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Infection risks following accidental exposure to blood or body fluids in health care workers: A review of pathogens transmitted in published cases

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Hospital staff and all other human or veterinary health care workers, including laboratory, research, emergency service, or cleaning personnel are exposed to the risk of occupational infection following accidental exposure to blood or body fluids (BBF) contaminated with a virus, a bacteria, a parasite, or a yeast. The human immunodeficiency virus (HIV) or those of hepatitis B (HBV) or C (HCV) account for most of this risk in France and worldwide. Many other pathogens, however, have been responsible for occupational infections in health care workers following exposure to BBF, some with unfavorable prognosis. In developed countries, a growing number of workers are referred to clinicians responsible for the evaluation of occupational infection risks following accidental exposure. Although their principal task remains the evaluation of the risks of HIV, HBV, or HCV transmission and the possible usefulness of postexposure prophylaxis, these experts are also responsible for evaluating risks of occupational infection with other emergent or more rare pathogens and their possible timely prevention. The determinants of the risks of infection and the characteristics of described cases are discussed in this article. (*Am J Infect Control* 2006;34:367-75.)

The risk posed by “septic wounds” is well documented by pathologists since the 19th century. The realization of the risks linked with exposure to blood and body fluids (BBF) in hospitals, however, only became widespread with the advent of the human immunodeficiency virus (HIV)/AIDS pandemic. Any patient with viremia,^{1,2} parasitemia,³ bacteriemia,⁴ or fungemia⁵ may potentially transmit a pathogen to a health care worker (HCW) either during a sharps injury (needlestick or cut by a scalpel blade or any other sharp object contaminated by BBF) or by mucocutaneous contact (MCC; BBF contact with nonintact skin or the mucosa of the eyes or mouth). We were repeatedly faced with challenging requests for postexposure

expertise at Bichat-Claude Bernard University hospital in Paris, France. Although other pathogens (eg, monkeypox⁶) have been shown to be transmissible via needlestick in experimental animals, we found it useful to limit our efforts to compiling an updated and exhaustive list of BBP whose transmission was documented following occupational exposure in humans.

METHODS

We proceeded to a complete review of the literature referenced since 1966 using Medline, Webspirs, CAB Abstracts, and Embase without language restrictions. The MeSH terms used were “stab wound,” “injury,” “health personnel,” “accidental blood disease,” “occupational disease,” “occupational exposure,” and “blood-borne pathogen.” Reference handbooks were consulted in extenso. The bibliographic references for each article, review, or book chapter were systematically researched. The inocula transmitted by blood transfusion, in the clinical laboratory, during accidental sharps injuries in the health care setting, or during dissection represent situations with rising transmissibility profiles (Fig 1). When several cases of occupational infection of a given bloodborne pathogen were associated with various types of exposure, we described the case associated with the exposure with the lowest theoretic inoculum order to approximate the pathogen’s transmissibility. Cases that occurred

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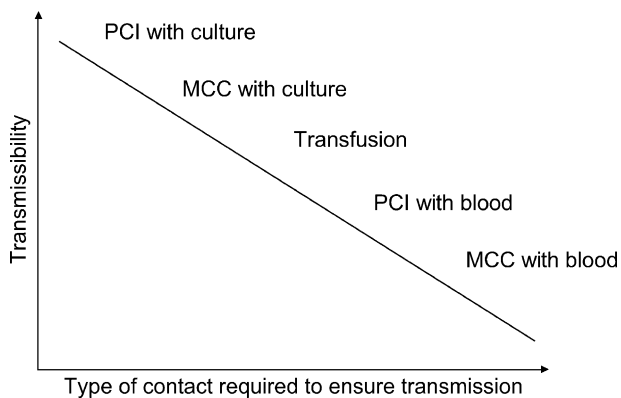


Fig 1. Schematic drawing showing the relationship between the transmissibility of a pathogen and the importance of the blood inoculum needed to ensure transmission following exposure in a HCW. *PCI*, percutaneous injury; *MCC*, mucocutaneous contact; *culture*, viral or bacterial culture concentrates in the laboratory setting.

following exposure to aerosolized BBF were not included because it was not possible to differentiate between respiratory and mucocutaneous routes for transmission.

RESULTS

Three viruses alone (HBV, HCV, and HIV) account for most cases of occupational infection described in the literature because of their prevalence among patients and the severity of the infections they cause. Published case reports were found for a total of 60 pathogens or species: 26 viruses, 18 bacteria/rickettsia, 13 parasites, and 3 yeasts.

Viruses

The 26 viruses that have caused documented occupational infections following exposure to BBF are shown in Table 1.

The hepatitis viruses. In 1987, the Centers for Disease Control and Prevention (CDC) estimated that approximately 12,000 HCW were becoming occupationally infected in the United States each year.⁷ According to the CDC, 700 to 1200 would become chronic carriers, and 200 to 300 deaths a year were due to occupationally acquired HBV infection in HCW. In France, the yearly number of notified, occupationally acquired viral hepatitis by HCW to the social security system went from around 600 in the mid-1970s to less than 50 in recent years, thanks to the compulsory anti-HBV immunization in HCW and improvements in hygiene procedures. One case of occupational coinfection with the virus responsible for hepatitis D has

been described in a surgeon.⁸ Immunization against HBV would have protected him against infection with virus Delta, which cannot develop unless there is concurrent HBV infection. It became clear in the mid-1970s that HCW were also exposed to the risk of becoming infected with “non-A, non-B” hepatitis. Most of these were due to HCV, which was identified in 1991. In France, 43 occupational seroconversions for HCV were documented in HCW following exposure to BBF as of June 30, 2001, including 32 cases in which the source patient was known to be infected with HCV.⁹ Finally, a case of transmission of hepatitis G following BBF exposure was proven at the molecular level in a nurse with chronic HCV infection, who was an asymptomatic carrier of HGV RNA without any other biologic sign.¹⁰

HIV. The first case of transmission of HIV from a patient to an HCW was described in 1984.¹¹ In total, 334 occupational seroconversions have been documented or considered likely as of December 2002 (106 documented and 238 possible cases).¹² None of these cases were documented in HIV-burdened sub-Saharan Africa, with the exception of 2 cases in South Africa and 1 in Zambia. This suggests that the number of HCW occupationally infected with HIV is underestimated. In France, 42 cases of probable or documented occupational HIV infections were documented in the health care setting as of June 30, 2001, including 13 documented seroconversions.⁹ The successes achieved in the control of exposures to BBF and the advent of potent treatments against HIV that allowed many HIV-infected patients to avoid being hospitalized have reduced HCWs’ risk of being injured with HIV-contaminated hollow-bore needles in France as in other European countries such as Italy (SIROH, unpublished data). No new case of occupational infection with HIV has been documented in France since 1997.⁹

Viral hemorrhagic fever viruses. The most feared risk is that of being exposed to the viruses that cause viral hemorrhagic fever (VHF): viruses Machupo, Lassa, Hantavirus, Ebola, Marburg, Crimean-Congo, Sabia, Dengue, Yellow Fever, Junin, Guanarito, Kyasanur as well as Chikungunya and Omsk Fever.¹³ These pathogens have caused limited but sometimes devastating outbreaks in African or Asian countries. Although some are known to be endemic (Lassa), these sudden, high-visibility outbreaks are mainly health care-related. Hospital referral of patients with febrile hemorrhagic syndromes caused by Lassa, Ebola, Crimean-Congo, or, more recently in Angola, Marburg virus, viruses was followed by grouped cases of secondary transmission and spillover into the community in some cases.^{14,15} Most documented VHF victims are frontline HCW with little or no access to means of protection while exposed to the BBF of patients. One case of suspected interhuman

Table I. Viruses that have caused documented occupational infection following exposure to BBF in HCW or laboratory personnel

Pathogen	Exposure	Setting	Source
Argentinian VHF (Junin virus)	Nonintact skin	Contact with rodents' blood	73
Bolivian VHF (Machupo virus)	Needlestick, nonintact skin	Health care	74,75
Brazilian VHF (Sabia virus)	Needlestick	Research laboratory	18
Crimean Congo VHF	Nonintact skin	Health care	14
Dengue	Needlestick	Health care	1
Ebola VHF	Nonintact skin	Health care	76
Hendra virus	Nonintact skin	Veterinary care	77
Hepatitis B virus	Needlestick, nonintact skin	Health care	78
Hepatitis C virus	Needlestick, nonintact skin	Health care	2
Hepatitis D virus	Needlestick	Health care	8
Hepatitis G virus	Needlestick	Health care	10
Herpes simplex I	Needlestick, nonintact skin	Health care	23,24
Human immunodeficiency virus I (HIV I)	Needlestick, nonintact skin	Health care	11,79
Kyasanur virus	Needlestick	Research laboratory	80
Lassa VHF	Nonintact skin	Health care	15
Marburg VHF	Needlestick, nonintact skin	Health care	81,82
Rift Valley Fever virus	Nonintact skin	Veterinary care	82
Simian Foamy virus	Nonintact skin	Animal handling	83
Simian immunodeficiency virus (SIV)	Splash to eyes	Research laboratory	84
Epizootic vesicular stomatitis	Nonintact skin	Veterinary care laboratory	85
Vaccine virus (recombinant)	Needlestick	Research laboratory	30
Varicella zoster virus (VZV)	Needlestick	Health care	25
Venezuelan VHF (Guanarito virus)	Nonintact skin (suspected)	Health care	86
Virus B (Herpes I)	Splash to eyes	Research laboratory	26,28
West Nile virus	Scalpel cut, needlestick	Research laboratory	22
Yellow Fever virus	Nonintact skin (suspected)	Hospital laboratory	87

VHF, viral hemorrhagic fever.

transmission of Hantavirus following exposure of nonintact skin to BBF in an Argentinian HCW has been described but remains arguable.^{16,17} Cases of transmission to laboratory personnel have been described for Sabia virus in Brazil¹⁸ and Ebola in the United Kingdom¹⁹ and Russia. Patients infected with other VHF viruses have been admitted in hospitals of industrialized countries^{20,21} with no documented case of secondary transmission. The recent emergence of West Nile virus in the Northern Hemisphere has led to cases of occupational infection in laboratory personnel.²²

Viruses of the herpes group. Localized lesions of the hand have been reported in personnel who sustained documented accidental inoculation of herpes virus 1, some of which simulated whitlow.^{23,24} One case of virus varicella-zoster inoculation may have led to zoster in a physician after he had sampled a vesicle in a patient.²⁵

Zoonotic viruses. Zoonotic viruses have also been transmitted across the interspecies barrier by exposure to BBF. Such exposures are frequent and usually benign, but they can also lead to death.²⁶ This is a risk mainly for veterinary personnel or animal handlers, as well as research laboratory staff. Students in human or animal biology working in tropical zones

may also be affected, and their medium-term medical follow-up is often lacking. Exposure is probably very common in animal keepers or research staff. In the United States in 1990, 26 of 266 (9.8%) of quarantine staff and 16 of 284 (5.6%) of those who had contact with primates had measurable titers of antibodies against Ebola virus or a strain of Marburg virus.²⁷ Exposure to the saliva of infected monkeys by bites or scratches or accidental exposure to infected blood or tissues have led to over 25 infections by virus B (*Herpesvirus simiae*) since the 1930s, nearly two thirds of which have been fatal in the infected person.²⁸ A laboratory technician who received a splash of virus B-infected biologic fluid became infected and died.²⁶ To date, there are no cases of occupational infection by Severe Acute Respiratory Syndrome (SARS) following a needlestick or cut or contact with nonintact skin.

Viral vectors

An emerging and heretofore little-known risk is that of exposure to viral vectors used in gene therapy.²⁹ This issue was illustrated recently at Bichat University Hospital in Paris when a researcher was referred to the emergency room after accidental exposure to a recombinant adenovirus—with no apparent consequence at

Table 2. Bacteria and rickettsia that have caused documented occupational infection following exposure to BBF in HCW or laboratory personnel

Pathogen	Exposure	Setting	Source
<i>Brucella abortus</i>	Needlestick	Research laboratory	88
		Veterinary care	89
<i>Burkholderia mallei</i>	Nonintact skin	Research laboratory	90
<i>Corynebacterium diphtheriae</i>	Needlestick	Hospital laboratories	91
<i>Corynebacterium striatum</i>	Scalpel cut	Health care	92
<i>Leptospira icterohaemorrhagiae</i>	Needlestick	Research laboratory	93
<i>Mycobacterium leprae</i>	Needlestick	Health care	94
<i>Mycobacterium marinum</i>	Needlestick	Hospital laboratory	95
<i>Mycobacterium tuberculosis</i>	Needlestick	Health care	96
<i>Mycoplasma caviae</i>	Needlestick	Research laboratory	97
<i>Neisseria gonorrhoeae</i>	Cut	Research laboratory	98
<i>Orientia</i> (or <i>Rickettsia tsutsugamuchi</i>)	Cut	Research laboratory	99
<i>Pasteurella multocida</i>	Needlestick	Veterinary care	100
<i>Rickettsia rickettsii</i> (Rocky Mountain Spotted Fever)	Needlestick	Health care	101
<i>Rickettsia typhi</i> (typhus)	Needlestick	Research laboratory	102
<i>Staphylococcus aureus</i>	Needlestick	Housekeeping	103
β -hemolytic streptococcus (<i>S pyogenes</i>)	Scalpel cut	Autopsy	104
<i>Streptococcus A</i> (necrotizing fasciitis)	Nonintact skin	Health care	105
<i>Treponema pallidum</i>	Needlestick	Research laboratory	106,107

1-month follow-up. A case of accidental inoculation of recombinant vaccine virus in a laboratory technician has been published.³⁰ Progression was benign because this technician had been vaccinated against smallpox some years earlier, and no seroconversion was noted. The detailed analysis of lymphocytic response markers showed, however, that the virus had been transmitted. The uses of this new technique may become more widespread in the years to come. The risk of occupational infection will therefore increase in a growing number of research laboratory personnel in cases of ex vivo handling as well as health care personnel in cases of in vivo gene therapy.³¹ The potential consequences of infection in health care or laboratory personnel by genetically modified vectors should be systematically documented, and primary and secondary prevention methods must be known to all.

Bacteria, parasites, and yeasts

Bacteria. Bacteria caused some of the first cases of occupational infection described in the dissection room and the laboratory, whether in medical or in literary texts.^{32,33} The risk of occupation transmission of bac-

Table 3. Parasites that have caused documented occupational infection following exposure to BBF in HCW or laboratory personnel

Pathogen	Exposure	Setting	Source
<i>Leishmania</i> species (6 species)	Needlestick, nonintact skin	Hospital laboratory	39,108
<i>Plasmodium cynomolgi</i>	Needlestick	Research laboratory	109
<i>Plasmodium falciparum</i>	Nonintact skin	Health care	3
<i>Plasmodium malariae</i>	Needlestick, nonintact skin	Health care	110,111
<i>Plasmodium vivax</i>	Needlestick	Health care	109
	Undetermined	Autopsy	112
<i>Toxoplasma gondii</i>	Splash to eyes, needlestick	Research laboratory	39,113
<i>Trypanosoma brucei</i>	Needlestick	Hospital laboratory	39
<i>Trypanosoma cruzi</i>	Projection	Hospital laboratory	39

teria and rickettsia in the laboratory has been greatly reduced by the observance of hygiene rules. Cases that used to be common among pathologists have now become rare.³⁴ Most cases of bacterial inoculation give rise to a local, nodular lesion at the site of injury, such as *Mycobacterium* species, *Neisseria gonorrhoeae*, *Treponema pallidum*, or *Streptococcus pyogenes* (see Table 2). In some rare instances, local infections became extensive (tenosynovitis, bacteriemia).

Parasites. Parasites that caused occupational infections are shown in Table 3. Most of these cases are due to *Plasmodium* species, usually *Plasmodium falciparum*. A case was described recently in France in a nurse who sustained a needlestick.³⁵ An extensive review of the literature found 20 other published cases (21 in total).^{36,37} Fifteen of the 21 cases (71%) described occurred in Europe (8 in France). Seven (33%) cases occurred in physicians or biologists/researchers. In 5 cases (24%), infection was caused by mucocutaneous contact. This percentage of transmissions occurring after a low-volume exposure such as MCC is high as compared with those found for documented cases of HIV or HCV infection, at 8.5% and 2.3%, respectively.⁹ Although the transmission rate cannot be evaluated precisely for lack of denominator data, this may reflect a high rate of transmission.¹² Diagnosis was excessively delayed in some cases. Such delay may have severe consequences, such as occurred with the death of an Italian physician.³⁸

Approximately 60 cases of occupational infection by *Trypanosoma cruzii* (the agent of Chagas disease) following exposure to BBF have been described, mainly in Latin America.³⁹ Cases of *T brucei* are more rare. Most of these occurred in research laboratories in Europe. Laboratory technicians working on Toxoplasmosis have also been infected following exposure to BBF.³⁹

Yeasts. Reports of occupational infection by yeasts are rare. They are shown in Table 4.

Table 4. Yeasts that have caused documented occupational infection following exposure to BBF in HCW or laboratory personnel

Pathogen	Exposure	Setting	Source
<i>Blastomyces dermatitidis</i>	Scalpel	Autopsy	114
<i>Cryptococcus neoformans</i>	Needlestick	Health care	5
<i>Sporotrichum schenkii</i>	Needlestick	Research laboratory	115

Other risks linked with BBF

BBF exposure and transfusion. There are no documented cases of occupational infection for several pathogens that are ubiquitous and known to be bloodborne. Some, however, have caused documented cases of infection following transfusion in patients (see Table 5) and may—at least in theory—be transferred by BBF exposure. The massive inoculum caused by blood transfusion is far greater than that associated with occupational exposures. Pathogens such as cytomegalovirus (CMV), parvovirus, or TT virus—one that is often found in hemophiliacs or patients who underwent dialysis or multiple transfusions⁴⁰—were transmitted in this way.⁴¹ In a recent and dramatic incident, 3 patients died of rabies following organ transplantation from a deceased donor in the United States.⁴²

BBF exposure and prion disease. Animal experiments have shown that the agent of Creutzfeldt-Jakob disease (CJD) and new variant CJD can be transmitted by transfusion⁴³⁻⁴⁵ or following the intracerebral injection of white blood cells in the guinea pig⁴⁶ or subcutaneous and intramuscular injection in monkeys.⁴⁷ Human cases have been described following direct cerebral inoculation (dura mater grafts) or intramuscular injection of growth hormones.^{48,49} Cases of CJD have been described in Australian patients who received transfusion, although the origin of the blood could not clearly be established. In Canada, a patient who received albumin elaborated using blood products from a patient who developed CJD was found to have CJD at autopsy.⁴⁸ One case of CJD was described in a neurosurgeon,⁵⁰ one in a pathologist,⁵¹ and 24 others in laboratory personnel.^{52,53} Finally, a debatable case occurred in a surgeon who worked with animals.⁵⁴ A suspected case of vCJD transmission in a blood recipient has been described recently.⁵⁵ HCWs, however, are not overrepresented among CJD/vCJD cases in the United Kingdom, and there is no definitive proof of transmission by transfusion in humans (Dr. Peter Smith, London, personal communication, October 12, 2002).^{56,57} Studies are based on a small number of cases and depend on relatives' recall because this disease is rare and has an extremely long incubation

Table 5. Other pathogens for which there are no documented occupational infection following exposure to BBF in HCW or laboratory personnel but that are transmitted through blood transfusion or organ transplantation

Pathogen	Source
<i>Babesia microti</i>	116
<i>Borrelia dunotti</i>	117
Colorado Tick Fever	118
Cytomegalovirus	119
Epstein-Barr virus	119
Hepatitis A virus	119
Human T-lymphocytic virus (HTLV)-1, HTLV-2	120,121
Parvovirus B19	121
Rabies	42
TT virus	40

period.^{48,56} In view of available sources, we may conclude that, if the risk of prion transmission following occupational exposure to BBF actually exists, then it is extremely low.

DISCUSSION

Antiretroviral postexposure prophylaxis (PEP) is leading a growing number of HCW to seek medical expertise and assistance following exposure to BBF. In most cases, the risk is due to HIV, HCV, or HBV, and management guidelines are readily accessible in most countries. Efforts are being made by some European countries to standardize management guidelines.⁵⁸

Exposure to some of the rare pathogens described here may, however, pose a real challenge for the PEP expert. First, HCW may be unaware that they have been exposed to a rare pathogen.³⁹ Second, injured personnel do not always seek assistance immediately. Third, clinicians responsible for postexposure management (often in the emergency room) may be at a loss because the progression of these infections is undocumented when their “natural” route is bypassed by direct inoculation.²⁶ It may then become difficult to define a postexposure management strategy or to decide whether prophylaxis is indicated. There are no validated recommendations based on scientific proof for preventing infection by pathogens other than HIV and HBV, even when well-established treatments are available, such as is the case for *Plasmodium* species or Lassa or CCHF viruses. Fourth, HCW may be referred to a hospital other than the one in which the injury occurred, and there is no document to guide follow-up, a vital resource, especially if the infection causes neurologic symptoms preventing them from telling of their injury, as occurred with an occupational *P. falciparum* infection in France or a lethal case in Italy.

HCW and the clinicians responsible for postexposure evaluation must bear in mind that many pathogens other than HBV, HCV, or HIV may be transmitted, not to mention the anecdotal case of the transmission of tumoral cells during an occupational exposure in the laboratory setting.⁵⁹ Prospective follow-up in exposed HCW with denominator data is available only for HBV, HCV, and HIV. For other pathogens, the transmission risk cannot be rigorously assessed because of the small number of documented cases. It is nevertheless reflected to some extent by the mode of transmission: the lower the volume of the inoculum that causes infection by a given pathogen, the higher the theoretic risk of transmission for that pathogen. A low transmissibility and rare pathogen may be transmitted only by contact with cultures in the research laboratory, for instance, whereas a ubiquitous and highly transmissible pathogen may be acquired following MCC in the clinical setting. Some cases of occupational infection, however, were described only in the laboratory. This may be due to the pathogen's prevalence being extremely low in the clinical setting but may principally reflect the higher risk of transmission associated with concentrated cultures used in the laboratory setting.

Some of these pathogens may be concentrated in body fluids other than blood: HIV is found in cerebrospinal or spermatic fluid; the hepatitis viruses may be present in ascites fluid. The clinicians responsible for risk evaluation must therefore think in terms of exposure to potentially infectious body fluids and not solely in terms of blood. Furthermore, they must bear in mind that the risk of BBF exposure does not only concern HCW but all personnel at risk of exposure to BBF or BBF-soiled devices. A high proportion of documented cases occurred in laboratory personnel, and a few others occurred in emergency assistance, police, or health care waste elimination personnel.⁶⁰⁻⁶³ Finally, veterinary personnel or animal technicians in laboratories are exposed to infection risks with zoonotic pathogens following exposure to BBF.

Several factors are needed for successful infection to occur. First, a pathogen must have the capacity to replicate within a human host.⁶⁴ The risk for HCW to be exposed to a given pathogen increases with its prevalence among treated patients and with the chronic character of the infection. In case exposure occurs, the risk of transmission increases with the importance of the infectious inoculum. This varies according to either the volume of blood inoculated (deep needlestick, large-bore needle, large surface of nonintact skin exposed) or to the number of infective agents (high viral load, bacteremia, or parasitemia) contained in it.

These microbiologic notions are illustrated by existing data on transmission rates, which vary according to source patient parasitemia. The seroconversion

rate following accidental needlestick in nonimmunized HCW is estimated at approximately 10% and as high as 30% in case of Ag-Hbe carriage in the source patient.⁶⁵ A metaanalysis of available data estimated the global risk of transmission of HCV following needlestick injury at 1.5% to 2.0%.⁶⁶ Studies conducted following exposure to BBF in Japan, however, found varying rates of seroconversion according to polymerase chain reaction (PCR) results in the source patient: 0% in case of negative HCV-PCR; 10% in case of positive PCR.⁶⁷ Finally, the systematic serological follow-up of exposed HCW provided data on the rate of seroconversion for HIV following occupational needlestick injury, which was estimated at 0.29% (95% CI: 0.13%-0.70%).⁶⁸ A case-control study was conducted by the CDC on the risk factors for seroconversion in HCW following needlestick exposure to HIV-infected blood.⁶⁹ This study showed that this rate could be increased if risk factors were present: deep (bloodletting) injury; device visibly contaminated with blood; needle used for an intravascular procedure (therefore containing blood); patient in terminal phase of infection by HIV (therefore with a high viral load). It also showed the protective role of postexposure prophylaxis with AZT.

Although rates of exposure to blood in HCW are diminishing in industrialized countries, their risk of encountering little-known pathogens may increase with international travel and the emergence or reemergence of diseases.⁷⁰⁻⁷² Data on transmission rates and possible prophylaxis for pathogens other than HBV, HCV, or HIV are needed to guide postexposure management experts.

CONCLUSION

The risk for HCW to be exposed to rare "exotic" pathogens increases with intercontinental travel and migrations. Emerging disease risks are also associated with progress in medical techniques, changes in nutritional or other social habits, or ecologic changes. Although the principal risks to which PEP experts are confronted are linked with HIV, HCV, and HBV, these experts must also be able to suspect other, less common transmissible pathogens. Clinicians should systematically follow up personnel who have sustained exposure to "inhabitual" pathogens. We hope that this article will be a useful tool for postexposure management experts. Extended national recommendations must nevertheless be developed to guide experts in the management of HCW following exposure to BBF.

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