EXPOSURE TO BIOLOGICAL AGENTS AND RELATED HEALTH PROBLEMS FOR HEALTHCARE WORKERS

Health effects related to exposure to biological agents in the workplace

Between 2015 and 2017, the European Agency for Safety and Health at Work (EU-OSHA) carried out a project to address the lack of knowledge and awareness of exposure to biological agents and the related health problems, as well as the lack of a systematic approach to workplace prevention in relation to biological agents at work. In 2016, an extensive literature review was carried out on work-related diseases due to biological agents. This research confirmed that workers in the healthcare sector are at a high risk of exposure to biological agents. In addition to the literature review, expert survey and collection of data on health problems and exposure from monitoring systems, information on policy measures intended to reduce the risks posed by biological agents was obtained from interviews with experts and focus group sessions with workplace practitioners. Additional information was gained during a stakeholder workshop in 2017. This article focuses on the healthcare sector and health effects related to exposure to biological agents and summarises some results from this research.

Infections

Table 1 provides an overview of the infectious health effects related to exposure to biological agents in the workplace, reported in reviews published since 2010. In the underlying scientific literature review (EU-OSHA, 2019), the definition of healthcare workers was broad and included, for example, hospital workers; caregivers such as home care workers; dentists; and (para)medical professionals. The table shows that healthcare workers are exposed to a wide range of viruses and bacteria. Infections due to fungi and parasites are less common. The diseases primarily found in this sector are influenza, tuberculosis, hepatitis and HIV infection. Furthermore, the healthcare sector accounted for a considerable proportion of the incidences of hepatitis C, hepatitis A and hepatitis B virus infections in the reported recognised occupational infectious diseases in 12 European countries in 2001 (Karjalainen and Niederlaender, 2004). It is estimated that 14.4 % and 1.4 % of hospital workers are infected with the hepatitis B virus and the hepatitis C virus, respectively. The highest prevalence of hepatitis B virus infection among healthcare workers is reported among dentists. In an evaluation of the development of Hepatitis C worldwide, Alter et al. (2007) found a dramatic increase in infections, with estimations that hepatititis C accounts for 27% of cirrhosis and 25% of hepatic cancer worldwide. Hepatitis C-infected people serve as a reservoir for transmission to others and are at risk for developing chronic liver disease, cirrhosis, and primary hepatocellular carcinoma. Likewise, an estimated 257 million people are living with hepatitis B virus infection (defined as hepatitis B surface antigen positive). In 2015, hepatitis B resulted in 887,000 deaths, mostly from complications (including cirrhosis and hepatocellular carcinoma). The hepatitis B virus can survive in dried blood for up to seven days at 25°C and is significantly more infectious than either hepatitis C or HIV, with a reported transmission rate of up to 30% from needlestick injuries (WHO, 2018).

Table 1: Overview of reported occupations, biological agents and related diseases in the healthcare sector

Biological agent	Occupation	Health effect
Bacteria		
Bacillus cereus	Healthcare worker	—
Bacillus anthracis	Healthcare worker	Anthrax
Bartonella henselae	Healthcare worker	Cat scratch fever

Biological agent	Occupation	Health effect
Borrelia burgdorferi	Healthcare worker	Lyme borreliosis
Brucella spp.	Healthcare worker	Brucellosis
Campylobacter	Healthcare worker	Campylobacter enteritis
Chlamydophila psittaci	Healthcare worker	Psittacosis
Coxiella burnetii	Healthcare worker	Q fever
Francisella tularensis	Healthcare worker	Tularaemia
Legionella spp.	Healthcare worker Healthcare worker (dental care)	Legionellosis
Mycobacterium tuberculosis	Emergency services (ambulance, fire, police, rescue)	Tuberculosis
Mycobacterium tuberculosis/bovis/caprae	Healthcare worker	Tuberculosis
Salmonella spp.	Healthcare worker	Salmonellosis
Streptococcus pyogenes	Healthcare worker	—
Treponema pallidum	Healthcare worker	Syphilis
Multidrug-resistant bacteria		
Methicillin-resistant *Staphylococcus aureus* (MRSA)	Healthcare worker	—
Vancomycin-resistant enterococci	Healthcare worker	—
Fungi		
Sporothrix schenckii	Caregiver	Sporotrichosis
Blastomyces	Healthcare worker	Blastomycosis
Coccidioides	Healthcare worker	Coccidioidomycosis
Histoplasma	Healthcare worker	Histoplasmosis
Indoor moulds	Healthcare worker	Sick building syndrome, asthma, upper respiratory diseases, infections, coughs, headaches and flu-like symptoms, allergic diseases, and irritation of the nose, throat, eyes and skin

Biological agent	Occupation	Health effect
Mycotic agents	Healthcare worker (dental care)	Skin infections (onychoses)
Parasites		
Babesia	Healthcare worker	Babesiosis
Cryptosporidium parvum	Caregiver	Cryptosporidiosis
Cryptosporidium spp.	Healthcare worker	Cryptosporidiosis
Viruses		
Avian influenza virus	Healthcare worker	Avian influenza
Colorado tick fever virus (CTFV)	Healthcare worker	Colorado tick fever
Corona virus A	Healthcare worker	Severe acute respiratory syndrome (SARS)
Crimean Congo haemorrhagic fever virus	Healthcare worker Healthcare worker (dental care)	Crimean Congo haemorrhagic fever
Cytomegalovirus	Caregiver Healthcare worker	—
Dengue virus	Healthcare worker	Dengue fever
Ebola virus	Healthcare worker Healthcare worker (dental care)	Haemorrhagic shock, death
Hantaviruses	Healthcare worker	Hanta
Hendra and Nipah virus	Healthcare worker	Hendra and Nipah virus diseases
Hepatitis A virus	Caregiver Healthcare worker	Hepatitis A infection
Hepatitis B virus	Emergency services (ambulance, fire, police, rescue) Healthcare worker Healthcare worker (dental care)	Hepatitis B
Hepatitis C virus	Emergency services (ambulance, fire, police, rescue) Healthcare worker Healthcare worker (dental care)	Hepatitis C
Hepatitis D virus Hepatitis E virus	Healthcare worker	Hepatitis D Hepatitis E

Biological agent	Occupation	Health effect
Herpes simplex virus	Healthcare worker	Herpes
Herpesvirus B	Healthcare worker	B virus infection
Human immunodeficiency virus (HIV)	Emergency services (ambulance, fire, police, rescue) Healthcare worker Healthcare worker (dental care)	Acquired immune deficiency syndrome (AIDS)
Human parvovirus, parvovirus B19	Caregiver Healthcare worker	Parvo
Influenza virus	Healthcare worker	Influenza
Lassa virus	Healthcare worker (dental care)	Lassa fever
Lymphocytic choriomeningitis virus	Healthcare worker	Meningitis
Lyssa virus	Healthcare worker	Rabies
Marburg virus	Healthcare worker Healthcare worker (dental care)	Haemorrhagic shock, death
Measles virus	Healthcare worker	Measles
Monkeypox virus	Healthcare worker	Monkeypox
Mumps virus	Healthcare worker	Mumps
Newcastle disease virus	Healthcare worker	Newcastle disease
Papillomavirus	Healthcare worker	Plantar, butcher warts
Rift Valley fever virus	Healthcare worker	Rift Valley fever
Rota virus	Healthcare worker	Gastroenteritis
Respiratory syncytial virus	Healthcare worker	—
Rubella virus	Healthcare worker	Rubella
Varicella zoster virus	Caregiver Healthcare worker	Chickenpox, herpes zoster (shingles)
West Nile virus	Healthcare worker	West Nile fever
Yellow fever virus	Healthcare worker	Yellow fever

Note: The literature review did not provide information on specific health effects for all causative biological agents. Where there was no information in the literature, health effects have been identified based on general knowledge if possible, that is, if the biological agent causes one specific disease; for those biological agents that cause a range of health effects, cells have been marked with a dash.

- **Sharps and needlestick injuries**

Healthcare workers worldwide are especially exposed to injury by sharp instruments in the course of their duties. The most frequently executed procedures with injury risk are intramuscular or subcutaneous injection (22 %), taking blood samples or intravenous cannulation (20 %) and repeatedly replacing the cap on an already used needle (30 %) (Goniewicz et al., 2012). De Carli et al. (2014) found that phlebotomy was the procedure carrying the highest risk of exposure and infection, involved in 30–50% of HIV and HCV cases following accidental blood exposures since the 1990s in Italy and France. In laboratories, problems in the management of sharps containers, recapping, needle disassembly by hand and blood transfer from syringes into tubes were observed and accounted for two-thirds of injuries. Sharps and needlestick injuries among healthcare workers are a significant risk for seroconversion of hepatitis and HIV. The amount of publications on this topic identified in the literature search was large.

Table 22 provides an overview of the prevalence data found in the literature examined for hepatitis and HIV seroconversion[1] via sharps and needles.

Table 2: Overview of prevalence data found in literature examined for hepatitis and HIV seroconversion via sharps and needles

Type of injury	Incidence (%)	Hepatitis B seroconversion (%)	Hepatitis C seroconversion (%)	HIV seroconversion (%)	Study
Sharps	3.7	0.42	0.05-1.3	0.04-0.32	Elseviers et al., 2014
Sharps and needlestick		6-30	0.5-10	0.09-0.3	Hadaway, 2012
Needlestick	59 ([a])				Kouyoumjian et al., 2013
Needlestick				0.3 ([b]) 0.09 ([c])	Shrosbree et al., 2011
Sharps and needlestick		10-30	4-10	0.1-0.3	Trevisan, Nicolli and Chiara, 2015
Unsafe sharps handling, mucocuta-neous exposure from body fluid splashes, and glove perforation from excessive wear		2-40	2.7-10	0.3	Tso and Athreya, 2013

([a]) Occupational injuries among healthcare workers are common, although they are underreported. In one study, 59 % of healthcare workers reported a needlestick injury in the previous year.

([b]) Assuming that no post-exposure chemoprophylaxis is given to healthcare workers.

([c]) Risk of mucous membrane exposure.

[1] During an infection or immunisation, antigens enter the blood, and the immune system begins to produce antibodies in response. In immunology, seroconversion is the time period during which a specific antibody develops and becomes detectable in the blood. After seroconversion has occurred, the disease can be detected in blood tests for the antibody.

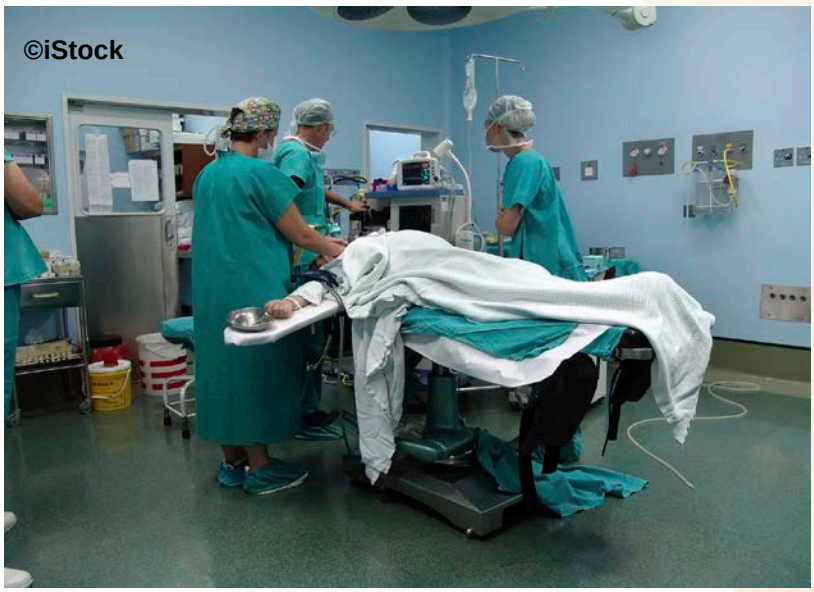
Factors that affect the risk of infection include the type of needle (closed or hollow), the HIV RNA level and the volume of inoculated blood, and the depth of the injury (Shrosbree et al., 2011).

Injuries may also be linked to the use of catheters (Hadaway, 2012), which is increasing, for example in interventional cardiology (Smilowitz et al., 2013). Hepatitis C infections were also linked to dialysis centres (Shaheen and Idris, 2015)

- **Airborne exposure**

Pedrosa et al. (2011) also investigated other exposure pathways for infection with partly serious viral diseases to healthcare and laboratory workers and found that aerosol inhalation was an important pathway too, for example lymphocytic choriomeningitis virus, hantavirus infections, and coxsackievirus infections.

Tuberculosis is one of the best known, most studied occupational respiratory infectious diseases, caused by mycobacteria transmitted through the air. Healthcare workers are a well-known risk group for tuberculosis (Alavi and Alavi, 2013; Brewczyńska et al., 2015; EU-OSHA, 2007, 2009; Haagsma et al., 2012; Ling and Menzies, 2010; Montano, 2014; Narasimhan et al., 2013), and in high-income countries are estimated to be twice as likely to become infected as the general population of the country. In low- and middle-income countries healthcare workers are up to 10 times more likely to become infected with tuberculosis than the general population of the country (Trajman and Menzies, 2010). Among healthcare workers in high-income countries, the overall incidence of tuberculosis in the general population and native-born healthcare workers was less than 10 and 25 per 100,000 per year, respectively (Narasimhan et al., 2013). Eurostat reported in 2001 that in 12 European countries the majority of cases of tuberculosis (88 %) were in health and social care workers and public administration workers (Karjalainen and Niederlaender, 2004). In addition to transmission via the air, entry via the skin due to needlestick injury is described in the literature (Goniewicz et al., 2012; Haagsma et al., 2012), and there are concerns about the possible risks of viable Mycobacteria tuberculosis potentially present in surgical smoke (Chowdhury et al., 2011). Seidler et al. (2005) found the risk of tuberculosis to be elevated in hospital workers in wards with tuberculosis patients; nurses in hospitals; nurses attending HIV-positive or drug-addicted patients; pathology and laboratory workers; respiratory therapists and physiotherapists; physicians in internal medicine, anaesthesia, surgery and psychiatry; non-medical hospital personnel in housekeeping and transport work; funeral home employees; and prison employees.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A significant number of publications are available on the risk of surgical smoke among healthcare workers ([2]) (Chowdhury et al., 2011; Lewin, Brauer and Ostad, 2011; Mowbray et al., 2013; Okoshi et al., 2015; Pierce et al., 2011). Bioaerosols may be produced in surgical smoke generated at low temperatures, for example when using harmonic scissors ([3]), lasers or electrocautery tools (Okoshi et al., 2015). This smoke may contain live multidrug-resistant *Mycobacterium tuberculosis* or viral DNA of hepatitis B virus, hepatitis C virus, HIV or human papilloma virus (Chowdhury et al., 2011; Mowbray et al., 2013; Pierce et al., 2011). However, the evidence of pathogen transmission via surgical smoke is reportedly inconsistent (Pierce et al., 2011),

([2]) Surgical smoke plume is a dangerous by-product generated from the use of lasers, electrosurgical pencils, ultrasonic devices, and other surgical energy-based devices. As these instruments cauterise vessels and destroy (vaporise) tissue, fluid and blood, a gaseous material known as surgical smoke plume is created. It is estimated that approximately 95 % of all surgical procedures produce some degree of surgical plume.

([3]) A surgical instrument used to simultaneously cut and cauterise tissue.

in that some publications state that pathogen transmission occurs via surgical smoke whereas others state the contrary. However, the risk of transmission of an infectious disease if bacterial or viral fragments are inhaled via surgical smoke (Okoshi et al., 2015), is of concern. No epidemiological studies have been conducted with regard to bacterial transfer via surgical smoke (Pierce et al., 2011). However, virological analyses have suggested or confirmed a causative link between occupational exposure to human papillomavirus DNA in the laser plume generated by medical lasers and the occurrence of laryngeal papillomatosis (Pierce et al., 2011). Khajuria et al. (2013) and Mohebati et al. (2010) reviewed prevention measures applicable to surgeons and auxiliary staff.

According to Kuster et al. (2011), healthcare workers are at a higher risk of asymptomatic, but not symptomatic, influenza infection. Their cumulative exposure to influenza (or the influenza vaccine) over time may be higher than that of other workers, so that prior immunity reduces symptom severity.

Furthermore, it is generally accepted that working areas with air-conditioning systems, high humidity or systems containing stagnant warm water are amenable to the growth of Legionella (EU-OSHA, 2011) and that healthcare workers may be at risk. A number of epidemics of legionellosis have been recorded in recent years in the hospital environment in Europe.

Allergens

Workers in the healthcare sector are also exposed to allergenic agents that can cause asthma. An overview of allergenic agents is presented in Table 3. As shown in Table 3, healthcare workers and dental technicians may develop asthma owing to the inhalation of small particles of latex or powder from powdered gloves, which are present in the air after, for example, removing gloves. The literature review also revealed that these healthcare workers may have an anaphylactic reaction as a result of dermal exposure to dust from latex gloves (Moscato et al., 2011; Moscato et al., 2014; Quirce and Bernstein, 2011; Raulf et al., 2011; Raulf et al., 2012; Raulf, 2016).


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Fungal enzymes have a number of applications in healthcare. Fungal enzymes derived from *A. niger* are used in powdered form with other enzyme extracts by pharmacists to prepare digestive powders. Biodiastase and Flaviastase have been associated with sensitisation in hospital workers and pharmaceutical workers. Catalase, a fungal enzyme used in hygiene products, pharmaceuticals, and textiles, has been identified as an allergen in *Metarhizium anisopliae*. the biotechnology and pharmaceutical industries, Glutathione-S-transferase has a number of applications. It has also been identified as a major *Alternaria alternata* allergen and is highly conserved across fungi.

Table 3: Overview of allergenic agents and related diseases related to healthcare professions

Category	Agent	Occupation	Health effect
Biologic enzymes (*) (allergenic)	Empynase (pronase B)	Hospital personnel	Asthma
Plant material (*) (allergenic)	Latex	Dental hygienist	Asthma

Category	Agent	Occupation	Health effect
Plant-derived natural products (*) (allergenic)	Latex	Healthcare worker	Asthma
Plant-derived natural products (*) (allergenic)	Pharmaceutical plants	Healthcare worker	Asthma

Exposure pattern, intentional versus unintentional use and available exposure limits

In the healthcare sector, unintentional exposure takes place through more or less accidental exposure resulting from processes that involve many different microorganisms, or in environments in which biological agents occur naturally because the conditions are favourable for the growth of microorganisms. In cases of unintentional use (not part of the primary process), the risk of exposure is not always obvious, and, since some of the health effects related to biological agents are also rather unspecific, it is hard to estimate how frequently exposure to biological agents leads to disease among healthcare workers. Intentional use may occur in the healthcare sector when microorganisms are used in laboratory settings or when patients with known infectious diseases (e.g. AIDS or Ebola) are treated in specific environments, such as isolation wards. Although it is not always easy to distinguish specific risk factors, workplace risk assessments need to take account of possible exposures, and some tools are available that provide guidance on such assessments.

In the healthcare sector, the extent to which healthcare workers are exposed to biological agents may vary. Some will be directly exposed to infection (e.g. clinical and nursing staff caring for a patient with a bacterial infection such as tuberculosis), while others may be exposed to potential sources of infection (e.g. during the transport of blood samples or other specimens from ward to laboratory, the removal of clinical waste, the cleaning of wards, or surgery). Potential exposure sources include blood, bodily fluids and body parts, excreta (faeces, urine and vomit), direct skin contact, and respiratory secretions and excretions. Each source is likely to be associated with a particular type of microorganism (or group of organisms), characterised in terms of how the microorganism is transmitted, the severity of the disease/symptoms, how easily the disease is spread, whether or not there is a vaccine (or post-exposure prophylaxis) available, and how well the microorganisms survive in the environment (HSE, 2017).

Although substantial information is available on the types and means of exposure in the healthcare sector, quantitative data on exposure and the associated health effects are lacking. Exposures to biological agents are not measured frequently, and there are only a few databases available that contain measurement results Exposure measurement and sampling methods should also cover sectors such as healthcare Therefore, it is not possible to derive actual occupational exposure limits. However, based on the available scientific literature, threshold limits or reference values ([4]) have been derived for bioaerosols in occupational environments. In certain specific environments such as hospital rooms or clean rooms during an operation, these should be within the range of 1.0×10^0-4.0×10^3 colony forming units (cfu)/m³ or $< 1.0 \times 10^0$-1.0×10^3 cfu/m³ respectively. In addition, recommended limits for microbiological contamination of surfaces should be applied in indoor spaces that require high air quality.

Vulnerable groups

Some groups of workers can be considered ‘inherently’ vulnerable, the ‘particularly sensitive risk groups’ (e.g. ageing workers, young workers, female workers). In the case of workers with high levels of exposure, however, their vulnerability can be attributed to the job itself (and possibly to the fact that,

([4]) See the OSHwiki article ‘Bioaerosols and OSH’: https://oshwiki.eu/wiki/Bioaerosols_and_OSH

in the sector in question, the high level of exposure is a result of OSH regulations not being properly implemented). However, there is an overlap between these groups, and the different conditions may interact. Consequently, differences in metabolism, pre-existing health problems — including those caused by work, such as respiratory disorders — the norms of the sector, its safety culture and employment conditions, and the specific conditions of the workplace need to be considered when identifying vulnerable groups.

As in other sectors, in healthcare, trainees and workers in their first jobs are considered vulnerable groups, because they have less practical experience and are generally less aware of the risks. For instance, nurses in training are reported to be a group of young workers in the healthcare sector at risk of hepatitis B infection (Zandi, Alavian and Bagheri-Lankarani, 2011). When medical trainees participate in the healthcare systems of resource-poor countries, they are at considerable risk of contracting HIV and other locally endemic diseases, such as malaria, dengue fever, travellers' diarrhoea, and sexually transmitted infections. They are also exposed to the risk of nosocomial ([5]) transmission of blood-borne or body fluid-borne pathogens such as hepatitis B and hepatitis C (Mohan, Sarfaty and Hamer, 2010).

Groups at particular risk of hepatitis E virus infection and its ensuing complications are elderly men, pregnant women, immunocompromised patients (e.g. transplant recipients and HIV-infected patients), and patients with pre-existing liver disease. Healthcare workers who come into contact with these vulnerable groups of patients are therefore at a higher risk of infection.

As a result of an increase in immunosuppressive treatment methods that enable people with severe autoimmune diseases (e.g. chronic diseases such as diabetes mellitus, renal failure or rheumatic arthritis) to stay in employment and live for longer, there is an increasing risk for healthcare workers. These patients are at an increased risk of infectious diseases in general, which also increases the risk for healthcare workers who come into contact with this group. In addition, any healthcare worker who has a chronic disease and receives immunosuppressive treatment can also be affected.

Furthermore, older workers are generally considered to be more susceptible to health problems, and this group is increasing in size owing to the ageing of the population, including in the healthcare sector.

Pregnant workers are considered a vulnerable group, especially in healthcare. HIV is of great concern to pregnant orthopaedic surgeons, for example, because of the potentially fatal consequences for the foetus if the mother is infected and goes untreated (Keene et al., 2011). However, according to one study, no additional risk with regard to HIV or hepatitis is generally indicated for pregnant or lactating workers (Downes, Rauk and VanHeest, 2014).

Experts consider cleaners to be an important vulnerable group, since they often perform tasks that may put them at risk, such as cleaning or disposing of sharp instruments, which poses a relatively high risk of injury. In addition, there may be less clarity for externally contracted cleaning services, compared with internal cleaning services, with regard to, for instance, who is responsible for providing information about risks and safety measures, the provision of personal protective equipment and the vaccination of personnel. External cleaning services that provide services at different locations need to be prepared for different (organisations within) hospitals that might make working safely more difficult. Therefore, workers from an external cleaning company should be informed of any particular risks that they may be exposed to at a specific location. It must be ensured that the tools that are used for cleaning are adequate and that cleaners follow workplace instructions accurately.

Emerging risks

An 'emerging OSH risk' is any occupational risk that is considered to be new or increasing. Emerging risks include newly created or newly identified risks, increasing risks and risks that are becoming widely known or established. The focus group discussions on emerging risks in the healthcare sector that took place as part of the project highlighted a number of issues, namely antibiotic resistance, infection through blood-borne pathogens, accidental exposure and risks linked to globalisation.

Biological agents with antibiotic resistance, such as MRSA, are considered an emerging risk in healthcare. In Finland, for example, farmers visiting healthcare facilities are considered a group that

([5]) A nosocomial infection, also known as a hospital-acquired infection or HAI, is an infection that is acquired in a hospital or other healthcare facility.

poses a risk to healthcare workers, as they may transmit resistant microorganisms. This is despite the fact that there are no reported cases of MRSA infection in healthcare settings in some countries and the hygienic measures currently applied (e.g. washing hands with antibacterial soap) are considered sufficient. Consequently, experts advise that protocols/guidelines for prescribing antibiotics to patients should be reviewed to ensure that antibiotic resistance is considered. By reviewing the entire chain of events ([6]) regarding the development of multidrug-resistance (a 'helicopter view'), including the use of antibiotics in medical treatment and animal farming (as well as further contamination with resistant microorganisms by, for example, farmers visiting the hospital), improvements can be made to tackle this problem.

Increasing international trade and changing travel patterns, as well as migration flows are considered a huge problem, especially with regard to agents with antibiotic resistance, because they increase the likelihood of the global spreading of diseases. A disease that is present but under control in Europe, for example, may cause health problems in people from other continents because they are not vaccinated against the biological agent that causes the disease, and it may be reintroduced to Europe although it has been controlled or eradicated in Europe. This is the case for example for tuberculosis, influenza or measles. Novel viruses and prions, emerging in various parts of the world may pose a threat to the health and life of healthcare workers and veterinarians. Healthcare workers working abroad are at risk of acquiring some emerging infections such as Middle East respiratory syndrome coronavirus (MERS-CoV), Ebola virus disease (Ebola), severe acute respiratory syndrome (SARS), and avian influenza (Suwantarat and Apisamtharat, 2015) and infection control measures may be limited during an initial encounter, at the beginning of outbreak and with an overwhelming number of patient cases. As was emphasised in the focus groups, in addition, globalisation leads to an increase in travel to other continents, and this is expected to lead to pressure on health systems (i.e. local health systems will have to deal with global health problems). Prevention efforts to address the risk of infection may also be needed among groups of workers who are in first contact with travellers and migrants (e.g. customs and healthcare workers). Lastly, climate changes have led to a wider spread of some diseases previously not endemic in Europe, such as chikungunya fever or tick-borne diseases and this may put healthcare workers at risk. The transfer of biological agents from the Middle East and Africa may need to be given a particular focus.

Infectious diseases transmitted through blood-borne pathogens and accidental exposure were also identified as emerging OSH risks. In relation to accidental exposure, experts indicated that an expected increase in workload may also increase the risk of accidental exposure among workers (higher risk of exposure, more accidents and errors due to stress).

Policy measures (including preventive measures) for the healthcare sector

Infection prevention and hygienic work practices

The measures outlined in Directive 2000/54/EC include special control measures such as containment categories for laboratory work and special attention is paid to healthcare and veterinary care facilities. In addition, Annex I to the directive contains an indicative list of activities that entail exposure to biological agents (i.e. work in healthcare, including isolation and post-mortem units; work in clinical, veterinary and diagnostic laboratories, excluding diagnostic microbiological laboratories). The requirements for notification of selected activities to the authorities are also defined. For workers likely to be exposed to certain biological agents in higher risk categories, employers have to keep records including information on exposure and health surveillance. The regulation sets out minimum requirements that must be implemented in national legislation. However, some EU Member States have introduced more detailed codes of practice and guidelines for the safe handling of biological agents, including guidelines for healthcare occupations. Example are the technical rules for biological agents established in Germany (ABAS/BAuA, 2014). The German GESTIS database (DGUV, 2017; available in English) provides information on typical exposures and links to guidance documents. A similar

([6]) A chain approach involves considering the whole chain of events during which exposure, and thus related health effects, can occur, and enables action to resolve the problem, or, even better, to prevent the problem from occurring, on multiple levels (or links of the chain).

approach was taken in France and Spain, with databases and information sheets providing information related to specific biological agents.

From the literature review and the discussions with experts, it can be concluded that successful policy measures exist in hospitals, focusing primarily on the protection of patients and secondarily on the protection of workers. These measures are aimed, for example, at preventing the spreading of infectious diseases such as influenza through hygienic work practices and the administration of seasonal flu shots. In pandemic influenza situations, an evaluation of personal protection equipment (N95 masks or surgical masks) to protect healthcare workers from influenza infection concluded that ocular protection should also be included to prevent infection via the mucous membrane of the eyes (Gralton and McLaws, 2010).

By monitoring and evaluating incidents, and the implementation of a management system, the prevention measures can be developed further, which leads to correction and subsequent improvement. Healthcare workers must be able to accurately document their exposure; under-reporting, incomplete recall due to stressful situations and non-compliance with protocol are all referred to in the articles and are noteworthy complications.

Healthcare services are known for the high level of implementation of regulation and control measures. In general, the workers active in these sectors are likely to be better trained and more aware of the risks they are exposed to. In some sectors, however, for example in retirement homes, prevention measures such as the hand hygiene of personnel could be improved to prevent epidemics of respiratory and gastrointestinal illnesses among the elderly and workers; this could be done by implementing an intensified information programme about good hand hygiene at work for both personnel and residents.

Several prevention- and policy-related topics were also addressed in the literature. A better understanding of the factors influencing low vaccination take-up among healthcare workers is an important subject for further research. It is not fully understood why there are low vaccination rates for example against influenza and Bordetella pertussis among healthcare workers, as pointed out in some of the research identified in this review, but vaccination rates may be important when it comes to protection of workers and patients.

According to Garg et al. (2012), dental unit waterlines may be a source of infection for patients and for dental workers. They therefore propose a set of hygiene measures to protect both collectives. DeOliveira et al. (2012) and Mitchell et al. (2015) referred to the role of healthcare apparel and clothing in the transmission of pathogens and Yezli et al. (2014) and Volquind et al. (2013) to operating room surfaces, in particular anesthesis equipment which is complex and may be difficult to clean. Ulger et al. (2015) investigated the role of mobile phones in disease transmission, as mobile phones are rarely cleaned after handling. There may be repeated contamination between the hands and face (e.g., nose, ears, and lips). They may transmit microorganisms, including multiple resistant strains, after contact with patients, and can be a source of bacterial cross-contamination. Utsumi et al. (2010) investigated disease outbreaks in elderly care facilities and found a variety of infectious agents with high median attack rates for healthcare workers were caused by *Chlamydia pneumoniae* (41%), noroviruses (42%) and scabies (36%). Furthermore, laundry workers who handle hospital textiles may be at risk of infection from contamination for example by by Sarcoptes scabei, *Microsporum canis*, *Salmonella typhimurium/hadar*, or the hepatitis A virus (Fijan et al., 2012).

Kortepeter et al. (2010) reviewed the risks to healthcare workers in developing-world clinical settings (needlestick injuries, haemorrhagic fever viruses, severe viral respiratory disease, and (multiresistant) tuberculosis), with suggestions for risk mitigation. They highlighted the fact that surveillance systems do not classify this group separately from business or leisure travellers but record them instead as tourists, missionaries, or others. Furthermore, this is a diverse group, ranging from short-term travellers to workers in refugee camps; consequently, their individual activities and travel destinations around the globe pose varied risks.

Hersi et al. (2015) reviewed the protective measures, in particular PPE, for workers caring for patients with diseases such as Ebola and Marburg virus infections, for the WHO guidance on the topic and

recommended provision of training to healthcare workers in affected regions as a “key strategy” for preventing transmission. WHO developed job aids for HCWs on how to put on and remove PPE, and provided training on clinical management to healthcare workers. The case of an auxiliary nurse infected in Spain by an Ebola patient returning from an endemic region (WHO, 2014) illustrates that to avoid cases of serious diseases similar prevention approaches need to be taken in Europe. A preparedness plan is essential to cope with the importation of such diseases and limit their subsequent spread (Wong and Wong, 2015).

- **Prevention of blood-borne infections through sharps injuries**

As blood-borne infections (transmitted by injuries from sharp instruments such as needles) are a clear risk in the healthcare sector, policy measures need to be in place to prevent these infections. The literature review and discussions investigated the reasons for the increased risk and found that many organisations have transitioned to the use of safe needle systems, although this transition is not yet complete within the sector. The availability of these systems on the ‘shop floor’ can be limited, which may be related to both the purchasing policy of the employer (safe needle systems are generally slightly more expensive) and what is offered by the supplier/producer. Producers of these systems may have carried out a cost-benefit analysis of products to determine whether or not the cost of development outweighs the (expected) revenue. Furthermore, it is not always possible to use a safe needle system, for example when a longer needle is needed. For instance, blood is still not taken using safe needles. For some applications, such as flu shots, no safe needle system is yet available. One reason for workers’ non-use of safe needle systems is that they find working with other needle systems easier or more precise, being used to working with these systems.

Several successful policies to prevent blood-exposure accidents and blood-borne infections (e.g. AIDS, hepatitis B) have targeted healthcare professionals. The measures include risk education/information on biological risks, vaccination rules for professional caregivers, the development of protective clothing and equipment, and a national surveillance system for accident types/circumstances that prioritises the prevention of risks. Health professionals are informed about and educated to be aware of infection risks in relation to blood-borne infections, the use of protective equipment, and the importance of vaccination to prevent infections. The vaccination of healthcare staff is common, although the percentage of personnel ‘at the bedside’ that is vaccinated could be higher. Campaigns focusing on vaccination and providing correct and appropriate information to the public are also recommended to prevent false information from spreading. In addition, training on a continuous basis and the repetition of instruction on procedures to all workers (e.g. using training videos) are recommended.

Regarding the prevention of HIV infections among healthcare workers, according to Wild and Dellinger (2013), international guidelines recommend universal screening for HIV in healthcare settings, but only when the undiagnosed prevalence of HIV in the general population is > 0.1 %, or the diagnosed prevalence is > 0.2 %. However, there is no convincing evidence that knowledge of the serostatus of a patient leads to changes in the behaviour of healthcare workers (Wild and Dellinger, 2013), indicating that universal screening may not always be an effective measure. ILO guidelines for improving health workers’ access to HIV and TB prevention, treatment, care and support services provide a framework for workplace policies, programmes, and training (ILO/WHO, 2010) . Rey (2011) reviewed different antiretroviral combinations used after exposure, including of workers, their safety profile, the recommendations and indications of post exposure prophylaxis.

- **Avoiding exposure to multidrug-resistant biological agents**

The prevention of infection with agents with antibiotic resistance (which was identified as an emerging risk) in particular should be improved, which is also mentioned in the section of this article on vulnerable groups. Policies should be developed that reduce the use/prescription of antibiotics (as this is still very common in current protocols that are used in cases of infection); that help to prevent the spread of agents with antibiotic resistance among healthcare workers, between healthcare workers and patients, and within hospitals generally; and that increase immunisation. It is recommended that current guidelines for prescribing antibiotics be checked, to resolve this issue at the source, and that it be taken into account when new guidelines are developed. Furthermore, it is suspected that the readiness with which antibiotics are made available to patients differs within the healthcare sector. It is also suspected that not all patients finish their course of antibiotics, which should also be taken into account. Attention should be given to the admittance of visitors to reduce the risk of their bringing diseases (e.g. multidrug-resistant bacteria) into hospitals. Finally, when setting regulations, the way in which waste is handled

should be considered, to prevent antibiotics being released into the environment. It is important to control the use of antibiotics and ensure registration and recording of cases. In some countries, such as the Netherlands, there is a systematic evaluation of the evolution of antibiotic resistances by a dedicated expert group. This is an area where better collaboration between public health and OSH authorities could be beneficial to monitor the extent of the problem and improve prevention, including targeted measures to protect workers in the healthcare and related sectors.

- **Biological agents in higher risk groups**

With regard to concerns about the increase in the occurrence of biological agents in higher risk group (as detailed in EU Directive 2000/54/EC), it is recommended that smaller hospitals and workers in outpatient care be helped to prepare for exceptional situations, by informing them, as well as larger organisations, on how to act in specific circumstances to prevent infections. There is a clear need for contingency planning for exceptional conditions, such as protecting workers from Ebola. It is also recommended that finance be made available for purchasing appropriate personal protective equipment. Exceptional conditions can also originate from other sectors, such as animal-related occupations and waste treatment. For instance, it is possible that a disease might originate in cattle that must be slaughtered by abattoir workers and the remains disposed of by waste workers. Therefore, contingency plans are needed for these sectors to protect workers from the risk of exceptional outbreaks, and they need to include protection measures for healthcare workers.

Prevention of risks from allergens

In addition to the strict measures recommended above, following the hierarchy of prevention measures, and regarding the use of latex gloves, targeted training courses about the risks posed by allergens (including education on the law, prevention and other information) are recommended for all workers, including those not directly involved in healthcare, such as cleaning personnel. Furthermore, obligatory e-courses and targeted information campaigns are recommended.

Protection of vulnerable workers

Policy measures for vulnerable groups also exist. As pregnancy does not seem to be an independent risk factor for healthcare workers (see the section ‘Vulnerable groups’ above), primary prevention with the use of appropriate infection control precautions and vaccination where indicated is imperative for preventing occupationally acquired infectious diseases among all healthcare workers. Pregnant healthcare workers who are at risk of occupational exposure to communicable diseases should be evaluated immediately for appropriate post-exposure prophylaxis and monitored for the development of an active infection (Lynch and Spivak, 2015). Another vulnerable group is temporary workers. In one of the interviews conducted as part of this project, a Finnish expert described an initiative targeting temporary workers, ‘Best Practice on Sharp Instruments in Healthcare’. This project included the development of new regulations on combined biological exposures and sharp instruments. An element of the project is a video tutorial that is constantly displayed on a monitor in the working area.

Conclusion

Workers in the healthcare sector are clearly at risk of infection from biological agents due to unintentional exposure to bacteria, viruses and fungi. Diseases that occur frequently in this sector include influenza, tuberculosis, hepatitis and HIV infection. Nurses in training are a vulnerable group in the healthcare sector because of their lack of experience. It is recommended that policy measures should target this specific group, such as frequent accompaniment/observation of nurses in training during work procedures by more experienced nurses. The immunosuppressed also warrant attention, as they are more susceptible to infectious diseases and might increase the risks posed to healthcare workers by personal contact. Emerging risks in the healthcare sector are primarily antibiotic resistance and secondarily infection with blood-borne pathogens and the effects of globalisation. Policy measures are in place to prevent antibiotic resistance, but they should be extended, as this risk is still growing. The spread of infectious diseases is often prevented by vaccination. However, healthcare workers who are reluctant to be vaccinated should be made more aware of the risk of infection. A safe needle system is in use in many healthcare settings to reduce the occurrence of injuries from needles, but the use of such systems still needs to be increased and injuries in groups such as cleaners need to be more effectively prevented and monitored. In addition, threshold limits have been derived in certain healthcare

settings. Ideally, threshold limits should be derived for all kinds of healthcare settings and limits for microbiological contamination in indoor spaces that require high air quality should be implemented.

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