surgical ward nurse[79]; the nurse had not assisted in exposure-prone procedures and the transmission route remained unclear. Another incident of doctor-to-patient transmission occurred in Spain during a caesarian section[80]. Despite these four episodes, most evidence suggests that the probability of provider-to-patient transmission is extremely low[4]. This may mainly be because of a low prevalence of seropositivity in most providers; however, since reporting of sharps injury is poor among many providers, the risk may be greater than has been documented[81].

Occupational HIV transmission from infected patients

The risk of occupational HIV acquisition by HCWs is multifactorial. Three important factors include the prevalence of HIV among patients, the efficiency of virus transmission after a single contact with blood, and the nature and frequency of occupational contacts with blood[82]. The average risk of infection due to a single percutaneous injury is estimated at 0.3%, higher than the 0.09% estimated risk after exposure of a mucosal membrane. There are a few well-documented case reports of seroconversion following cutaneous contact with HIV-infected blood; however findings from prospective surveillance of occupational contacts among HCWs support a low risk of transmission from cutaneous exposures[4,82-84]. Four factors were associated with an increased risk of HIV transmission, including deep injury, visible blood on the device that caused the injury, a procedure involving a large-gauge, hollow-bore needle directly placed in a vein or artery, and exposure to a patient with AIDS or a high plasma viral burden[4,27,82,85].

More than 4% of HIV infections worldwide among HCWs may be attributable to occupational sharps injuries[86]. Most of the estimated 1000 occupational HIV infections per year associated with sharps injuries are believed to occur in sub-Saharan Africa[86]. A literature review identified 94 documented and 170 possible cases of occupational HIV infection worldwide through September 1997[87]. Of note, among HCWs in the USA, 57 documented and 137 possible incidents of occupational HIV transmission were reported between 1983 and 2001[82,88], which represents nearly two-thirds of cases of occupational HIV infections reported worldwide. This observation is at odds with the fact that 96% of the world's HIV-infected population is located in the regions outside North America and Western Europe. A possible explanation of this discrepancy is that in the poorer regions of the world where the HIV prevalence is high, there is little follow-up or documentation of occupationally acquired blood exposures. Additionally, in high-income countries, postexposure prophylaxis has considerably reduced the risk of HIV infection for HCWs who experience injuries by sharps used on an infected patient. Unfortunately, the management of occupational exposures with postexposure prophylaxis is relatively costly and requires a responsive health system. Such resources and systems are likely to be present mainly in countries where efficient system-wide, pre-event phase measures of automatic passive protection (see pages 57-58) against exposure to unprotected sharps have already reduced the incidence of sharps injuries. Prevention of infection by occupational blood-borne pathogens, including HIV, was discussed in detail by Jagger, et al. in 2003[82].

Prevention of healthcare-associated HIV transmission

The published recommendations for reducing healthcare-associated HIV transmission risk in developing countries are weak because they are not adequately fleshed out, and due consideration is not given to the challenges of implementation in such environments. Prevention of healthcare-associated HIV can be accomplished by various discipline-oriented structured approaches, or more comprehensively by a multidisciplinary combination of approaches[9,89]. Nonetheless, the challenge is enormous and much more needs to be known about the best approach for resource-poor countries.

In infectious disease circles, the best known approach includes the application of standard precautions to prevent infection. In the injury prevention field, a more structured approach is used, including management of the three main categories of risk factors during the three time phases of potentially hazardous incidents[9,10,89,90]. In occupational safety and in injury prevention, the hierarchy of controls emphasizes different categories of protection, with elimination of exposures ranking highest and use of personal protective equipment lowest[1,9,91].

In order to convince policy makers and health-system administrators to spend money on HIV infection prevention, valid data on attributable mortality and morbidity are helpful. It is noteworthy that most healthcare-associated HIV outbreaks have been reported from countries with a low prevalence of HIV infection. While in countries where HIV seroprevalence is higher, healthcare-associated infections would be expected to be more frequent, they are rarely detected or reported. Hence, one of the steps in prevention for such countries may be improved surveillance and detection of nosocomial HIV, which should improve the awareness of risks among HCWs and their patients. While details of healthcare-associated HIV infections vary from patient to patient, many contributory incidents are almost monotonous in their predictability and preventability. In light of this, their continuing occurrence has to be considered unacceptable.

By helping people in low-income countries to minimize the risks of contracting HIV and other blood-borne pathogens in unsanitary healthcare, it should be feasible to improve understanding, reduce risks, and raise participation to help control the HIV/AIDS epidemic. To reduce HIV transmission via healthcare, four policies have been recommended that can be adopted and implemented by international, foreign, and local public and private organizations, even with limited or no additional funds[92]. These include: educating the public about the risks of contracting HIV through unsanitary healthcare, promoting transparent practices for injections and other procedures that allow patients to see and know that care is safe (such as taking a new auto-disposable syringe out of a sealed package and drawing up injectables from a single-dose vial), promoting safe healthcare practices equally for clients and staff, and establishing a zero-tolerance policy for iatrogenic HIV infections, with publicly reported monitoring and investigations. Given the frequency of unnecessary injections in many developing countries, another low-cost policy would be to strongly discourage use of injectable medications and substitute safer modes, such as oral administration.

Table 2 provides an overview of specific countermeasures for different modes of transmission. This is followed by a more detailed discussion of some of these issues.

While infection rates can be reduced with the help of infection and injury control programs, once implemented such programs require periodic evaluation to ensure maximum effectiveness. Effective continuing educational programs can encourage compliance with basic infection control procedures[1,6,89].

Blood products safety

The technology is available to make blood and blood products safe for use. An effective means of making blood safe against HIV infection is by screening it for HIV antibodies; however, recent infections of donors can be missed. More effective methods such as antigen and polymerase chain reaction (PCR) tests have become available for the prevention of HIV transmission in healthcare settings[13,14]. Hence, with antibody and other tests, it has become feasible to reduce HIV transmission via blood to a very low level in high-income countries[93]. However, in many low-income countries, clinicians should be alert to the possibility of infection with HIV because preventive measures may not be available in all cases. In such countries, lack of fi-

Table 2. Interventions for different modes of healthcare-associated HIV transmission for all countries, with special priorities for low-income countries

Mode of nosocomial HIV transmission	Interventions to eliminate/reduce risk for all countries, with special priorities for low-income countries
Transfusion of blood and blood products	All countries: – Screening blood for HIV antibodies – Use of sensitive HIV tests – Proper selection of blood donors • Appropriate use of blood: • Reducing the number of transfusions • Using blood substitutes/autologous blood Low-income countries: – Centralized blood-banking system – Modernization of blood banks – Training blood bank staff and doctors – Low-cost disposables
Transplantation	All countries: – Adequate methods used to screen donors for HIV – Accurate accounting of distributed allografts – Prompt reporting of HIV infection in recipients
Artificial insemination	All countries: – HIV screening of semen donors – Avoiding use of fresh sperm – Compliance with up-to-date national guidelines for donor insemination
Unsafe equipment a. Instruments	All countries: – Use of adequately disinfected/sterilized instruments
b. Plasma donation	– Use of adequately disinfected/sterilized equipment in donor collection – Plasma products and donors screened for HIV – Permanent surveillance of plasma donors
c. Hemodialysis	– Adherence to standard precautions during all sessions for all patients – Procedures that expose patients to other patients' blood not permitted – HIV serologic testing of all new patients beginning long-term dialysis Low-income countries: – Periodic retesting of patients in countries where HIV transmission has been a problem – Low-cost sterilization equipment and training for staff
Unsafe injections/sharps	All countries: Hierarchy of controls, Haddon matrix and other measures: – Use of alternative routes for medication delivery/immunization, when feasible – Substitute adhesive strip or glue closure of skin in place of suturing; blunt-tip needles for closing other layers – Specimen collection systems – Single-use, safe injection devices – Management of sharps waste – Monitoring of indicators of injection practices – Specifically targeted interventions for informal private health providers – Educational programs on the risks associated with unsafe injections – Essential drugs programs ensuring access to single-use injections in national drug policy Low-income countries: – Sufficient funding for equipment and training – Low-cost disposables, gloves, and where necessary and appropriate, reusables – Low-cost sterilization equipment – Eliminate unnecessary injections of pharmaceuticals by substituting safer modes. – Promote transparent practices for injections and other procedures that allow patients to see and know that care is safe – Promote safe healthcare practices equally for patients and staff – Establish a zero-tolerance policy for iatrogenic HIV infections, with publicly reported monitoring and investigations

(Continue).

Table 2. Interventions for different modes of healthcare-associated HIV transmission for all countries, with special priorities for low-income countries *(Continued)*

Mode of nosocomial HIV transmission	Interventions to eliminate/reduce risk for all countries, with special priorities for low-income countries
Transmission from patient to HCW and from HCW to patient	All countries:
a. HCW to patient	Hierarchy of controls, Haddon matrix and other measures: – Proper implementation of infection control/engineering techniques – Adoption of safer work practices – Exposure-prone procedures not to be performed by HIV-infected HCWs – HCWs responsible for their serologic status
b. Patient to HCW	Hierarchy of controls, Haddon matrix and other measures: – Elimination/reduction of use of needles and other sharps – Eliminate recapping of needles contaminated with blood – Isolation of the hazard, i.e. Implementation/wider use of safe devices – Work-practice controls – Personal protective equipment – Education of HCWs on the risk of occupationally acquired infection – Secure work environment – Adequate staff-to-patient ratio – Access to occupational health services

nancial resources is still a main obstacle to universal blood screening for HIV antibodies, while antigen and PCR tests are expensive and not recommended for screening of blood in such countries[13,14]. For example, in Kenya it was estimated that more than 40% of donated blood was not screened for all relevant transfusion-transmissible infections[94].

In addition to routine screening for HIV antibodies, other measures are necessary for blood safety, including proper selection of donors, rational blood use by reducing transfusions to the absolute minimum and by the use of blood substitutes or autologous blood, and the use of sensitive HIV tests[6,7,19]. For low-income countries, a centralized blood bank system, modernization of blood banks and training of blood bank staff and doctors are additional factors for the success of blood safety[94,95]. Since many remote hospitals do not have funding for blood banks and must rely on either autologous transfusions or donations from family and friends, simple, inexpensive but safe low-technology training, HIV testing, and supplies for collecting and infusing blood are essential. People may be afraid to donate blood due to the fear of HIV infection from blood-collecting equipment, even in wealthy developing countries where resources are sufficient to ensure that donation is completely safe[96]. Publicity about the risk of receiving contaminated blood, and a lack of clarity between receiving and donating blood creates a climate of fear.

For control of HIV infection in plasma-collecting centers, all equipment used in donor collection should be sterilized adequately, plasma products and donors screened for HIV, and a permanent surveillance system of plasma donors created[71].

Organ and semen donation safety

Improvements in methods of screening donors for HIV, advances in techniques of virus inactivation, prompt reporting of HIV infection in recipients, and accurate accounting of distributed allografts would all help to reduce the already low risk of acquiring HIV by organ and tissue transplantation[61]. Continued HIV screening of semen donors, refraining from use of fresh sperm, and compliance with up-to-date national guidelines for donor insemination are recommended to eliminate the possibility of HIV transmission by artificial donor insemination[66,67].

Dialysis safety

Standards and recommendations regarding infection control measures outlined by the WHO and the U.S. CDC, as well as by national authorities, can prevent transmission of HIV and other infectious agents in dialysis centers[50]. Dialysis staff should become conversant with practices related to the prevention of HIV transmission in their units. Centers should adhere to standard precautions during all sessions for all patients, and procedures that expose patients to other patients' blood should not be permitted. Centers not complying with effective measures to prevent the transmission of blood-borne pathogens should be closed and not allowed to reopen until compliance can be ensured by on-site inspection. The HIV serologic testing of all new patients beginning long-term dialysis, together with periodic retesting in countries where HIV transmission has been a problem, may hasten the recognition of HIV transmission. However, negative results of HIV antibody tests should not be used to justify practices that promote the transmission of blood-borne pathogens[57,97].

Sharps safety

Hazard elimination or reduction methods are the elimination or reduction of use of needles with alternative routes for medication delivery and immunization, needle-free tubing systems, and a review of specimen-collection systems to identify opportunities for the elimination of unnecessary punctures[91]. To discourage inappropriate treatment by injection, HIV programs should communicate the risks. Essential drugs programs should ensure access to single-use injections in the national drug policy. Additionally, donors and lenders who supply injectable substances should also fund adequate quantities of single-use injection devices and/or reusables with simple sterilization equipment and training for staff. National health systems should manage sharps waste, and indicators of injection practices should be monitored as technical indicators of the performance of health systems. Finally, the issue of informal, untrained, private health providers may require specifically targeted interventions[26]. Non-disposable equipment other than needles must be safely decontaminated after use[6]. Some prioritization of interventions by feasibility and costs may lead to an emphasis on elimination of the main hazardous practices such as recapping, even while seeking additional resources to provide syringes with automatically retracting needles. Much more needs to be known about what works, since discussions of infection control for health facilities in low-income countries tend to provide few guidelines for the specific issue of HIV prevention[2].

Many cases of blood-borne infection result from injury and some are occupational. Hence, in addition to standard precautions for infection control, it is useful to consider the approaches of modern injury epidemiology and prevention and of occupational safety. Such approaches are unfamiliar to many infection-control practitioners, which is unfortunate since they provide a more comprehensive practical and theoretical basis for the prevention and management of hazardous incidents. Such conceptual frameworks should be applicable not only to the protection of HCWs, but also to improving safety for patients and donors of blood products[89].

Injury prevention and safety

As for prevention in the framework of injury epidemiology, such an approach is frequently developed in the context of Haddon's injury matrix, which cross tabulates three major categories of risk factors (host, equipment, environment) and the three time phases of an injury incident (pre-event, event, post-event)[9,10,90]. This is a more sophisticated elaboration of the epidemiologic triad of host, environment, and agent factors. For injury in the healthcare context of prevention of blood-borne infections, there is only one main agent of injury that needs to be managed, kinetic energy, but there are a range of potential negative and positive equipment factors; negatives include factors such as use of unprotected sharps, and positives, implementation of safety devices such as retractable needles and lancets.

In using this approach for injuries by sharps contaminated with blood, a first step could be to consider the feasibility of all possible pre-event phase interventions for personal risk factors that could increase host resistance to the occurrence of sharps injury. Pre-event phase equipment measures can also prevent sharps injuries from ever occurring; examples are appropriate safety equipment such as retractable, resheathable, and self-blunting needles, sharps-free intravenous connectors in patient-care areas, and Kevlar gloves for hazardous procedures such as autopsies of AIDS patients[9,82]. Noteworthy is that depending on the type of device and procedure involved, 62-88% of sharps injuries are potentially preventable by implementation of safer medical devices[98]. In the USA, the use of safety engineered devices was mandated by the Needlestick Safety and Prevention Act of 2000[99] and the overall incidence of percutaneous injuries decreased by more than 50%[100].

Implementation of safety devices is a challenge in developing countries. A common reason for neglect is the alleged cost. Although this is a popular mythology and excuse for inaction, the immediate costs of purchasing technologically advanced medical devices do not even come close to the total long-term costs of HIV infection, AIDS, deaths, loss of family income, and workers' compensation resulting from a lack of such devices. Evidence-based data calculated by the WHO Safe Injection Global Network demonstrated the cost-effectiveness of safe injections for the patients and community[101]. Such data need to be more widely known among all healthcare administrators. The American state of California projected a saving of more than $200 million from prevention of occupational HIV and hepatitis transmission following the implementation of safer needle devices[102]. Further economic research of such nature could be useful in low-income countries to provide strong support for the purchase and use of safety engineered devices. In high-income countries, nurses are being trained to take a greater role in hospital epidemiology, including infection control[103]. For high-prevalence, low-income countries, such training including specific measures appropriate for the prevention of HIV and other blood-borne infections should be an urgent priority for nurses and administrators who control budgets for infection-control devices, in all hospital and healthcare facilities; training programs do require evaluation.

Compliance with standard precautions should be everyday practice. Such measures include the use and disposal of sharps in a safe manner, including eliminating re-capping or removal of needles from syringes, promptly placing disposable sharps in puncture-resistant bins, protection of existing skin lesions and wounds, and good basic hygiene[104].

Improvements in operative techniques, including "no-touch" passing of instruments, use of instruments and not fingers to hold all sharps, minimizing the use of hands in body cavities with limited visualization, and sewing away from the surgeon have all been proposed to reduce the risk for blood-borne HIV transmission by sharps injury in the operating room[9,82,105,106]. Examples of equipment measures that provide passive protection by substitution or elimination include: sterile adhesive strips or glue for skin closure; blunt-tipped needles for closure of other layers where feasible; use of nylon sutures to replace wire; blunt-tipped scalpels or diathermy/cautery knife rather than sharp-pointed scalpels, where appropriate. Courses in basic low-risk surgical skills for all health providers who need them, not only doctors, should be a priority for low-income countries. Healthcare workers must assume that all patients are potentially infected, and adopt universally applied standards of behavior to minimize contact with blood.

In the event that an injury occurs (i.e. the event phase of an incident), personal protective equipment such as single or double latex gloves reduce the quantity of blood on the surface of a needle or other sharp, and thus also reduce the corresponding dose of HIV virus for both the HCW and the patient[82,105]. Finally, in the post-event phase, appropriate reporting procedures and hospital surveillance systems help ensure that exposures are reported immediately and that appropriate postexposure prophylaxis is provided in a timely manner[107-109]. Such approaches should be consistently provided by all healthcare facilities, implying that all hospital staff with a potential for exposure to nosocomial HIV, together with their administrators who are responsible for implementing safety equipment and a positive safety culture in their health facility, need to be well trained in the fundamentals of infection and injury control.

Injury epidemiology favors the implementation of automatic or passive protection measures that protect at all times, rather than active protection, which requires constant vigilance and will inevitably fail from time to time. Injury control also incorporates certain approaches that resemble the occupational hierarchy of controls, in that hazards should be eliminated, controlled, or contained, rather than forcing individuals to accept and adapt to constant risk[1,10,91,98].

Occupational approaches and safety

As for occupational approaches to safety, in the well-known and respected occupational hierarchy of controls, which is similar in many respects to Haddon's 10 basic strategies for injury control[10,90], strong emphasis is given to eliminating the most serious hazards in order to provide continuous automatic protection for workers at all times, even if they are inexperienced or fatigued[10,91,98]. Hence, continuous system measures such as the elimination and substitution of hazardous procedures or substances are favored over repetitive and never-ending requirements for wearing of personal protective equipment by HCWs or patients.

While there is general acceptance among HCWs of the need for standard precautions for control of nosocomial HIV infections, there are also high levels of fear of occupationally acquired HIV observed among nurses and doctors[110-113]. In some institutions, at least, such fear has been somewhat mitigated by educational programs for nosocomial HIV prevention and by actual experience of working with HIV patients[114].

Large differences in policies, approaches and recommendations to address the issue of infected HCWs occur despite the potential availability of the same information for all decision makers. Needlestick and other sharps injuries in some healthcare settings create a potential for transmission to both patients and HCWs. In view of the insufficient recognition and reporting of such exposures and the low risk of transmission from HCWs to patients, it is unlikely that a policy of mandatory postexposure testing of HCWs would contribute significantly to a reduction of HCW-to-patient transmission of HIV[1,115-118]. Recommendations to reduce such transmission include the proper implementation of infection and injury control, including engineering, the widespread utilization of safety devices and practices that help reduce sharps injuries in surgical settings, making HCWs responsible for their own serologic status, and improved reporting of exposures. Exposure-prone procedures must not be performed by an HIV-infected HCW[1]. Occupational health services, if sufficiently developed, can also play an important role in: education, training, and awareness; providing advice; incident investigation; counselling and post-exposure prophylaxis; and where necessary, assistance with HCW rehabilitation[119].

Conclusions

Any risk of nosocomial HIV transmission, however small, must be avoided as far as possible. Mobilizing and sustaining the resources required to ensure infection and injury control pose a constant challenge, especially to low-income countries. Healthcare-associated HIV is now uncommon in high-income industrialized countries, that is to say, the probability is very low and only a limited number of infections occur by unusual occurrences. It remains a relatively important problem in developing countries where standard, specific, HIV preventive measures are applied inconsistently or simply not at all. While there is still a potential for further success of specific, often costly preventive efforts in wealthy countries**,** it must not be forgotten that for infection control, poverty is often an underlying determinant. While educational and economic equity greatly reduce the risk of healthcare-associated HIV infection and should be a priority for decision makers for many reasons, action is also needed at an international level to develop and implement appropriate and efficient safety equipment, training, and surveillance that will be feasible even for rural hospitals and clinics in remote areas of low-income countries. The marginal cost of such improvements should be low compared to the large benefit in reduction of healthcare-associated HIV and other agents.

Among impoverished villagers and even in high-income developing countries many injuries and diseases, including AIDS, are believed to be wrought by sorcery or destiny[10,120]. In industrialized countries, such health conditions have often been attributed to bad luck, God's will, or sin. Prevention begins when HCWs and the public accept that nosocomial infections and the injuries that cause many of them are truly avoidable. Experiences with health providers and patients in high- and low-income countries in Central and Eastern Europe, Africa, Asia, the Middle East, and the Pacific have shown that relatively simple and low-cost interventions can be implemented to control nosocomial infection. The prevention of transmission of HIV in healthcare settings requires successful interventions that are feasible in the context of local conditions, together with good management and positive attitudes among not only HCWs but also health administrators, public health professionals, policy makers, economists, governments, and nonprofit and other private organizations. Success in freeing nations from healthcare-associated HIV infection should hopefully be a less difficult task than changing the sexual and other high-risk practices of their populations.

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