The risk of transmission of blood-borne viral diseases such as hepatitis and AIDS among health-care workers is a matter for concern, particularly to surgeons, anaesthetists, nurses and others involved in the surgery of orthopaedics and trauma.

By the late 1970s, 13% to 18% of surgeons had been infected with the hepatitis-B virus (HBV) compared with 3% to 5% of the general population.¹ The annual rate of infection in health-care workers was found to range from 0.5% to 5.0%, compared with 0.1% in the general population of the USA.¹ An anti-HBV vaccine became available in 1981 and has helped to control this problem; the risk of occupational infection from the hepatitis-C virus (HCV) has been increasingly recognised. A new and threatening problem has arisen from the emergence of the human immunodeficiency virus (HIV) and its rapid spread.

Epidemiology of HIV infection

At the end of 1999, the Joint United Nations Programme on HIV and AIDS (UNAIDS) and the World Health Organisation (WHO) estimated that about 33.6 million individuals were infected with HIV throughout the world, including 32.4 million adults and 1.2 million children under 15 years of age. About 16.3 million people had died from the disease.² It is estimated that 5.6 million people had become infected in 1999, including 570 000 children.²

Europe. The prevalence figures for European countries are based on the numbers of AIDS patients declared to national surveillance systems. By 30 June 1999, 224 359 cases had been registered in the WHO European region; 60% had died.³ There has been a declining trend in the incidence of AIDS since 1996 due in part to measures for prevention, but also because of the efficiency of antiretroviral treatment. For this reason, the data from AIDS surveillance do not now reflect the full impact of the epidemic. A case-

reporting system for HIV was set up at European level in 1999 to complement registration of cases of AIDS in order to improve the monitoring of the disease. National registration of HIV infection is now used in 37 countries of the WHO, including 11 in the EU.

At the end of 1997, the mean prevalence of adult HIV in western Europe was estimated at 0.23% ranging from 0.01% in Slovenia to 0.69% in Portugal (Table I). There are large variations in the incidence and prevalence of HIV infection which may reflect differences in pathology as well as in the efficiency of surveillance systems. In 1998, 24 978 new cases of HIV infection were reported. Sexual transmission accounted for 88% of those in western Europe while injecting drug users represented 80% of new infections in eastern Europe. Trends in the annual number of cases of HIV reported during the 1990s varied markedly by geographic area. In western Europe, the number decreased in

Table I. Cumulated number of HIV and AIDS cases registered in June 1999³ and estimated prevalence of HIV in adults (15 to 49 years) in Europe at the end of 1997⁴

Country	HIV cases Number	AIDS cases Number	HIV prevalence Percentage
Austria	NA*	1915	0.18
Belgium	11 067	2599	0.14
Bulgaria	NA	60	0.01
Croatia	248	144	0.01
Czech Republic	393	125	0.04
Denmark	2482	2216	0.12
Finland	945	294	0.02
France	NA	49 421	0.37
Germany	NA	18 239	0.08
Greece	NA	1964	0.14
Hungary	772	328	0.04
Ireland	NA	674	0.09
Italy	NA	44 516	0.31
Luxembourg	342	139	0.14
Netherlands	NA	5054	0.17
Norway	1869	638	0.06
Poland	5591	794	0.06
Portugal	10 012	6020	0.69
Romania	5928	3704	0.01
Russian Federation	10 935	395	0.05
Slovakia	68	22	<0.005
Slovenia	140	81	0.01
Spain	NA	54 964	0.57
Sweden	4911	1663	0.07
Switzerland	23 821	6641	0.32
United Kingdom	33 329	16 437	0.09
Yugoslavia	NA	806	0.10

* not available

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some countries while it was relatively stable in others. In central Europe, it was generally low although increasing in some countries. In eastern Europe, it has increased dramatically since the mid 1990s in several countries. In 1998, the rates of reported cases of HIV per million of the population in countries with national data ranged from 16 (Finland) to 90 (Switzerland) in western Europe, from 2 (Slovakia) to 26 (Romania) in central Europe, and from 0.2 (Uzbekistan) to 169 (Ukraine) in eastern Europe (the former Soviet Union). France and Italy reported only regional data, with rates of 77 per million in France and 94 in Italy.³

Infectivity of patients with HIV. HIV has been isolated from many organs and tissues, including bone. Any body fluid which contains even microscopic traces of blood is a potential source of infection. Semen, vaginal secretions, breast milk and, possibly, saliva have all been implicated. The main routes of HIV transmission are sexual, parenteral and maternal-to-infant. Health-care workers can be infected by parenteral injection of blood, or through exposure of the skin or mucous membranes to blood or other body fluids. Parenteral inoculation can be by accidental percutaneous injection of infected blood, or injury by a sharp instrument combined with exposure to blood or other body fluid.

The natural history of HIV infection has three consecutive stages:

Acute. This lasts for two to six weeks after inoculation. During this phase, the number of virions produced is equivalent to the number that will appear over several years in the chronic phase. The patients remain seronegative, but their blood has a high contaminating potential.

Chronic asymptomatic. This typically lasts for several years. Anti-HIV antibodies have been developed but the patients remain asymptomatic. Blood and other body fluids have a definite potential for contamination during this phase.

AIDS. This is characterised by the clinical manifestation of an immunodeficiency syndrome. Viraemia is increased by 100- to 1000-fold, for example from 15 000 to 1 500 000 infective particles per ml of blood, and the potential for contamination becomes much greater than in the chronic asymptomatic stage.

Serological tests. HIV is a human RNA retrovirus; its DNA is synthesised from RNA, a reversal of the usual process of transcription, involving the enzyme reverse transcriptase. Two strains of HIV have been identified: HIV-1 is much the most common in the USA and Europe and HIV-2 was initially found only in West Africa and India, but was later isolated in Europe. The two strains differ in nucleotide sequences and in serology.

Detection is based either on finding induced antibodies against viral proteins, or by direct detection of components of the virus. The routine method for antibody detection is by an enzyme-linked immunosorbent assay (ELISA). Double testing is routine, using two different antigen preparations, and two negative results are sufficient to confirm that the serum is clear of infection. Two positive tests require

confirmation by another technique, usually immunotransfer or the Western blot test. This detects antibodies against specific viral antigens using gel electrophoresis. The Western blot test is more specific and is considered positive if at least one protein from the virus envelope has been recognised. Its disadvantages are that it takes longer, costs more and requires much more serum. Direct detection of the virus or of one of its constituents may be indispensable in certain circumstances, such as during the few weeks between infection and seroconversion. Viral antigens can be detected using an ELISA-type method and viral nucleic acids after enzyme amplification by the polymerase chain reaction (PCR).

Occupational infection

The risk of occupational infection in health-care workers depends on: a) the prevalence of HIV infection among the patients being treated; b) the nature and frequency of occupational exposures to blood or other body fluids; and c) the risk of HIV transmission from a single exposure, the seroconversion rate.

HIV prevalence. National serosurveillance systems cannot specify prevalence figures for groups of patients such as the practice of one particular surgeon, or those treated in a specific orthopaedic or trauma unit. At the end of 1997 the baseline adult prevalence in western Europe was estimated to range from 0.01% to 0.69%, being lower in northern Europe (0.02% to 0.12% in Scandinavia) than in most southern countries (0.31% to 0.69%).⁴ There are also regional variations within countries: the overall adult prevalence in Belgium was estimated at 0.14% at the end of 1997, but it was 10 to 15 times higher in the metropolitan district of Brussels than in the rural provinces.⁵

The prevalence of HIV in patients admitted to hospitals or treated as outpatients will reflect that in the general population but is generally higher. In some but not all studies, patients admitted with injuries, particularly penetrating ones, have been found to have a higher prevalence.^{6,7} In 1986, the Center for Disease Control (CDC) found a mean prevalence of 1.0% in 39 acute-care hospitals in the USA, based on over 250 000 blood samples from patients admitted for reasons unrelated to HIV infection; the range was 0.1% to 5.6%.⁸ Even within a small area there may be marked differences: a trauma centre in Baltimore found a prevalence of 1.7% in patients from 23 counties surrounding the city,⁹ but it was 5.6% in another Baltimore emergency department treating mainly the indigent Black population.¹⁰ A study in six emergency departments in areas of New York, Chicago and Baltimore showed an overall rate of HIV infection ranging from 4% to 9%.¹¹ A similar situation is likely in Europe. Parazzini et al¹² reported an HIV prevalence of 6.9% in patients visiting clinics for sexually-transmitted diseases in two Italian cities, but that in those undergoing surgery is about 0.8%¹³ and is only 0.31% in the entire adult population.²

In Hamburg, Froschle, Uner and Wening¹⁴ conducted HIV-antibody studies on patients with open wounds in the trauma emergency room of a university hospital and found six HIV infections in 220 patients tested, corresponding to a prevalence of 2.7%. In Lisbon, Mineiro et al¹⁵ found five (1.7%) HIV-positive patients among 288 treated surgically in the orthopaedic department of an urban public teaching hospital.

These figures take no account of the risk of possible infection from HIV-seronegative patients during the window between infection and seroconversion. Hernigou et al¹⁶ estimate that this group forms about 0.1% of the adult population in France. The HIV status of a patient is usually unknown at first. A CDC study in 1993 estimated that only 30% of HIV-infected patients are recognised as such at the time of admission to urban public hospitals, and in small clinics this proportion is 10% to 60%.¹¹

Most patients with HIV are between 15 and 55 years of age. Most data from serosurveillance systems refer to this age group. The risk of occupational infection is minimal during the treatment of patients outside this age range. The risk factor is also related to the type of pathology requiring treatment, and as already mentioned HIV prevalence is higher in trauma units.^{6,10,11} A much higher prevalence should be expected among patients with risk factors such as intravenous drug use, in male homosexuals, and in females having sexual contact with bisexual males. Other factors include: sexual contacts with intravenous drug users or with multiple partners, including prostitutes; a history of sexually-transmitted disease, viral hepatitis, lymphadenopathy, recent tuberculosis or blood transfusion; imprisonment; the presence of tattoos; and artificial insemination or tissue transplants, especially from untested donors.¹⁷

For these reasons, it is impossible for any surgeon to know the precise HIV prevalence among his patients, without prospective systematic testing.

Occupational exposures. The nature and frequency of blood contact among surgical personnel have been studied prospectively. Between 6% and 50% of operations involved one or more blood contacts, and one or more sharp injuries were noted in from 1.3% to 15.4% of procedures.¹⁸⁻²⁰ These varied with the type of surgery and, within each specialty, procedure-specific rates are available.

The risk decreases with surgical experience, but increa-

ses with the duration of operations.¹⁸ The area most commonly involved is the volar aspect of the index finger and thumb of the non-dominant hand; suture needles cause 85% of these injuries.²⁰ Scrub nurses are exposed to a smaller risk. Other nursing personnel and laboratory technicians also have a substantial risk of HIV infection; they account for 78% of recorded cases of occupational HIV conversion.²¹

The greatest risk is from the parenteral injection of blood or the exposure of an open wound to blood; these cause most occupational HIV infections in health-care workers.²¹ Most of these have been linked to injury by hollow needles; so far there are no reports of occupational infection by solid suture needles.²¹

Other modes of infection are possible. One occupational infection due to exposure of mucous membranes to blood has been reported in a prospective study,²² and there are case reports of seroconversion after isolated skin exposure to HIV-infected blood. None has been reported from prospective studies of health-care workers.

In orthopaedics and trauma surgery, there has been concern about aerosols containing blood from the power instruments used for drilling, reaming, or sawing²³ and of the danger from bone chips contacting the surgeon's eyes. These risks are theoretical. There is no biological or epidemiological evidence that HIV can be transmitted by aerosols entering the respiratory tract.²⁴

Risk of transmission. Serological surveillance of several thousand health-care workers has shown that the risk of HIV seroconversion after a single percutaneous exposure is of the order of 0.3%, much less than that reported for hepatitis at 10% for HCV and 30% for HBV.^{21,22,25,26} Several factors influence this risk:

Physical circumstances. The risk of seroconversion is increased after a deep injury, injection of a large quantity of blood, injury by a hollow needle, or during the insertion of catheters or venous arterial lines.^{21,24}

Viral status of the patients. The risk of HIV seroconversion is higher when the patient is in an advanced stage of AIDS, due to the higher titre of HIV. The titre of circulating virus may be reduced in a patient who is receiving effective antiretroviral therapy.

Prophylactic measures. Double gloving reduces the inoculum²⁷ and post-exposure prophylaxis with zidovudine pro-

Table II. Theoretical calculation of the lifetime risk of occupational HIV seroconversion as percentages of surgeons, related to HIV prevalence in patients and the estimated annual number of breaks in skin exposed to patients' blood. A career of 40 active years has been assumed. Values have been calculated based on a seroconversion rate of 0.3%; figures in parentheses have been calculated based on a reduced seroconversion rate (0.045%) assuming that skin breaches by suture needles are not infective

Number of breaks in skin per year	HIV prevalence in patients population (%)				
	0.1	0.5	1.0	2.0	5.0
5	0.06 (0.009)	0.3 (0.045)	0.6 (0.090)	1.2 (0.180)	3.0 (0.450)
10	0.12 (0.018)	0.6 (0.090)	1.2 (0.180)	2.4 (0.360)	6.0 (0.900)
20	0.24 (0.036)	1.2 (0.180)	2.4 (0.360)	4.8 (0.720)	12.0 (1.800)

vides a reduction of 79% in the rate of seroconversion.²⁶

Cumulative risk. The cumulative risk (R) for occupational HIV conversion of a surgeon in the course of his professional career has been calculated^{13,17,28} from the HIV prevalence among the patients treated (P), the number of parenteral exposures to patients' blood (E), and the seroconversion rate after a single parenteral exposure (S).

Based on a seroconversion rate of 0.3%, a surgeon operating over a period of 40 years on patients with a seroprevalence of 0.5% and having an average of ten percutaneous blood contacts per year, has a cumulative risk of 0.6% according to the equation:

$$R = P \times E \times S = 0.005 \times (40 \times 10) \times 0.003 = 0.006$$

More elaborate formulations are possible and would be found to be more satisfactory by epidemiologists but that proposed has the merit of simplicity while integrating relevant variables.

Table II gives theoretical values for different levels of seroprevalence and frequencies of parenteral contacts per year, but provides only rough estimates since many factors are uncertain.

HIV prevalence. In the population treated this is assumed to be constant, but one surgeon may treat several different types of population in his career and, in addition, prevalence is expected to increase unless efficient vaccination becomes available.

Nature of occupational injuries. As already mentioned, 85% of occupational injuries in surgeons are caused by suture needles²⁰ and no case of occupational HIV infection has been reported so far after such injuries. If only the remaining 15% of injuries carry a real risk, then a more selective approach should be adopted to register skin breaks, or else the seroconversion rate in surgeons should be revised accordingly.

Rate of occupational injuries. This will vary considerably with experience, emergency conditions, type of elective surgery, and length of operations. Only parenteral exposure to blood is considered. The exclusion of other possible modes of infection may underestimate the risk.

Seroconversion rate. After an exposure this is known to vary considerably with the patient's condition: the virus titre ranges from 15 000/ml of blood in an asymptomatic HIV-positive patient to 1 500 000/ml of blood in a patient with clinically advanced AIDS. The use of chemotherapy may keep viraemia relatively low, at least temporarily, in some HIV-positive patients, which reduces the risk. Efficient early postexposure prophylaxis will also reduce the risk for health-care workers.

An approximation for the lifetime risk of occupational HIV seroconversion for an active surgeon performing 250 operations per year for 40 years in an area with low to moderate prevalence of HIV is in the range of 0.05% to 1.2%, based on such data as those in Table II and assuming a seroconversion rate of 0.045% after a single parenteral exposure. If, however, the 'official' seroconversion rate of 0.3% is used, the risk will appear much higher, in the range

of 0.3% to 8%. In more general terms, in a European country with 10 000 active surgeons in all disciplines, this means that some 5 to 120 (optimistic hypothesis) or 30 to 800 (pessimistic hypothesis) would be infected by HIV at some time during their career, giving an annual rate of between 0.125 and 3 (optimistic hypothesis) or between 0.75 and 20 (pessimistic hypothesis).

These figures are in excess of the documented cases of occupational HIV seroconversion, but it must be recognised that the actual number of surgeons and health-care workers infected with HIV is unknown because of the passive nature of surveillance systems and probable under-reporting throughout the world.

Data from HIV surveillance of health-care workers. By September 1997, 94 cases of documented occupational HIV infection of health-care workers had been reported worldwide, with a further 170 cases of possible occupational HIV infection.²⁹

In Europe, 32 documented seroconversions among health-care workers had been reported by September 1997: 11 in France, five in Spain and Italy, four in the UK, three in Germany and two each in Belgium and Switzerland.²⁹ There were also 43 possible occupational conversions, not fully documented: 27 in France, nine in the UK, three in Germany, two in The Netherlands, and one each in Belgium and Denmark.²⁹ Documented occupational seroconversions had also been reported in South Africa (3), Zambia (1), Australia (4), Canada (1) and Argentina (1), as well as possible seroconversions in Mexico (9), South Africa (1), Canada (2) and Israel (1).²⁹

These numbers exclude cases of occupational HIV conversion collected before 1988 in the USA, before 1989 in the UK and before 1990 in France, because some important data had not been recorded. Ten of the documented occupational seroconversions were in doctors, including one surgeon. Among the possible occupational seroconversions at least eight cases were in doctors, including four surgeons, who were 'most probably' infected while working in Africa under more or less primitive conditions.²¹

In both the USA and Europe over half of the seroconversions affected nurses (52%); there were 18 nurses among the 21 documented cases from France, Spain and Italy where nurses are usually responsible for drawing blood; laboratory technicians accounted for 21% of cases.²⁹

Most infections (87.2%) followed a single percutaneous injury, usually a needlestick, but the injury was caused by a scalpel in two cases and by an orthopaedic pin in another. Eight infections occurred after mucocutaneous exposure to blood or to concentrated HIV; two cases had both percutaneous and mucocutaneous exposure to blood. Among cases for which the stage of HIV infection in the source patient was reported, the latter had AIDS in 77% of cases, was asymptomatic in 15%, and was symptomatic but did not have AIDS in 7.6%; one exposure occurred during the 'window period'.²⁹

Some cases probably go unreported and unregistered by

the passive surveillance systems; 10% to 60% of percutaneous injuries are not registered^{30,31} being considered as too trivial or because of lack of awareness of the reporting procedure, deliberate avoidance of reporting for reasons of confidentiality or fear of professional implications.

Monitoring of HIV prevalence in health-care personnel may give a better evaluation, with an insight into unreported and unregistered seroconversion. One study in surgeons was performed on a voluntary and anonymous basis by the CDC and the AAOS during the AAOS Annual Meeting in 1991. All 3267 orthopaedic surgeons who reported only occupational risk factors were found to be HIV-negative. Two of the 153 surgeons who also self-reported behavioural risk factors were HIV-positive.³² A second study by Panlilio et al³³ concerned 770 US surgeons working in areas of moderate to high prevalence of HIV. Of 740 surgeons with occupational risk factors only one was HIV-positive; he recalled three percutaneous injuries while operating on patients with HIV or AIDS since 1978. All 20 surgeons who reported other risk factors were HIV-negative. Serosurveys carried out on other groups of health-care workers have shown HIV prevalence of under 0.1%.²⁷

Prevention of occupational HIV infection

Preoperative HIV screening of patients. Routine preoperative screening for transmissible diseases such as HIV has been suggested so that special precautions can be taken,¹⁷ but there are arguments against this. HIV testing requires informed consent and this is not possible when the patient is not conscious. For patients requiring emergency operations the results of HIV testing are not available in time. Routine HIV testing is negative during early infection and before seroconversion. It has been shown that preoperative knowledge of seropositivity fails to influence the surgeon's behaviour as regards the risk of percutaneous exposure.^{18,20}

Preoperative HIV screening is now agreed not to be cost-effective and precautions should apply to every surgical procedure, not selectively for patients known or suspected to be HIV-positive. The CDC, however, recommends routine screening for HIV, with informed consent, for patients between 15 and 54 years of age in regions of high HIV prevalence.³⁴

Patients known to be 'at risk' for HIV should also be tested, with their consent. Any selection of patients on this basis is a sensitive matter; AIDS activists, the media and politicians may object to what they consider is arbitrary discrimination. Some clinicians test such patients for HIV despite the legal context, but the use of positive information is a matter for debate. It is generally agreed that such information should remain confidential to the patient and should not be given to any other person, not even to the wife, husband or sexual partner, except by the patient.

Universal precautions. No surgeon would now consider operating under the conditions that prevailed before Semmelweis, Lister and Pasteur, when every procedure, how-

ever simple, carried a considerable risk of death from infection. This risk has been largely eliminated for elective orthopaedic surgery and it is difficult to admit that even greater efforts are needed to address the problem of transmission of blood-borne diseases from patient to surgical team.

A number of precautions, to be applied universally, were recommended by the CDC in 1987 to prevent contact with blood, or other body fluids and tissues.³⁵ These recommendations were published by the AAOS in 1989¹⁷ and new guidelines were introduced in 1996.³⁶

'Standard precautions' aim to prevent contact with blood and other body fluids, secretions, excretions, non-intact skin and mucous membranes of all patients. In addition to these, 'transmission-based precautions' are advised for patients documented as or suspected to be infected with highly transmissible or epidemiologically important pathogens.

An effective barrier between the patient and the surgical team requires appropriate protective draping and garments of non-woven, impervious materials; towel clips should not be used. The surgical gown should be reinforced over the sternum, abdomen and forearms for trauma surgery. Masks and surgical hoods, also of non-woven material, should provide extended coverage, and impermeable boots should be preferred to the traditional footwear.

The routine use of protective glasses or facial shields integrated with a mask or helmet is advised despite their relative discomfort: projection of blood or aerosols of blood cause 3% to 5% of contaminations.²¹ Gloves must be worn whenever contact with blood is anticipated.

Any defects in gloves or peroperative perforations may cause prolonged contact with the patient's blood.²⁷ Double gloving reduces the risk of contact from 29% to 18%,³⁷ but the outer pair should be changed at least every two hours, or every hour for trauma surgery. Gloves reinforced with Kevlar or polyester/stainless-steel wire weave liners are designed to reduce perforations of the inner glove, but provide variable protection and variable comfort. They should be considered when bone fragments are to be manipulated or sharp instruments or saws are in use.³⁸

The rules for surgical technique:

- 1) Avoid the use of sharp instruments when possible.
- 2) Avoid direct passing of sharp instruments between team members.
- 3) Use a no-touch technique.
- 4) Use a scalpel for skin incisions only, then scissors and electrocautery.
- 5) Avoid simultaneous suture of the same layer by two members of a team.
- 6) Prefer to use blunt suture needles.
- 7) Avoid hasty gestures.
- 8) Comply with regulations for the elimination of disposable material.
- 9) Always wear gloves when handling material covered with blood.

In addition, all high-risk procedures should be reviewed to identify the specific hazards for each team member and to develop better reduction of risk.

Efficacy of 'universal precautions'. The efficacy of 'universal precautions' is uncertain, and the attitude to them depends largely on the perception of danger. Gerberding, Lewis and Schecter³⁹ reported that 80% of surgeons used routine double gloving in San Francisco General Hospital where the general HIV prevalence was known to be about 20%. This is compared with 10% to 15% of surgeons in another hospital where 80% of the operations were not trauma-related and in a population with a low HIV prevalence, although the population of trauma patients was essentially similar to that in San Francisco General Hospital.

A number of surveys have been conducted in several countries, such as by McCarthy et al³⁹ in the USA or by Asante and Tait⁴⁰ in Scotland. They all found that most surgeons were moderately to very concerned about the risk of acquiring HIV at work and yet failed to comply fully with the recommended universal precautions. Another survey in The Netherlands⁴¹ produced similar findings and also concluded that there was insufficient protection of general and orthopaedic surgeons against viral infection either by the lack of protecting devices or, mostly in emergency departments, by non-compliance of the surgeons.

Vaccination against HIV may be seen as the ultimate solution, but it should be remembered that although there is a vaccine against HBV, up to 30% of surgeons still work under 'at-risk' conditions without appropriate immunisation.³³

An Italian study has suggested that 'universal precautions' could halve the life-time risk of seroconversion for HBV, HCV and HIV: the most significant factor was the reduction in the incidence of breaches in the skin.¹³

Prophylaxis soon after exposure, using zidovudine (AZT), which is a nucleosidic reverse transcriptase inhibitor, has been associated with a decrease of 79% in the risk for seroconversion after percutaneous exposure to HIV-infected blood in a case-control study.²⁶ The potency and toxicity of antiretroviral drugs are known from studies of HIV-infected patients, but it is uncertain how this information applies to non-infected individuals. In HIV-infected patients, combinations of AZT and other nucleosides such as lamivudine (3TC) are more effective than AZT alone. Adding a protease inhibitor such as indinavir (IDV) further increases antiretroviral activity. Such combined therapy is now recommended for health-care workers after the highest risk exposures, such as percutaneous injection of a larger volume of blood containing a high titre of HIV. This prophylaxis should be offered after lower risk exposures to either a significant volume of blood or to blood with a high titre of HIV, but not when neither of these major risk factors is present.⁴² Expert advice is needed for other situations, with counselling and information on drug effi-

ciency and potential toxicity. Ideally, prophylaxis should begin within two hours of exposure, which means that an emergency kit should be available at all times. The optimal duration of prophylaxis is unknown; a minimum of four weeks is indicated if tolerance permits. Prophylactic chemotherapy should be monitored clinically and with HIV-antibody tests at the baseline and every six months after exposure.

Transmission from surgeon to patients. In theory, there is a risk of transmission of HIV from surgeon to patient but it is very small. Six patients were reported to have been infected by one dental surgeon in Florida, but the circumstances of the contamination are obscure.⁴³

Mathematical models of direct transmission from health-care workers to patients suggest that the risk is extremely low. With a surgeon known to be HIV-seropositive, the risk of reverse transmission of HIV to the patient is about 1 chance in 83 000 hours of surgery.⁴⁴

For invasive procedures performed by surgeons of unknown HIV status, the risk of transmission of HIV from surgeon to patient has been estimated at 1 chance per 21 million hours of surgery with an upper-bound 95% risk of 1 in 4 million.⁴⁴ This would imply that it is not justified to restrict the work of persons infected with HIV.

A survey in the USA found no case of HIV transmission in 22 171 patients treated by 51 HIV-positive health-care workers.⁴⁵ This contrasts sharply with data on hepatitis B: 42 HBV-positive health-care workers, including 38 surgeons, have been shown to have contaminated 375 patients during surgical procedures.⁴⁵ This difference is due to the higher level of viraemia in HBV and the greater stability of the virus, which remains active in the environment, such as on surgical instruments. By contrast, HIV is extremely labile.

AIDS and professional activity of health-care workers. Occupational infection with HIV is not only a medical problem; it is a personal tragedy in physical, psychological, social, professional and financial terms. The relatively few cases so far in Europe mean that there are no agreed actions, and the situation will differ from one country to another. Such situations are usually handled with extreme confidentiality; neither the health-care worker nor the institution will wish to publicise such an accident.

In some European countries, occupational infection with HIV has not yet been recognised as an occupational disease, in contrast to infections with hepatitis-B or hepatitis-C. It is treated as an occupational accident. This is more than a semantic distinction since different legislation applies. Compensation for occupational accidents is the responsibility of the employer, who has a legal obligation to cover all personnel by insurance. This does not apply to surgeons working independently. They must have social-security coverage, but may or may not have optional insurance covering occupational accidents. By law, compensation for HIV infection cannot be excluded from any

such contract, either individual or institutional, in several European countries.

A salaried health-care worker infected with HIV by occupational exposure will receive fair compensation, by legislation, but seroconversion is nevertheless a tragedy, for many reasons.

There is no moral compensation for a ruined private life in terms of interference with sexual activity or pregnancy, and the prospects of divorce, depression and the hardship of continued follow-up and treatment. Although present legislation has made illegal any form of discrimination by the employer on the basis of HIV status, an infected worker will probably be smoothly put aside from any activity that involves physical contact with patients. Any opposition to this will cause moral pressure from the employer, and may eventually result in the loss of occupation, for an official reason other than HIV status. In this situation the worker will not be entitled to compensation unless physically incapable. In theory, seroconversion of a health-care worker should not be reported to the employer, but in these circumstances it is clear that confidentiality is pure myth.

No European country is known to have introduced a legal obligation to inform patients of the HIV status of health-care workers and particularly of surgeons, but this may happen in the future. In some countries it is already a requirement of law to recall all patients who have had invasive procedures involving a seropositive doctor or worker and to offer them HIV tests. Such an action is incompatible with confidentiality; it penalises seropositive health-care workers and may discourage others from discovering their own HIV status or reporting a seroconversion.

Such review studies are extremely expensive and probably not worth the cost. No single case of reverse HIV transmission has been documented in several such studies to date.^{45,46} The cost of a single study may be high, in excess of 150 000 Euros.⁴⁶ From a scientific viewpoint, there are no grounds spending so much money on useless investigations, and the main justification of these reviews appears to be self-protection against the media.

Compensation by an insurance company is usually based upon precise requirements including immediate declaration of the contaminating accident, demonstration of HIV-negative status within eight days of the event and of seroconversion within six months. It is also necessary to show that the source patient was HIV-positive at the time or within six weeks of the infecting incident.

An insurance company will be even more reluctant to accept an occupational HIV seroconversion which cannot be referred to a specific injury but only unreported exposures to blood from patients who were certainly, probably or possibly HIV-positive.

Accidental exposures to blood are notoriously under-reported, especially by surgeons. This creates administrative problems after HIV seroconversion, and it is not reasonable to test HIV status after every exposure to blood.

To consider HIV seroconversion as an occupational accident seems unsatisfactory. It would be better if the health authorities recognised HIV infection as an occupational disease. All salaried personnel, including the nurses and technicians who account for most of the cases reported, and salaried surgeons would then be covered. Surgeons working independently should seek adequate insurance coverage, while understanding the practical problems of proof mentioned above. The major implications for a surgeon of a reported HIV conversion make under-reporting and accidental exposure even more likely.

An HIV-positive surgeon does not provide a significant public-health problem; the risk of HIV transmission from surgeon to patient is very limited, but it may cause social and medicolegal complications. For an average patient, psychological 'significance' is very different from statistical significance: words are just as frightening as facts. Self-disclosure of HIV-seropositivity by a surgeon to his prospective patients may be regarded by certain courts as a necessary element of informed consent, however small the risk of HIV transmission. Some patients have already claimed compensation from a surgeon, alleging that emotional injury resulted from the retrospective discovery of the surgeon's HIV-positive status and that emotional damage continued through the serological 'window period'. Any surgeon who notifies prospective patients of his own seropositivity before invasive procedures is likely to lose his practice very quickly. This is still a contentious and unsolved issue.

The great concern about occupational HIV infection of health-care workers stems from the perception that HIV seroconversion was a delayed death penalty. Effective anti-retroviral therapy may substantially change this view. It reduces the risk of seroconversion after exposure by keeping a low titre in the source patient's blood and by prophylaxis after exposure.

Most occupational HIV infections have followed exposures outside surgical settings, affecting nursing personnel by needlestick injury with a hollow needle in 85% of cases. Much attention and expense have been devoted to reducing risks at operation, and the needlestick problem has not yet been properly addressed. Alternative methods, such as needle-less intravenous infusion systems, should become more widely used; self-capping needles should replace conventional ones.

Concern over HIV infection should not divert attention from the risk of acquiring hepatitis infection under similar conditions. Viral hepatitis is caused by at least five distinct viruses, two of which (HBV, HCV) provide a significant threat to health-care workers as they can be transmitted by percutaneous exposure to blood or blood-contaminated objects. Studies conducted before a vaccine against HBV became available showed a prevalence of past or present HBV infection in surgeons of between 13% and 18%.¹ These studies also showed that 0.8% to 4.0% of health-care workers were chronically infected with HBV, compared

with 0.3% of the general US population.¹ Shapiro¹ calculated that among the estimated 136 000 individuals who acquired HBV infection in 1994 in the US, there were 1012 health-care workers, of whom approximately 22 would die of the acute and chronic consequences of HBV infection. More pessimistic figures were put forward by Panlilio et al,³³ quoting data from the CDC; the latter had estimated that, in 1991, 5100 health-care workers acquired HBV infection, of whom 125 would die as a consequence.

Approximately 90% to 95% of acute infections by HBV are self-limiting, and infected persons clear the virus from their bodies and have lifelong immunity against HBV. The other 5% to 10% develop chronic infection. They remain serologically positive for hepatitis B surface antigen (HB_s Ag); about a quarter of them progress to chronic active hepatitis. These have an estimated 20% lifetime risk of dying of cirrhosis and 6% risk of dying of hepatocellular carcinoma.¹

The usual route of transmission to health-care workers is by percutaneous exposure to blood. The viral titre is often very high (10^8 to 10^9 particles per mm³) and the risk of transmission is at least 30% after a needlestick exposure with blood from an HBe-Ag positive source, but less than 6% with HBe-Ag negative blood (HBe Ag is a marker associated with high circulating viral titres). Transmission through mucous membranes or non-intact skin has also been reported. HBV is relatively stable in the environment; it can remain infective in dry blood for up to one week.¹

Hepatitis B vaccine has been available since 1981; it gives efficient protection in more than 90% of recipients. Several surveys had shown, however, that a significant proportion of surgeons had not received the vaccine. In a survey made at the 1991 AAOS Convention, it was found that 90% of surgeons under 29 years of age had received the vaccine, but 35% of those aged 60 years or more had not. Not surprisingly, the prevalence of previous infection with hepatitis B increased with increasing age, from 3% under 29 years to 27% above 60 years of age.⁴⁷ In another survey on hospital-based surgeons, 25% of surgeons who had practised for ten years or longer had not received the vaccine and were still susceptible to HBV infection.³³

It is likely, however, that most surgeons will eventually be immunised against HBV due to the high use of the vaccine in younger surgeons. All other health-care workers who anticipate contact with blood or other potentially infectious material should receive hepatitis B vaccine during training or early in their careers.

Following infection by HCV, symptoms of acute hepatitis occur in 25% or fewer persons. It is believed, however, that most individuals infected with HCV will develop chronic HCV infection with persistent viraemia, despite the absence of symptoms at times, and over 60% have ongoing liver injury reflected by elevated liver enzymes. Between 26% and 50% develop chronic active hepatitis and 3% to 26% develop cirrhosis within several years.¹

The major route of HCV transmission is by exposure to blood. The seroconversion rate after a single parenteral exposure has been estimated at 3% and even at 10% based on results from second-generation tests and PCR.⁴⁸ All anti-HCV-positive persons should be considered potentially infectious, although the virus titre in hepatitis C is usually low compared with that in hepatitis B. Environmental transmission is not important, since HCV is relatively fragile.

Among the risk factors, the prevalence of anti-HCV antibodies in patients remains uncertain with figures ranging from 0.5% to 18% reported.⁴⁹⁻⁵¹

Studies on anti-HCV prevalence among health-care workers also give diverging results ranging from 0% to 1.7%.^{1,33,52-54} This may reflect different study locations and risk factors but also the use of different anti-HCV tests.¹

Contrary to HBV, HCV infection does not seem to result in the development of protective antibodies. Postexposure prophylaxis with immunoglobulins has been found to be ineffective¹ and administration of antiviral agents such as alpha interferon is not recommended.⁵⁵ Preventive measures rely essentially on universal precautions used to maintain a barrier and avoid skin breaks. The risk reduction strategy being developed for HIV should thus also be directed towards HBV and HCV transmission.

Transmission of viral disease through musculoskeletal allografts

It has been established from case reports that HIV as well as HBV and HCV can be transmitted through musculoskeletal allografts.⁵⁶⁻⁵⁹ Knowledge gained from these historical cases has been instrumental in defining guidelines which have since been issued by the American Association of Tissue Banks (AATB)⁶⁰ and by the European Association of Musculoskeletal Transplantation (EAMST).⁶¹

The risk can originate from several factors:

1) Screening of potential living donors is based on the medical history and medical records, which may not be available or reliable, and also on serological tests which may be negative if the donor is in the window period between infection and seroconversion. Every donor of surgical bone should be screened for anti-HIV, anti-HB_c Ag and anti-HCV antibodies and for HB_s Ag at the time of procurement and the tests should be repeated after six months, during which the allografts, typically femoral heads, will be kept in quarantine. This applies to unprocessed deep-frozen allografts. If processing and secondary sterilisation are performed, these precautions may be redundant but each procedure used must be thoroughly validated.^{62,63} After thorough screening, the risk of procuring bone from an HIV-infected donor has been estimated by Buck, Malinin and Brown⁶⁴ to be one in 1 667 600, but the risk may be as high as one in 161 if appropriate techniques are not followed.

2) Neither HIV nor HBV/HCV is destroyed by deep freezing; unprocessed deep-frozen allografts are potentially infective if they have been procured from untested donors or from donors in their seronegative window.

3) Allograft processing using physical and chemical agents can reduce or eliminate the risk of viral transmission as follows:

a) Mechanical removal of the bone marrow, blood and soft tissues by high-pressure washes with sterile water and alcohol rinses will reduce the viral load.

b) Ethylene oxide has been shown to inactivate HBV, HCV and HIV, but is not used any more in tissue banking since residuals of the gas have been shown to elicit adverse inflammatory reactions.⁶⁵

c) Irradiation can kill HIV, HBV and HCV, but the amount of radiation necessary to achieve a sterile state, defined as a one in a million chance of a viable organism being present on the irradiated object, depends on the radiosensitivity of the virus considered and the number of organisms in the tissue. Doses ranging from 10 to 40 kgrays have been advocated and it must be realised that irradiation does not achieve absolute sterility; the latter is defined in terms of probability.⁶⁶ It must also be realised that irradiation with high doses adversely affects the mechanical properties of cortical grafts.⁶⁷ Hence, a number of tissue banks have chosen not to use irradiation but to rely on donor screening, which is an essential step in the procedure in any case.

d) Heating by thermoincubation at 80°C⁶⁸ or autoclaving at 121°C⁶⁹ can kill HIV, HBC and HCV. The autoclaving cycle should be adapted to the volume of the allograft processed, so that the required temperature is maintained in the core of the graft for a sufficient amount of time. Thermoincubation at 80°C can destroy HIV but 100°C appears to be necessary for HBV and HCV. Autoclaving has been shown to affect adversely the mechanical properties of a bone allograft, particularly as the temperature becomes higher. This may be a problem with massive cortical allografts used in some revision arthroplasties, but less so with cancellous chips used for impaction bone grafting or filling contained defects. Prions are heat-resistant; their inactivation requires at least autoclaving at 134°C for 30 minutes.⁷⁰

4) No case of viral transmission has been reported using freeze-dried allografts.⁷¹ This may be explained by the fact that such grafts are usually processed before freeze-drying. This process may also have a beneficial effect but its possible mechanism is unknown.

In the case of a concomitant organ tissue donor, similar serological testing should be performed and the recipients of vascularised organs from the same donor should undergo screening; in immunosuppressed patients, seroconversion should have occurred by three months. If the recipients test negatively by that time, musculoskeletal grafts may be used with minimal risks.

If musculoskeletal allografts are procured from cadaver

tissue donors, this procedure is not applicable and the initial serological screening should be expanded to detect viral antigens using PCR.⁶² If these tests do not show clearly negative results, tissues must be rejected or processed and sterilised as discussed earlier.

The patient must be informed about the risk of viral infection through an allograft before surgery and must have given informed consent. More than one million musculoskeletal allografts have been implanted worldwide.⁷¹ There are large variations between countries, centres and surgeons in the frequency of use of allografts. Alternative techniques are often available, and the use of an allograft therefore imposes optimal conditions of security. Even if the risk of viral transmission through an allograft may be considered remote with the current standing of tissue-banking, a patient may still prefer not to receive one. The risks linked to anaesthesia or thromboembolic disease cannot be avoided, but the use of an allograft should be an active choice. How complete should information for the patient be? The average candidate for surgery has heard of AIDS and hepatitis, but is unlikely to know of HTLV-1, a blood-borne retrovirus which may be responsible for adult T-cell leukaemia and, more rarely still, for another form of myelopathy with an incubation period of between ten and 30 years. Testing for anti-HTLV1 antibodies has been introduced in the serological screening of potential donors and is a legal requirement in France, but its transmission through cadaver tissue has not been documented.

The agent responsible for Creutzfeldt-Jacob disease can in theory also be transmitted through an allograft⁷⁰ although no such case has ever been reported. There is presently no serological assay to detect antigens or antibodies against this agent, and the processing and sterilising techniques usually used in tissue-banking do not seem to be efficient against the prions that are considered responsible for the disease. It appears to be difficult to quantitate the risk at the present time, due to lack of documentation.^{62,70}

Conclusions

The emergence and spread of HIV provide a new threat to surgeons and other health-care workers exposed to the risk of occupational infection and seroconversion. It is uncertain how many will be affected, but the theoretical lifetime risk to an orthopaedic surgeon can be calculated from estimates of prevalence in patients, the frequency of accidental exposures to blood, and of seroconversion after one exposure. This life-time risk lies between less than 0.01% and 12.0% depending on the population served and the type of surgery. Until vaccination becomes available, protection against HIV transmission is important. Systematic testing of patients before operation is not effective, but the use of precautions to reduce accidental exposure to blood is important.

Occupational HIV infection of a health-care worker

should be considered an occupational disease, as for hepatitis-B or hepatitis-C. The chemotherapy now available can reduce the risk of seroconversion after exposure. Prophylactic treatment after exposure is effective and should be used when there are very high risk factors. These approaches in developed countries will help to end the contentious atmosphere which has entered the relations between patients and surgeons concerning HIV. This was caused by regulations produced hastily under emotional pressure from the media and from AIDS activists.

The AIDS issue should not divert attention from the issue of viral hepatitis, which has never provoked great interest in the media but is a serious threat to health-care personnel.

Vaccination against hepatitis B virus should become generalised in these individuals including surgeons, during their training or early in their career. The only efficient protection against HCV is now provided by strict compliance with universal precautions which aim at preventing contact with patients' blood by avoiding skin breaks and by establishing a barrier between the health-care worker and the patient's blood.

The risk of viral transmission from surgeon to patient is virtually non-existent as regards HIV, but is significant with HBV and HCV.

HIV as well as HBV and HBC, can also be transmitted through musculoskeletal allografts, as has been established by historical case reports, but the risk may be considered remote with the current standard of tissue banking.

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