RISK OF RESPIRATORY INFECTIONS IN HEALTH CARE WORKERS: LESSONS ON INFECTION CONTROL EMERGE FROM THE SARS OUTBREAK

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Abstract. Close proximity of persons together with handling of human secretions (*eg* respiratory secretions) make health care workers (HCW) particularly vulnerable to transmission of droplet-transmitted respiratory infections. This was tragically highlighted during the international outbreak of severe acute respiratory syndrome (SARS) in 2003 with attack rates of more than 50% in HCW. The purpose of this article is to review common airborne and droplet-transmitted bacterial and viral respiratory tract infections with regard to their impact on health care workers. Lessons need to be learned from the SARS epidemic. The three main strategies to prevent or control occupationally acquired infections are relatively simple and cost-effective-droplet and contact precautions and for some pathogens also vaccination. Enforced implementation of stringent droplet precautions during the SARS crisis should be maintained; and this will most likely have a major additional impact on other nosocomial infections. Employee health services should proactively and creatively devise delivery systems that enhance compliance with vaccination programs for all health care workers. Hospital surveillance should be expanded to all respiratory diseases to facilitate early detection of nosocomial outbreaks, and this should also include surveillance of all HCW. Integrated syndromic and virological surveillance systems set up during the SARS epidemic will also further our understanding of other respiratory infections in the hospital setting. Even if pursuing early diagnosis for unspecific respiratory illnesses is expensive, identification of the causative organism may reduce unnecessary isolation, contact tracing and anxiety, in particular during an outbreak situation. We have a duty to protect our health care workers.

INTRODUCTION

Close proximity of persons together with handling of human secretions (*eg* respiratory secretions) make health care workers particularly vulnerable to transmission of droplet-transmitted respiratory infections. This was tragically highlighted during the international outbreak of severe acute respiratory syndrome (SARS) in 2003 with attack rates of more than 50% in health care workers (HCW) before infection control measures were instituted (Pieris *et al*, 2003). HCW accounted for 20-40% of the total number of SARS patients (Pieris *et al*, 2003). The vulnerability of HCW to this new respiratory disease should raise our awareness that this high-risk group is also vulnerable to other well known respiratory diseases.

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Droplets (>5 μm) are produced when the infected patient talks, coughs, or sneezes, and during some procedures (*ie* suctioning and bronchoscopy). Droplet transmission refers to infection via the projection of microbe-bearing respiratory droplets onto mucous membranes of the eyes, nose and mouth across a short (arbitrarily defined as 1-meter) distance. Examples include bacterial infections such as meningococcal disease, streptococcal infections, pertussis, *Haemophilus influenzae* type B, pneumococcal disease and *Mycoplasma* pneumonia, and viral infections such as influenza, mumps, rubella, parvovirus B19 infections, adenovirus and respiratory syncytial virus (Edmond, 2000). Droplet nuclei transmission, better known as airborne transmission, involves infection via small particles (≤5 μm) which can remain suspended in the air

and travel long distances. Examples include measles, varicella and tuberculosis (Edmond, 2000).

Common infectious respiratory tract diseases are not equally contagious. The likelihood that an organism will spread from one person to another and that disease will result is determined by the number of organisms in potentially infectious secretions, the capacity of these organisms to survive transmission the number required to colonize or infect, the virulence of the clone from which the organism is derived, factors relating to pathogenesis of infection, and the immune status of the host (Musher, 2003).

The purpose of this article is to review common airborne and droplet-transmitted bacterial and viral respiratory tract infections with regard to their impact on health care workers. We will focus on risk of transmission to health care workers and discuss preventive infection control strategies.

BACTERIAL INFECTIONS

Mycobacterium tuberculosis

Tuberculosis (TB) infections are caused by inhalation of droplet nuclei. A patient with pulmonary TB can produce 3,000 infectious droplet nuclei when coughing, a similar number when talking for 5 minutes an equal number, and when sneezing many more than that (Bates, 1993).The air in a room after a patient with pulmonary TB has left may remain infectious even after his or her absence. However, prolonged exposure and multiple aerosol inocula are usually required, and brief contact carries little risk (Bates, 1993). The incidence of *Mycobacterium tuberculosis* infection in HCW varies widely, depending on such factors as patient population and local prevalence of tuberculosis. From 4 to 70% of health care workers exposed to *M. tuberculosis* develop a positive skin test, with the risk being higher for those who perform bronchoscopy (Swinker, 1997). The estimated average lifetime risk of TB infection for hospital workers occupationally exposed to TB ranges from 30 to 386 infections per 1,000 workers (Anonymous, 1997). Without a known exposure, the yearly conversion rate for health care workers averages from 0.1 to 5.0% (Bowden, 1994). The Occupational Safety and Health Administration (OSHA) mandates that health care facilities conduct a risk assessment, perform tuberculosis skin testing at least yearly and develop isolation procedures for potentially infectious tuberculosis patients in hospitals and in some outpatient settings (Anonymous, 1997). OSHA guidelines mandate the use of two-stage testing for tuberculosis in all new employees at risk for *M. tuberculosis* exposure who have not had a PPD skin test in the past year (Anonymous, 1997). When providing care for patients with tuberculosis, health care workers must use fitted respiratory protective devices, such as high-efficiency particulate filters (or other approved masks) or helmet-type, powered air-purifying respirators. Bacille Calmette-Guérin (BCG) vaccine is not routinely recommended for preventive use in health care workers (Anonymous, 1997). However, vaccination may be considered in unusual circumstances, such as for a health care worker with significant repetitive exposure to patients with multidrug-resistant tuberculosis, when isoniazid prophylaxis could be ineffective (Anonymous, 1997).

The CDC has published comprehensive guidelines for control of transmission of TB in health care settings (CDC, 1994); however, severe shortcomings have been identified between guidelines and actual practice in hospitals (Sutton *et al*, 2000).

Bordetella pertussis

Pertussis is a frequent but often underestimated cause of prolonged cough illness in adults and this is thought to reflect waning of the immunity from childhood vaccination (Senzilet *et al*, 2001). Whereas in children pertussis is characterized by paroxysmal cough, whooping cough and posttussive vomiting, in adults the disease is often atypical, sometimes manifesting only with a protracted, nondistinctive cough (Wright, 1998). It remains, therefore, often undiagnosed in adults (Wright, 1998). Numerous pertussis outbreaks have been reported in a variety of healthcare settings, predominantly in pediatric settings and long-term care facilities for the elderly or developmentally disabled (Kurt *et al*, 1972; Steketee *et al*, 1988; Addiss *et al*,

1991). The annual incidence rate of symptomatic and asymptomatic pertussis among residents and emergency department staff was 1.3% and 3.6%, respectively (Wright *et al*, 1999), and this is substantially higher than that recorded among healthcare workers for any other vaccine-preventable disease (except influenza). Adult-type acellular pertussis vaccine confers safe and effective protection against pertussis (Campins-Marti *et al*, 2001). The recent recommendations from the International Consensus Group on Pertussis Immunization state that public health policy makers should target pertussis booster to adult risk groups (Campins-Marti *et al*, 2001). To date, Germany is the only country which recommends that HCW working in pediatric settings and in child-care facilities should be vaccinated (Anonymous, 2000c). France has started recommending adolescents to be vaccinated since 1998 (Anonymous, 2002b). Secondary chemoprophylaxis with erythromycin or another macrolide has been shown to be effective in prevention of disease in those exposed (Steketee *et al*, 1988), and this should be offered to HCW who did not receive an adult pertussis vaccine booster and had known contact with a case of pertussis.

Neisseria meningitidis

Meningococcal nasopharyngeal carriage is the primary source of transmission, and close contact (< 1 meter) with nasopharyngeal secretions or large particle respiratory secretions from a case is necessary (Rosenstein *et al*, 2001). The organism dies quickly in the environment. All reported secondary cases in HCW were due to unprotected airway exposure to nasopharyngeal secretions at the time of admission of a case with meningococcal disease (Stuart *et al*, 2001). Recommendations on chemoprophylaxis for exposed HCW vary between countries and reflect the uncertainty about the degree of risk (Stuart *et al*, 2001). The attack rate has been estimated to be 0.8 per 100,000 HCW at risk (close contact), which is 25 times that in the general population but much lower than that of household contacts (Gilmore *et al*, 2000). The general excess risk compared to the general population is small and, therefore, meningococcal vaccination for all HCW is controversial as the number of cases prevented would be minimal. This excess risk can be reduced by antibiotic chemoprophylaxis prioritised for HCW who have direct exposure to naspharynhgeal secretions from a patient with meningococcal infection (such as suctioning, intubation, etc) (Gilmore *et al*, 2000). Chemoprophylaxis prevents or eradicates colonization in recently exposed HCW and thereby reduces the risk of disease. Masks are recommended when working within 3 ft (1 m) of a patient with meningococcal disease (Garner, 1996).

Streptococcus pyogenes

S. pyogenes proliferates in the pharynx, causing local inflammation and a systemic response (Musher, 2003). Transmission is via intimate contact through the inhalation of or contact with large-droplet secretions. There are several anecdotal reports about clusters of streptococcal disease with spread from patient to health care workers (Schwartz *et al*, 1992; DiPersio *et al*, 1996) and more than 50 nosocomial outbreaks due to group A streptococcus have been reported since 1966 (Weber *et al*, 1996), but there are no data to estimate the incidence in HCW. Streptococcal pharyngitis develops in 40% of persons who become colonized with group A streptococci (Musher, 2003). Nosocomial transmission was described from a single source patient to 24 HCWs and symptoms of pharyngitis developed within 4 days after exposure (Kakis *et al*, 2002). Rapid streptococcal tests may be used for initial screening. Prompt identification and early treatment paired with barrier protection is the best infection control measure (Musher, 2003).

Streptococus pneumoniae

S. pneumoniae (pneumococcus) infection is the leading cause of death among vaccine preventable bacterial diseases in the US (Gardner, 1993). *S. pneumoniae* proliferates in the nasopharynx without recognized invasion or inflammatory response; and disease occurs when organisms are carried to a normally sterile air space (*eg* lungs, sinuses, or middle ear) and are not cleared (Musher, 2003). Colonization and transmission of *S. pneumoniae* occur under the same conditions as *S. pyogenes*, however due to the several steps in the infection process, pneumococcal pneumonia is relatively non-con-

tagious (Musher, 2003). Hospitalized patients with pneumococcal pneumonia are, therefore, generally not isolated (Musher, 2003). There are no published reports on transmission of pneumococcal disease to healthcare workers. However, outbreaks due to *S. pneumoniae* have been reported. In a nursing home, 23% of residents became colonized with a type 23 *S. pneumoniae*, disease developed in the majority of those colonized (Nuorti *et al*, 1998). In view of the low risk, pneumococcal vaccination is not recommended for all HCW, but according to the Advisory Committee on Immunization Practices (ACIP) it should be offered according to HCW with medical problems (such as diabetes, cardiovascular and pulmonary disease, functional or anatomical asplenia).

VIRAL RESPIRATORY DISEASES

Viral infections are generally more contagious than bacterial infections, but depend largely on the level of immunity in the population (Musher, 2003). Inhalation of as few as three infective particles can transmit infection, and the majority of infected persons have symptoms of disease.

Influenza

Influenza outbreaks in hospital settings are well described (Kapila *et al*, 1977; Van Voris *et al*, 1982; Bridges *et al*, 2003) and usually follow community outbreaks. The infectiousness of influenza is greater than that of most other respiratory infections: estimates of the basic reproduction ratio R_0 average around 30 compared to estimates of 3 for SARS (Bowden, 1994). The attack rate of influenza in HCWs during a nosocomial outbreak has been reported to be as high as 60% (Bridges *et al*, 2003). Moreover, HCWs often become the source of nosocomial spread of influenza (Weingarten *et al*, 1989; Elder *et al*, 1996). Mortality rates during nosocomial outbreaks vary according to the patient population and circulating strains, with the highest mortality (up to 60%) reported in the transplant or ICU settings (Meibalane *et al* 1977; Weinstock *et al*, 2000; Malavaud *et al*, 2001). Whilst influenza in HCW is largely a benign self-limiting disease, influenza vaccinations of HCW have a major impact, not only on reduction of febrile respiratory illnesses and days of absenteeism (Wilde *et al*, 1999), but also on the reduction of nosocomial outbreaks inclusive reduction of mortality rates (Potter *et al*, 1997; Bridges *et al*, 2003), particularly in geriatric settings. Since 1981, annual influenza vaccination has been recommended by the ACIP for HCW (CDC, 1988). Although the benefit of annual influenza vaccination for healthcare workers is beyond doubt, vaccine uptake rates among HCW have been low, ranging from 2% to 60% (Serwint *et al*, 1991; Serwint and Miller,1993; Evans *et al*, 1997). Antiviral medication, though effective, can only serve as adjuncts in the overall management during an influenza outbreak.

Avian influenza virus

Recent outbreaks of avian influenza A (H5N1) in poultry throughout Asia have had major economic and health repercussions (Hien *et al*, 2004). The threat of avian influenza virus looms for humans (Anonymous, 2004). Influenza A (H5N1) infection in humans, characterized by fever, respiratory symptoms, marked abnormalities on chest radiography, and clinically significant lymphopenia, carries a high risk of death (Hien *et al*, 2004). To date, there is no definitive evidence of human-to-human transmission nor transmission from patient to HCW. One health care worker died of avian influenza, but he was a veterinarian and had direct contact with infected animals (van Kolfschooten, 2003). However, the potential exists for genetic re-assortment with human influenza viruses and the evolution of human-to-human transmission (Hien *et al*, 2004). Influenza vaccination is recommended to those at high risk (in particular those handling infected poultry, but also HCW in endemic countries) to reduce opportunities for such re-assortment in co-infected individuals.

Adenovirus

In contrast to influenza virus, adenovirus has more genetic stability. This, together with the frequency of subclinical infection, and the persistence of antibody help to explain why adenovirus does not cause epidemic disease (Musher, 2003). Adenovirus has been reported as a cause of nosocomial infections affecting HCW (Brummitt *et al*, 1988; Sanchez *et al*, 1997), and the attack rate in HCW (particularly in oph-

thalmology clinics, ICU and long-term facilities) has been estimated to be 22 to 39% (Sepkowitz, 1996).

Respiratory syncytial virus (RSV)

RSV is most commonly considered a pathogen among infants and young children; however, it can cause serious LRTI throughout life (Anonymous, 2002d). Outbreaks in temperate climates coincide with influenza outbreaks (Zambon *et al*, 2001) and these have been associated with nosocomial outbreaks (Sepkowitz, 1996). Attack rates in HCW between 42-56% have been reported during such outbreaks (Sepkowitz, 1996) and droplet precautions clearly reduce the incidence (Leclair *et al*, 1987).

INFECTION CONTROL STRATEGIES

Airborne precautions require patients to be placed in private rooms with monitored negative air pressure. The door to the isolation room must remain closed. Air from the isolation room should be exhausted directly to the outside, away from air intakes, and not recirculated (Edmond, 2000). N95 masks must be worn at all times when entering the room. N95 masks must be fit-tested to obtain a leakage of 10% or less.

Except for pulmonary tuberculosis and under rare circumstances also for influenza (when major antigenic shift occurs with potential for rapid spread (Bridges *et al*, 2003), droplet precautions are sufficient for most respiratory infections which may put HCW at risk. Droplet precautions require patients to be placed in a private room, but no special air handling is necessary (Edmond, 2000). Cohorting patients with the same disease may reduces the number of required isolation rooms. (Bridges *et al*, 2003). Surgical masks can protect HCW against droplet transmission (Chen and Willeke, 1992). HCW should wear a mask when entering the room of patient with droplet-transmitted infections (Edmond, 2000). When the patient is transported out of the room, the patient should be fitted with a standard surgical mask. N95 masks are only required for airborne diseases, however during procedures associated with increased aerosolization of droplet transmitted infections (such as intubation, nasopharyngeal aspiration etc) N 95 or even positive air pressure respirators are indicated. As the majority of droplet infections (in particular SARS, influenza, adenovirus) are also transmitted from an infected or colonized patient through direct (touching the patient) or indirect (touching contaminated objects or surfaces in the patient's environment) contact, contact precautions together with droplet precautions need to be adhered to: handwashing, use of gloves, gown, and eye protection, if they are likely to come into contact with body fluids or contaminated surfaces.

The European Union carries a health directive stating that all HCW who are exposed to micro-organisms to which a vaccine is available should be vaccinated (Anonymous, 2002a). This is certainly in place for influenza, although low vaccine uptake (Beguin *et al*, 1998) necessitates improved awareness and vaccine delivery programs amongst HCW. The documented high incidence of pertussis warrants that adult pertussis booster vaccination should seriously be considered for all HCW as national or hospital-wide policies (Von Konig *et al*, 2002). The small excess risk of meningococcal disease does not justify vaccination of all HCW, except for those at highest risk such as HCW at ICU or emergency departments. Pneumococcal vaccines are indicated for HCW with underlying cardiopulmonary problems. Chemoprophylaxis is indicated for unvaccinated HCW exposed to patients with meningococcal disease and pertussis.

CONCLUSIONS

Lessons need to be learned from the SARS epidemic. The wrong lesson to be taken from SARS would be to pass new emergency regulations narrowly targeting funding for SARS research and control (Bloom, 2003). Improved surveillance programs in hospitals in response to the SARS outbreak should not only be in place in previously SARS affected countries but extended worldwide. This would reduce the delay between the diagnosis of a new outbreaks and implementation of appropriate measures. Hospital surveillance should be expanded to all respiratory diseases to facilitate early detection of nosocomial outbreaks, and this should also in-

clude surveillance of all HCW. Integrated syndromic and virological surveillance systems set up during the SARS epidemic will also further our understanding of other respiratory infections in the hospital setting. Even if pursuing early diagnosis for unspecific respiratory illnesses is expensive, identification of the causative organism may reduce unnecessary isolation, contact tracing and anxiety, in particular during an outbreak situation (Kaiser *et al*, 2003).

Lessons on infection control policies emerge from the recent SARS experience. Enforced implementation of stringent droplet precautions during the SARS crisis should be maintained; and this will most likely have a major impact on other nosocomial infections as well. A clinical study on handwashing has shown a reduction in the total rate of respiratory illnesses (Ryan *et al*, 2001). In the US, masks are recommended when working within 1 m of patients known, or suspected, to suffer from large-droplet infections (Garner, 1996). Masks became the symbol of the SARS epidemic (Syed *et al*, 2003) and the increasing public acceptance and even expectation that masks should be worn should become an impetus to increase the willingness of HCW to wear masks. Ongoing training on droplet precautions and mask-fitting sessions should not only be offered to those highest at risk such as HCW (such as ED or ICU), but also to non-front line workers: SARS or any other respiratory infection may arise at places least expected. Regular auditing on wards would ensure that infection control practices are maintained.

HCW with respiratory symptoms should either be removed from direct patient care or encouraged to wear masks. The hospital infection control team should be notified when HCW are absent from work for > 72 hours due to febrile respiratory illnesses so that new clusters of febrile illnesses in HCW do not evade the hospital surveillance system.

Employee health services should proactively and creatively devise delivery systems that enhance compliance with vaccination programs for all health care workers. Time will show whether the SARS crisis will contribute to a change in attitude in HCW towards the influenza vaccine (Wilder-Smith and Ang, 2003). As SARS may reappear, there is now even a stronger rationale for influenza vaccination for all HCW: influenza vaccine for HCW will reduce scenarios where new clusters of febrile illnesses in HCW (due to influenza) would set off an alarm bell for a new outbreak of SARS (Wilder-Smith and Ang, 2003). Policies for other vaccine preventable droplet-transmitted diseases such as meningococcal disease and pertussis remain controversial as public health measures, but should at least be discussed with and offered to HCW at the onset of employment.

The risk of airborne and droplet-transmitted respiratory infections in HCW is substantial. The three main strategies to prevent or control occupationally acquired infections are relatively simple and cost-effective – droplet and contact precautions and vaccination. We have a duty to protect our health care workers. In the same time, HCW also have the duty to comply to guidelines and policies (Stuart *et al*, 2001).

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