Ann. Occup. Hyg., Vol. 52, No. 7, pp. 615–622, 2008

doi:10.1093/annhyg/men044

Determination of Risk of Infection with Blood-borne Pathogens Following a Needlestick Injury in Hospital Workers

SABINE WICKER[1,2]*, JINDRICH CINATL[2], ANNEMARIE BERGER[2], HANS W. DOERR[2], RENÉ GOTTSCHALK[2] and HOLGER F. RABENAU[2]

[1]*Occupational Health Service, University Hospital, Johann Wolfgang Goethe University of Frankfurt, Theodor-Stern-Kai 7, 60590 Frankfurt/Main, Germany;* [2]*Institute of Medical Virology, University Hospital, Johann Wolfgang Goethe University of Frankfurt, Paul-Ehrlich-Strasse 40, 60596 Frankfurt/Main, Germany*

Received 27 March 2008; in final form 19 June 2008; published online 29 July 2008

Objectives: Our paper measures the prevalence of hepatitis B virus (HBV), hepatitis C virus (HCV) and human immunodeficiency virus (HIV) in patients at the University Hospital of Frankfurt/Main, and correlates the prevalence with risk factors for exposure to and infection of healthcare workers (HCWs). Individual risk assessments were calculated for exposed HCWs.

Methods: Survey of patients admitted to a German University Hospital. Markers for HBV, HCV and HIV were studied and evaluated statistically. Data on needlestick injuries (NSIs) among HCWs were correlated with the prevalence of infectious patients.

Results: The HBV, HCV and HIV prevalence among patients at the University Hospital were 5.3% (n = 709/13 358), 5.8% (n = 1167/20 163) and 4.1% (n = 552/13 381), respectively. Our results indicate that the prevalence of blood-borne infections in patients was about nine times higher for HBV, ~15 times higher for HCV and ~82 times higher for HIV than in the overall German population. The highest risk of acquiring a blood-borne infection via NSI was found in the department of internal medicine due to increased prevalence of blood-borne pathogens in patients under treatment.

Conclusions: While accidental NSIs were most frequent in surgery, the nominal risk of blood-borne virus infection was greatest in the field of internal medicine. The study underlines the importance of HBV vaccinations and access to HIV-post-exposure prophylaxis for HCWs as well as the use of anti-needlestick devices.

Keywords: blood-borne viruses; healthcare workers; occupational infections

INTRODUCTION

The problem of viral hepatitis and human immunodeficiency virus (HIV) in hospital populations around the world has been exhaustively studied, especially because of the fact that hospitalized patients overall, and in particular certain high-risk patients, represent a possible source of infection for healthcare workers (HCWs). Epidemiological studies on the prevalence of infectious diseases have already been published, covering isolated groups of high-risk patients (Kelen *et al.*, 1992; Montecalvo *et al.*, 1995; Weber *et al.*, 1995; Koulentaki *et al.*, 2001), HCWs (Cooper *et al.*, 1992; Fisker *et al.*, 2004; Wicker *et al.*, 2007) as well as the general German population (Thierfelder *et al.*, 2001).

It remains a challenge in term of counseling individual caregivers with respect to their own personal risk of infection, e.g. after a needlestick injury (NSI). This information, in turn, might drive their difficult decisions (e.g. whether or not to take antiretrovirals, whether or not to breast-feed for recent or soon to be lactating mothers and a host of other life decisions) (Aiken *et al.*, 1997; Beltrami *et al.*, 2000; Dement *et al.*, 2004; Panlilio *et al.*, 2004; Lee *et al.*, 2005; Gershon *et al.*, 2008, 2004, 1995).

Germany has a low prevalence of blood-borne infections. The prevalence of antibodies to hepatitis core antigen (anti-HBc) among the German

*Author to whom correspondence should be addressed.
Tel: +49-69-63014511; fax: +49-69-63016385;
e-mail: Sabine.Wicker@kgu.de

population is ~5 to 8%; the prevalence of HBs antigen (HBsAg) is ~0.4 to 0.8%. The prevalence of hepatitis C virus (HCV) in the general population in Germany has been estimated at at least 0.4–0.7%, with nearly 400 000–500 000 virus carriers—both for hepatitis B virus (HBV) and HCV. The prevalence of antibodies to HIV among the German population is ~0.05%; with about 56 000 people infected with HIV (RKI, 2008).

HCWs are at risk for blood-borne infections, like HIV and viral hepatitis, and can also act as focal points in their onward transmission. In the last decades in Germany, only a small number of transmission of blood-borne viruses from HCWs to patients was reported (three HCWs who infected 63 patients with HBV and five HCWs who infected 11 patients with HCV) (Roß and Roggendorf, 2007).

A vaccination is one of the best methods of protection against blood-borne infections. Vaccinations, however, are currently only available for HBV.

Occupational exposure to blood-borne pathogens can result from NSI, mucocutaneous contact or blood contact with non-intact skin. In Germany, ~500 000 NSIs occur among HCWs each year (Hofmann *et al.*, 2002). This exposure can lead to infections with HBV, HCV and HIV and other blood-borne pathogens, e.g. cytomegalovirus, herpes simplex virus and parvovirus B19.

The risk of transmission of hepatitis B infection by an NSI is up to 30% for susceptible HCWs without post-exposure prophylaxis (PEP) or sufficient hepatitis B vaccination (Hofmann *et al.*, 2002; Deisenhammer *et al.*, 2006). The risk of a HCV infection is estimated at between 3 and 10%, it increases >10-fold if the source patient has high levels of virus load (Trim and Elliot 2003; Hanrahan and Reutter 1997, Yazdanpanah *et al.*, 2005). A lower risk of infection is found for HIV, at <0.3% (Cardo *et al.*, 1997).

In other parts of the world, the risk factors for transmission (e.g. use of safety needles, pre-vaccination, rapid and appropriate post-exposure follow up, etc.) of blood-borne viruses among HCWs are much higher. Each year, ~66 000 HBV, 16 000 HCV and 1000 HIV infections were estimated to occur among HCWs worldwide due to their occupational exposure to percutaneous injuries (Prüss-Üstün *et al.*, 2005).

We recently completed a separate study on the incidence of NSI in HCWs at the University Hospital at Frankfurt/Main (Germany) (Wicker *et al.*, 2008). In this paper, we extended our research to cover the prevalence of virus carriers (HIV/HBV/HCV) among patients in different departments of the University Hospital who gave blood for laboratory tests. The aim was to determine individual risk of infection, given an exposure with the parameters provided by patient prevalence and the protective factors. We thereby calculated the statistical probability of blood-borne virus infection of HCWs in the classical fields of medicine and surgery and underlined the importance of sufficient preventive measures.

METHODS

Population

The study took place in Frankfurt/Main, Germany. The Johann Wolfgang Goethe University Hospital has 1247 beds, 4080 employees and 12 medical disciplines. There are ~44 000 in-patient admissions (2006) and ~200 000 outpatients.

We analyzed retrospectively the results of virological examinations for HBV, HCV and HIV carried out on blood samples from patients admitted between March 2005 and March 2007.

Data were obtained from blood samples of patients in dermatology, the ear, nose and throat department, gynecology, internal medicine, neurology/psychiatry, ophthalmology, pediatrics' and surgery. In pediatrics, only children >12 months in age were included in the study to avoid the inclusion of maternal antibodies. Blood samples were collected either as a universal testing of all patients (in some parts of surgery) or when ordered by healthcare providers. There were no patient identifiers in the frame of this study because data analysis was done using a statistical program (Viro, Braun, Stockach, Germany) which attributed patient data to the above-mentioned medical disciplines.

A total of 13 358 blood samples from patients were tested for HBsAg. Anti-HCV was tested in 20 163 blood samples and anti-HIV in 13 381 blood samples. In each discipline, and for each parameter, at least 100 blood samples (range 102–5567) were tested.

Data on NSI were obtained in a previous study in 2006–2007 via an anonymous questionnaire covering occupational blood exposure among HCWs in a German University Hospital in the last 12 months (Wicker *et al.*, 2008). Overall, 1342 HCWs from the same eight disciplines as mentioned above took part in the study.

Definition of HCW and NSI

A HCW is defined as an employee in healthcare who comes into contact with patients or patients' body fluids. An NSI is defined as a laceration or puncture with a needle or other sharp instrument contaminated with blood or other bloody body fluids.

Questionnaire on prevalence of NSI among HCWs

Employees of the University Hospital, Frankfurt, Germany, were asked to complete a survey if they held a job that involved direct contact with patients as well as contact with blood or body fluids or sharp objects. Data were obtained between April and June 2006 (anesthesia, dermatology, gynecology, pediatrics and surgery) (Wicker *et al.*, 2008) and between February and April 2007 (ear, nose and throat medicine, internal medicine, neurology/psychiatry, ophthalmology, pathology/forensic medicine and radiology) by an anonymous survey administered to 2085 HCWs [687 (32.9%) physicians, 1205 (57.8%) nurses, 54 (2.6%) cleaners and 139 (6.7%) medical technicians as well as research scientists]. The questionnaire included a brief introduction concerning the potential risk of NSIs. It also covered the incidence, reporting rate, risk factors and exposure mechanisms of NSIs, the procedure and instrument involved in the exposure, the circumstances and mechanisms that were thought to be a significant cause of the exposure, the professional group and, finally, the HBV vaccination status.

If the respondents had any further questions, they could contact the responsible occupational physician. This also applied if they had any other problems, e.g. sustained NSIs or questions about vaccination status and blood-borne infections. The completed questionnaires were collected on the various wards by the occupational physician or returned anonymously via internal mail. Feedback was not compulsory and informed consent was obtained by the participating personnel.

Serological testing

Sera were tested at the Institute of Medical Virology at the Johann Wolfgang Goethe University in Frankfurt/Main. Hepatitis B parameters were analyzed using AxSYM MEIA assays according to the manufacturer's instructions (Abbott, Wiesbaden-Delkenheim, Germany) (HBsAg—AxSYM HBsAg). Hepatitis C-specific antibodies were tested using an automated EIA system (Vitros ECI, Ortho Clinical Diagnostics, Neckargemünd, Germany). Reactive samples were confirmed in the Line Immunoblot Assay (INNOLIA™ Score, Innogenetics, Bayer Corporation, Wuppertal, Germany). Anti-HIV was screened with the AxSYM HIV 1/2 gO MEIA assay (Abbott) and HIV 1/2 assay Vitros ECI automatic (Ortho Clinical Diagnostics). Reactive samples were confirmed in a western blot assay (New Lav Blot I and II, Bio-Rad Laboratories, Munich, Germany).

Risk assessment and statistical analysis

To calculate the nominal risk assessment of occupational exposure (NRE) to blood-borne viruses, the prevalences of HBsAg, anti-HCV and anti-HIV among the patients in the different medical disciplines were multiplied with the prevalence of NSI among HCWs in the corresponding medical disciplines. The formulas used (with specific data for each medical discipline) are

$$\text{NRE for HBV} = \text{HBsAg prevalence} \times \text{prevalence of NSI} \times 1/100,$$

$$\text{NRE for HCV} = \text{anti-HCV prevalence} \times \text{prevalence of NSI} \times 1/100,$$

$$\text{NRE for HIV} = \text{anti-HIV prevalence} \times \text{prevalence of NSI} \times 1/100.$$

For the calculation of the nominal risk of infection (NRI), the HBV-, HCV-, and HIV-specific rate of infection per contaminated NSI was taken into account. This was considered to be 30% for HBV, 3% for HCV and 0.3% for HIV (Cardo *et al.*, 1997). The virus-specific rate was used as multiplier. Excluded from these calculations were the influence of a sufficient HBV vaccination and the effectiveness of a HIV-PEP. Furthermore, our calculations were made under the premise of independent transmission risks. This is, of course, not always accurate because double and triple infections of one patient might occur and so there might be a risk of transmission of HIV, HBV and HCV via a single NSI. The summation of the three virus-specific risk factors was named as 'maximal cumulative risk of infection (HBV, HCV and HIV) (MCRI)'. The formulas used (with specific data for each medical discipline) are

$$\text{NRI for HBV} = \text{HBsAg prevalence} \times 0.3 \times \text{prevalence of NSI} \times 1/100,$$

$$\text{NRI for HCV} = \text{anti-HCV prevalence} \times 0.03 \times \text{prevalence of NSI} \times 1/100,$$

$$\text{NRI for HIV} = \text{anti-HIV prevalence} \times 0.003 \times \text{prevalence of NSI} \times 1/100,$$

$$\text{MCRI} = (\text{NRI for HBV} + \text{NRI for HCV} + \text{NRI for HIV}).$$

For the nominal individual risk assessment for an infection (NIRI) with HBV, HCV and/or HIV, we took into consideration whether a HCW had had a sufficient HBV vaccination and if he or she had had access to HIV-PEP. If a sufficient HBV vaccination existed, the HBV transmission risk was calculated to be zero. Antiretroviral therapy (HIV-PEP) administered within 24–36 h after NSI is associated with an 81% reduction in HIV infection (Cardo *et al.*, 1997; Bassett *et al.*, 2004). Instead of a 0.3% transmission risk, we therefore used a factor of 0.06% in the calculation.

The formulas used (with specific data for each medical discipline) are

$$\text{NIRI (for HBV vaccinated HCW who underwent a HIV-PEP)} = \text{NRI for HCV} + \text{NRI for HIV} \times 0.2,$$

$$\text{NIRI (for HBV vaccinated HCW who did not underwent HIV-PEP)} = \text{NRI for HCV} + \text{NRI for HIV},$$

$$\text{NIRI (for HBV unvaccinated HCW who underwent HIV-PEP)} = \text{NRI for HBV} + \text{NRI for HCV} + \text{NRI for HIV} \times 0.2,$$

$$\text{NIRI (for HBV unvaccinated HCW who did not underwent HIV-PEP)} = \text{MCRI}.$$

We calculated the theoretical risk of acquiring an (HBV, HCV and HIV) infection via a single NSI. The calculation was done by dividing 100 by the ward-specific NIRI value.

For the statistical analysis 95% confidence intervals (CIs) for proportions were calculated using the program BiAS für Windows 8.3 (Epsilon Verlag, Hochheim, Darmstadt, Germany, 2007).

Ethical considerations

The seroprevalence data were collected by retrospective analysis of computer data from the Institute for Medical Virology. The NSI data were collected from a voluntary questionnaire completed by HCWs. Only personnel who gave informed consent participated. However, we can confirm that participants cannot be identified from the material presented and that no plausible harms to participating individuals arise from the study.

RESULTS

The study included 13 358 patients tested for HBsAg, 20 163 patients tested for anti-HCV and 13 381 patients tested for anti-HIV.

The prevalence of HBsAg was 5.3% (n = 709/13 358), for anti-HCV 5.8% (n = 1167/20 163) and for anti-HIV 4.1% (n = 552/13 381).

The prevalence of HBV carriers ranged from 0.95% (95% CI 0.7–1.3) in surgery to 11.35% (95% CI 10.5–12.3) in internal medicine. The prevalence of HIV and HCV seropositive were lowest in surgery (0.34%, 95% CI 0.2–0.6) and ear–nose–throat medicine (1.08%, 95% CI 0.7–1.6). The highest prevalence of HCV and HIV carriers was found in the department of internal medicine (14.62%, 95% CI 13.7–15.6 and 15.4%, 95% CI 14.2–16.9). Prevalence rates of HBsAg, anti-HCV and anti-HIV carriers among the patients of the different medical disciplines are summarized in Table 1.

In a previous study at the University Hospital in Frankfurt, the number of NSI among HCWs was recorded over a 12-month period in 2006–2007. The number of reported NSI was re-evaluated in this study and varied widely across the eight disciplines involved, ranging from 46.9% in medical staff in surgery to 18.7% in pediatrics. Overall, 32.3% (95% CI 29.8–34.9) of respondent HCWs had sustained at least one NSI. Table 2 shows the observed rates of NSI among the different medical disciplines as previously described (Wicker *et al.*, 2008).

The risk of NSI-related viral transmission for HCWs in the different medical disciplines depended on the frequency of NSI and the prevalence of infectious patients. Table 3 presents the risk assessment of

Table 1. Rates of patients tested positive for HBs antigen, anti-HCV and anti-HIV in the different medical disciplines at the University Hospital in Frankfurt/Germany

	HBsAg prevalence		Anti-HCV prevalence		Anti-HIV prevalence	
	%	95% CI	%	95% CI	%	95% CI
Dermatology	1.16 (n = 9/777)	0.5–2.2	2.95 (n = 25/848)	1.9–4.3	3.11 (n = 15/484)	1.7–5.1
Ear–nose–throat medicine	1.15 (n = 2/174)	0.03–6.2	1.08 (n = 25/2306)	0.7–1.6	0.70 (n = 15/2143)	0.4–1.2
Gynecology	1.19 (n = 14/1179)	0.7–2.0	4.31 (n = 35/812)	3.0–5.9	1.18 (n = 7/593)	0.5–2.4
Internal medicine	11.35 (n = 561/4942)	10.5–12.3	14.62 (n = 814/5567)	13.7–15.6	15.4 (n = 438/2832)	14.2–16.9
Neurology/psychiatry	1.38 (n = 18/1300)	0.8–2.2	2.90 (n = 117/4028)	2.4–3.5	2.30 (n = 34/1476)	1.6–3.2
Ophthalmology	3.92 (n = 4/102)	0.5–13.5	5.36 (n = 6/112)	1.1–14.9	5.20 (n = 10/194)	1.7–11.6
Pediatrics	6.06 (n = 65/1073)	4.7–7.7	2.12 (n = 41/1934)	1.5–2.9	1.27 (n = 19/1501)	0.8–2.0
Surgery	0.95 (n = 36/3811)	0.7–1.3	2.28 (n = 104/4556)	1.9–2.8	0.34 (n = 14/4158)	0.2–0.6
Overall	5.31 (n = 709/13 358)	4.9–5.7	5.79 (n = 1167/20 163)	5.5–6.1	4.13 (n = 552/13 381)	3.8–4.5
Prevalence in the German population	0.60		0.40		0.05	

Table 2. Prevalence of NSI among HCWs in various medical disciplines in a German University Hospital in a 12-month period 2006–2007 (Wicker *et al.*, 2008)

	HCWs with NSI		
	%	95% CI	*n*
Dermatology	39.7	27.0–53.4	23/58
Ear–nose–throat medicine	43.5	28.9–58.9	20/46
Gynecology	31.4	21.8–42.3	27/86
Internal medicine	40.2	35.0–45.6	138/343
Neurology/psychiatry	23.9	19.0–29.4	66/276
Ophthalmology	28.6	17.3–42.2	16/56
Pediatrics	18.7	14.4–23.8	53/283
Surgery	46.9	39.7–53.2	91/194
Overall	32.3	29.8–34.9	434/1342

Table 3. NRE to blood-borne viruses (HBV, HCV and HIV) for HCWs in various medical disciplines at the University Hospital of Frankfurt/Germany

	Nominal risk of exposure to		
	HBV (%)	HCV (%)	HIV (%)
Dermatology	0.46	1.17	1.23
Ear–nose–throat medicine	0.50	0.47	0.30
Gynecology	0.37	1.35	0.37
Internal medicine	4.56	5.88	6.19
Neurology/psychiatry	0.33	0.69	0.55
Ophthalmology	1.12	1.53	1.49
Pediatrics	1.13	0.40	0.24
Surgery	0.44	1.07	0.16
Overall	1.70	1.55	0.86

blood-borne infections (HBV, HCV and HIV) among HCWs in the different medical disciplines.

In addition to these risk assessments, the risk of an infection with HBV, HCV or HIV via an NSI varies for each blood-borne virus and is estimated to be at 30% for HBV, 3% for HCV and 0.3% for HIV. The summation of the risks of transmission of HBV, HCV and HIV showed that the nominal highest risk of acquiring a blood-borne infection via NSI was for HCWs in the field of internal medicine. A lower risk was found for HCWs in ophthalmology and pediatrics, while the nominal lowest risk was in dermatology, surgery, ear–nose–throat medicine, gynecology and neurology/psychiatry (see Table 4). Therein it is not taken into account that the exposure time, depth of injury and amount of transmitted blood volume are important factors for the risk of virus transmission.

The nominal individual risk assessment for an infection (Fig. 1) took into account in which department the HCW was working, if he or she had had a sufficient HBV vaccination and if he or she had had access to HIV-PEP.

DISCUSSION

Around 350 million people suffer from chronic HBV infection worldwide, ∼125 million people are infected with HCV and ∼33 million with HIV, making viral hepatitis and HIV two of the world's greatest infectious diseases (Russmann *et al.*, 2007). The rising number of people carrying blood-borne pathogens in the population consequently poses a significant occupational health hazard to HCWs (Weiss *et al.*, 2005). The high frequency of NSI among HCWs should increase the focus on prevention. Despite mandatory classes on exposure and universal precautions, a previous study among professionals at the University of Frankfurt found an under-report rate of 75% (Wicker *et al.*, 2008). However, the prompt reporting of NSI is important, not only for management of the exposure but also for identification of workplace hazards and evaluation of preventive measures (Beltrami *et al.*, 2000). The true number of NSIs sustained by HCWs is still unclear, primarily due to under-reporting and the issue of HCWs seeking care outside of the workplace for a host of reasons.

Several studies have quantified this blood-borne pathogen risk, with some focusing on the frequency of NSI and others concentrating on virus prevalence among patients. However, no study has as yet compiled a correlation of the frequency of NSI among HCWs and the prevalence of virus carriers among patients treated in different medical fields.

The current study presents data on the prevalence of blood-borne viruses in patients, as well as risk factors for transmission among HCWs in a German University Hospital. The prevalence of HBV, HCV and HIV among patients who were tested for these infections of the University Hospital Frankfurt/Main was 5.3% (ranging from 0.95 to 11.35% in the different disciplines), 5.8% (ranging from 1.08 to 14.62%) and 4.1% (ranging from 0.34 to 15.4%), respectively. Our results indicate that the overall prevalence in patients with blood-borne infection was about nine times higher for HBV, ∼15 times higher for HCV and ∼82 times higher for HIV, compared with the general German population (Table 1).

Similar data were published in several other studies, which showed that the prevalence among patients in the different hospitals and countries was always higher than in the general population (Kelen *et al.*, 1992; Neto *et al.*, 1995; Vladutiu *et al.*, 2000; Koulentaki *et al.*, 2001; Houston *et al.*, 2004; López *et al.*, 2005; Xeroulis *et al.*, 2005; Russmann *et al.*, 2007; Sit *et al.*, 2007). Thus, given a higher likelihood that an infected individual will require medical treatment, it may be inaccurate to base estimates of blood-borne pathogen incidence on the known estimates in the general population.

Table 4. NRI with HBV, HCV and/or HIV by an NSI for HCWs in the various medical disciplines at the University Hospital of Frankfurt/Germany

	NRI[a] with			MCRI (HBV, HCV and HIV) (%)
	HBV (%)	HCV (%)	HIV (%)	
Dermatology	0.14	0.04	0.004	0.184
Ear–nose–throat medicine	0.15	0.01	0.001	0.161
Gynecology	0.11	0.04	0.001	0.151
Internal medicine	1.37	0.18	0.019	1.569
Neurology/psychiatry	0.10	0.02	0.002	0.122
Ophthalmology	0.34	0.05	0.005	0.405
Pediatrics	0.34	0.01	0.001	0.351
Surgery	0.13	0.03	0.001	0.161
Overall	0.51	0.05	0.003	0.563

[a]The specific risk of an infection via NSI was considered to be 30% for HBV (without HBV vaccination or PEP), 3% for HCV and 0.3% for HIV (without PEP).

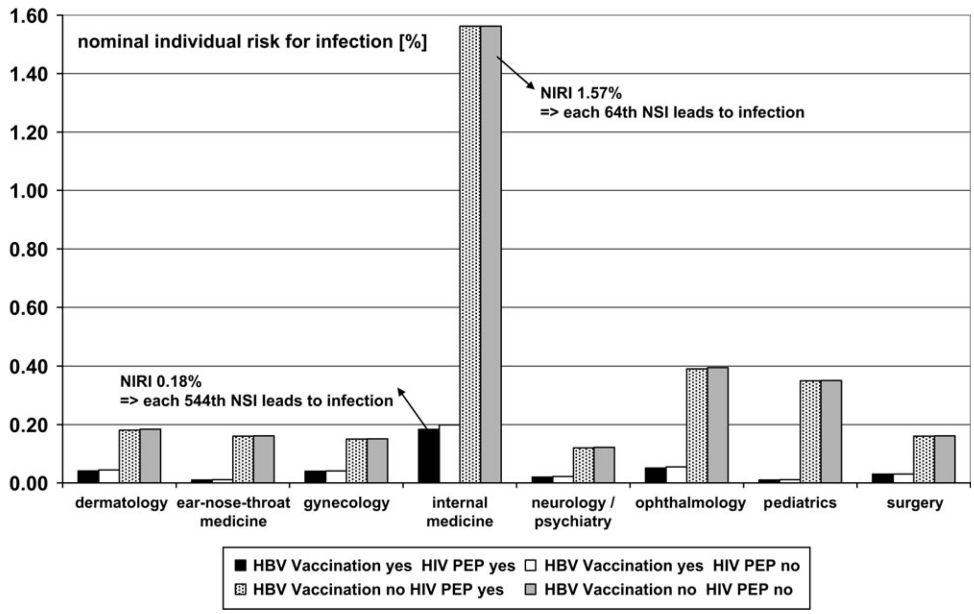

Fig. 1. Individual NIRI with HBV, HCV and/or HIV by an NSI for HCWs in various medical disciplines. The figures take into account whether the HCW had had a sufficient HBV vaccination and utilize HIV-PEP.

The transmission of blood-borne pathogens between patients and HCWs is related to the frequency of exposures that could potentially lead to transmission, the prevalence of disease in the source population, the risk of transmission given an exposure to an infected source (viral load, the depth of the injury and amount of transmitted blood) and the effectiveness of vaccines and PEP (Cardo *et al.*, 1997; Hofmann *et al.*, 2002; Xeroulis *et al.*, 2005).

An important tool to protect HCWs against occupational blood-borne viral infection is universal precautions (e.g. gloves, gowns and facial protection), HBV vaccination and the use of safety devices. These devices are a suitable and important tool in the reduction of NSIs, and the implementation of safety devices should result in an improvement in medical staff's health and safety (Sohn *et al.*, 2004; Tuma and Sepkowitz 2006; Wicker *et al.*, 2008). The use of safety devices is considerably lower in Germany than in US. This may be the reason for the higher injury rate in Germany [500 000 NSIs among 750 000 HCWs (Hofmann *et al.*, 2002)] versus 100 000 to 1 million NSIs among 6 million HCWs in US (Panlilio *et al.*, 2004; Sepkowitz and Eisenberg, 2005).

Previous data have shown that exposure to blood-borne pathogens is an occupational risk for HCWs, with surgeons having the highest rate of NSI compared with other specialists (Wicker *et al.*, 2008). Makary *et al.* recently published the results of a large

US multicenter study on the frequency of NSI among surgeons in training, showing that the frequency of NSI is much higher than commonly assumed. By their final year of training, 99% of residents had had an NSI (Makary *et al.*, 2007).

Summarizing the data of multiple studies (Alter, 2005; Weiss *et al.*, 2007), HCWs have a higher risk of occupational infections with blood-borne viruses in comparison to non-medical employees. But this risk varies widely, depending on the frequency and kind of contacts with potentially contaminated patient material. We therefore calculated a nominal individual risk of exposure (Table 3), comprising the most important risk factors, such as frequency of NSI (Table 2) and prevalence of infectious patients (Table 1). Nevertheless, the potential variability of degree of exposure (i.e. seriousness or severity of exposure, quantity of transmitted blood or contaminated material) was not taken into account. This might vary in the different disciplines, e.g. between internal medicine and surgery. Furthermore, because of lack of data, it was not clear whether multiple needlestick occurrences involved the same patient.

In this study, the nominal highest risk of needlestick-related viral infection (Table 4) was carried by HCWs in the field of internal medicine because of the higher prevalence of blood-borne pathogens in their patients, as well as a high rate of NSI.

The data in Fig. 1 show that without PEP or vaccination, theoretically each 64th NSI among HCWs in the department of internal medicine leads to an infection of one or more of the three major blood-borne viruses (HBV, HCV and HIV). Under the premise of a sufficient HBV vaccination and an 81% fall in the risk of HIV transmission when using a PEP after an NSI (Bassett *et al.*, 2004), the cumulative theoretical risk for the HCW of contracting HCV or HIV via an NSI drops to each 544th NSI in the department of internal medicine (see Fig. 1). This means that the individual risk for an NSI-related infection of HCWs mainly depends on preventive factors such as HBV vaccination and HIV-PEP. The data show that the HBV vaccination has the highest potential to reduce the individual risk of infection by NSI. Besides this, it should be stressed that an important tool to protect HCWs against occupational blood-borne viral infection are universal precautions (e.g. gloves, gowns and facial protection), HBV vaccination and the use of safety devices.

This study has some limitations: First, we covered only a proportion of our patients. A high ratio of the samples were ordered by healthcare providers, which could result in the fact that the prevalence of infection is much higher in this group of patients compared with all hospital patients, this may have unwillingly resulted in selection bias and led to an overestimation of the true seroprevalence rates. Second, data cannot be generalized to cover all German hospitals. Frankfurt/Main is a metropolis city and has one of the highest incidence rates of HBV, HCV and HIV in Germany.

Furthermore, it should be stressed that the transmission of blood-borne viruses is often not an independent risk because double and triple infections of one patient might occur and so the risk of transmitting HIV, HBV and HCV via a single NSI might be possible.

HCWs—especially in an urban university environment—face significant occupational risks through their exposure to HIV, HBV or HCV. A universal strategy for occupational safety is therefore required. Our results underline the importance of the consistent implementation of preventive measurements, such as HBV vaccinations and HIV-PEP, and for the increased use of safety devices to prevent occupational exposures in the healthcare environment. These devices are a suitable and important tool in the reduction of NSI, and their use should result in an improvement in medical staff's health and safety (Clarke *et al.*, 2002; Cullen *et al.*, 2006; Wicker *et al.*, 2008). Universal precautions are a vital part of any comprehensive occupational safety program and should be as sophisticated as possible.

CONCLUSIONS

(i) Our study offers an opportunity to calculate the nominal (individual) risk for exposure of and infection with blood-borne viruses after NSI in a hospital setting.
(ii) The prevalence of blood-borne infection in hospital patients is higher than in the general population.
(iii) Our study underlines the importance of HBV vaccinations and access to HIV-PEP for HCWs and the use of safety devices as the most important measures to prevent blood-borne infections of HCWs after NSI.

Acknowledgements—The authors would like to thank Hanns Ackermann (Department of Medical Information and Biomathematics) for his guidance in the statistical analysis. We also would like to thank Sarah Althaus for her editorial support. We herewith confirm that there are no potential conflicts of interests nor any sources of funding.

REFERENCES

Aiken LH, Sloane DM, Klocinski JL. (1997) Hospital nurses' occupational exposure to blood: prospective, retrospective, and institutional reports. Am J Public Health; 87: 103–7.

Alter MJ. (2005) The epidemiology of hepatitis B virus infection in healthcare workers in the West and Asia. Hep B Annu; 2: 186–92.

Bassett IV, Freedberg KA, Walensky RP. (2004) Two drugs or three? Balancing efficacy, toxicity, and resistance in postexposure prophylaxis for occupational exposure to HIV. Clin Infect Dis; 39: 395–401.

Beltrami EM, Williams IT, Shapiro CN *et al*. (2000) Risk and management of blood-borne infections in health care workers. Clin Microbiol Rev; 13: 385–407.
Cardo DM, Culver DH, Ciesielski CA *et al*. (1997) A case-control study of HIV seroconversion in health care workers after percutaneous exposure. N Engl J Med; 337: 1542–3.
Clarke SP, Sloane DM, Aiken LH. (2002) Effects of hospital staffing and organizational climate on needlestick injuries to nurses. Am J Public Health; 92: 1115–9.
Cooper BW, Krusell A, Tilton RC *et al*. (1992) Seroprevalence of antibodies to hepatitis C virus in high-risk hospital personnel. Infect Control Hosp Epidemiol; 13: 82–5.
Cullen BL, Genasi F, Symington I *et al*. (2006) Potential for reported needlestick injury prevention among healthcare workers through safety device usage and improvement of guideline adherence: expert panel assessment. J Hosp Infect; 63: 445–51.
Deisenhammer S, Radon K, Nowak D *et al*. (2006) Needlestick injuries during medical training. J Hosp Infect; 63: 263–7.
Dement JM, Epling C, Ostbye T *et al*. (2004) Blood and body fluid exposure risks among health care workers: results from Duke Health and Safety Surveillance System. Am J Ind Med; 46: 637–48.
Fisker N, Mygind LH, Krarup HB *et al*. (2004) Blood borne viral infections among Danish health care workers—frequent blood exposures but low prevalence of infection. Eur J Epidemiol; 19: 61–7.
Gershon RR, Vlahov D, Felknor SA *et al*. (1995) Compliance with universal precautions among health care workers at three regional hospitals. Am J Infect Control; 23: 225–36.
Gershon RR, Stone PW, Bakken S *et al*. (2004) Measurement of organizational culture and climate in healthcare. J Nurs Adm; 34: 33–40.
Gershon RR, Pogorzelska M, Qureshi KA *et al*. (2008) Home health care registered nurses and the risk of percutaneous injuries: a pilot study. Am J Infect Control; 36: 165–72.
Hanrahan A, Reutter L. (1997) A critical review of the literature on sharps injuries: epidemiology, management of exposures and preventions. J Adv Nurs; 1: 144–54.
Hofmann F, Kralj N, Beie M. (2002) Kanülenstichverletzungen im Gesundheitsdienst—Häufigkeit, Ursachen und Präventionsstrategien [Needle stick injuries in health care—frequency, causes and preventive strategies]. Gesundheitswesen; 64: 259–66.
Houston S, Rowe BH, Mashinter L *et al*. (2004) Sentinel surveillance of HIV and hepatitis c virus in two urban emergency departments. CJEM; 6: 89–96.
Kelen GD, Green GB, Purcell RH *et al*. (1992) Hepatitis B and hepatitis C in emergency department patients. N Engl J Med; 321: 1399–404.
Koulentaki M, Ergazaki M, Moschandrea J *et al*. (2001) Prevalence of hepatitis B and C markers in high-risk hospitalised patients in Crete: a five-year observational study. BMC Public Health; 1: 17.
Lee JM, Botteman MF, Xanthakos N *et al*. (2005) Needlestick injuries in the United States. Epidemiologic, economic, and quality of life issues. AAOHN J; 53: 117–33.
López L, López P, Arago A *et al*. (2005) Risk factors for hepatitis B and C in multi-transfused patients in Uruguay. J Clin Virol; 34 (Suppl. 2): S69–74.
Makary MA, Al-Attar A, Holzmueller CG *et al*. (2007) Needlestick injuries among surgeons in training. N Engl J Med; 356: 2693–9.
Montecalvo MA, Lee MS, DePalma H *et al*. (1995) Seroprevalence of human immunodeficiency virus-1, hepatitis B virus, and hepatitis C virus in patients having major surgery. Infect Control Hosp Epidemiol; 16: 627–32.
Neto MC, Draibe SA, Silva AEB *et al*. (1995) Incidence of and risk factors for hepatitis B virus and hepatitis C virus infection among haemodialysis and CAPD patients: evidence for environmental transmission. Nephrol Dial Transplant; 10: 240–6.
Panlilio AL, Orelien JG, Srivastava PU *et al*. (2004) Estimate of the annual number of percutaneous injuries among hospital-based healthcare workers in the United States, 1997–1998. Infect Control Hosp Epidemiol; 25: 556–62.
Prüss-Üstün A, Rapiti E, Hutin Y. (2005) Estimation of the global burden of disease attributable to contaminated sharps injuries among health-care workers. Am J Ind Med; 48: 482–90.
Robert Koch Institute (RKI). (2008) HIV/AIDS. Available at http://www.rki.de/cln_049/nn_196658/DE/Content/InfAZ/H/HIVAIDS/hiv__node.html?__nnn = true. Accessed 17 March 2008.
Roß RS, Roggendorf M. (2007) Übertragungsrisiko von HBV, HCV und HIV durch infiziertes medizinisches Personal [Risk of transmission of HBV, HCV and HIV by infected healthcare personnel]. 2nd edn. Lengerich, Germany: Pabst.
Russmann S, Dowlatshahi EA, Printzen G *et al*. (2007) Prevalence and associated factors of viral hepatitis and transferring elevations in 5036 patients admitted to the emergency room of a Swiss university hospital: cross-sectional study. BMC Gastroenterol; 7: 5.
Sepkowitz KA, Eisenberg L. (2005) Occupational deaths among healthcare workers. Emerg Infect Dis; 11: 1003–8.
Sit D, Kadiroglu AK, Kayabasi H *et al*. (2007) Seroprevalence of Hepatitis B and C viruses in patients with chronic kidney disease in the predialysis stage at a University Hospital in Turkey. Intervirology; 50: 133–7.
Sohn S, Eagan J, Sepkowitz KA. (2004) Safety-engineered device implementation: does it introduce bias in percutaneous injury reporting? Infect Control Hosp Epidemiol; 25: 532–5.
Thierfelder W, Hellenbrand W, Meisel H *et al*. (2001) Prevalence of markers for hepatitis A, B and C in the German population. Results of the German National Health Interview and Examination Survey 1998. Eur J Epidemiol; 17: 429–35.
Trim JC, Elliot TS. (2003) A review of sharps injuries and preventative strategies. J Hosp Infect; 53: 237–42.
Tuma S, Sepkowitz KA. (2006) Efficacy of safety-engineered device implementation in the prevention of percutaneous injuries: a review of published studies. Clin Infect Dis; 42: 1159–70.
Vladutiu DS, Cosa A, Neamtu A *et al*. (2000) Infections with hepatitis B and C viruses in patients on maintenance dialysis in Romania and in former communist countries: yellow spots on a blank map? J Viral Hepat; 7: 313–9.
Weber B, Rabenau HF, Berger A *et al*. (1995) Seroprevalence of HCV, HAV, HBV, HDV, HCMV and HIV in high risk groups/Frankfurt a. M. Germany. Zentralblatt Bakteriol; 282: 102–12.
Weiss ES, Makary MD, Wang T *et al*. (2005) Prevalence of blood-borne pathogens in an urban, university-based general surgical practice. Ann Surg; 241: 803–7.
Weiss ES, Cornwell EE, Wang T *et al*. (2007) Human immunodeficiency virus and hepatitis testing and prevalence among surgical patients in an urban university hospital. Am J Surg; 193: 55–60.
Wicker S, Rabenau HF, Gottschalk R *et al*. (2007) Seroprevalence of vaccine preventable and blood transmissible viral infections (measles, mumps, rubella, polio, HBV, HCV and HIV) in medical students. Med Microbiol Immunol; 196: 145–50.
Wicker S, Jung J, Allwinn R *et al*. (2008) Prevalence of needlestick injuries among health care workers in a German university hospital. Int Arch Occup Environ Health; 81: 347–54.
Xeroulis G, Inaba K, Stewart TC *et al*. (2005) Human Immunodeficiency virus, hepatitis B, and hepatitis C seroprevalence in a Canadian trauma population. J Trauma; 59: 105–8.
Yazdanpanah Y, De Carli G, Migueres B *et al*. (2005) Risk factors for hepatitis C virus transmission to health care workers after occupational exposure: a European case-control study. Clin Infect Dis; 41: 1423–30.