

AIDS and the Lung

Series editors: D M Mitchell, A A Woodcock

1—AIDS, aprons, and elbow grease: preventing the nosocomial spread of human immunodeficiency virus and associated organisms

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ABSTRACT Epidemiological evidence indicates that transmission of human immunodeficiency virus (HIV) other than by direct inoculation or sexual contact is extremely rare. HIV has, however, been found on fiberoptic bronchoscopes used on patients with AIDS and there is a clear theoretical risk of transmission by bronchoscopy. Applied experiments have underlined the importance of cleaning equipment thoroughly and have shown the limitations of disinfection. Infection control policies should be revised to meet the following four basic requirements: (1) all precautions should apply to all patients alike—that is, whether infectious or not; (2) equipment should be cleaned thoroughly in detergent immediately after use to remove body secretions and reduce contamination; (3) staff who may be exposed to body secretions should wear simple barrier clothing routinely; and (4) contaminated bronchoscopes should be disinfected for 20 minutes in 2% alkaline glutaraldehyde after cleaning.

How great is the risk?

Commensal and pathogenic bacteria, respiratory viruses, fungi, mycobacteria, hepatitis B virus, and the human immunodeficiency virus (HIV) are all potential contaminants of respiratory equipment. For example bacterial contamination inside a spirometer after one week's use has been measured at 10^8 organisms/ml.¹ Sampling of a series of bronchoscopes used on patients with AIDS found contamination with respiratory tract commensals, *Candida albicans*, hepatitis B virus, and in all cases HIV (Hanson, unpublished data).² Although often referred to as a fragile virus, HIV remains infectious at room temperature for up to three days if dried and for eight days in suspension.² Whereas an aerosol containing one or a few mycobacteria may cause clinical infection,³ viral infectivity is more dependent on a large inoculum. It is, however, impossible to determine the dose of HIV and hepatitis B virus that is infectious in man; furthermore, the

pathogenesis and possible portals of entry of HIV infection are incompletely understood.

EPIDEMIOLOGICAL EVIDENCE

With only limited experimental data available, great emphasis has been placed on epidemiological evidence. The risk from HIV to health workers has been assessed in several prospective studies.⁴⁻⁷ Overall, the incidence of seroconversion after a needlestick injury from a person with HIV infection is about 0-9%; from a person who is positive for the hepatitis B virus antigen the incidence is from 6% to 20%.⁸ Virtually all cases of HIV seroconversion after needlestick injuries have occurred after inoculation into deep tissues with hollow, bloodstained needles. Five cases of HIV infection after splashing of the skin or oral mucosa have been reported, three of which were in hospital staff; two were in members of the public providing nursing care for people with HIV infection.^{9,10} In all cases where splashing of skin resulted in transmission of HIV, clinically evident skin lesions are thought to have provided the portal of entry.

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Recovery of HIV from the saliva of patients with HIV antibodies in 1984 led to fears that AIDS might be transmitted by infected saliva.¹¹ Although this possibility cannot be discounted the weight of epidemiological evidence is very much against it. Friedland *et al* observed 101 individuals who had non-sexual household contact with 39 patients with AIDS or AIDS related complex.¹² Social contact included kissing on the lips and sharing of washing and eating facilities. HIV antibodies were detected in only one contact, a 5 year old child who had probably acquired the infection perinatally. The apparent lack of transmission of HIV in saliva has been attributed to the small amounts of virus in saliva¹³ and the possible presence of one or more inhibitor substances.¹⁴ Aerosols of saliva from HIV infected patients are not known to have transmitted HIV, and the low incidence of HIV infection among dentists with frequent exposure to such aerosols is evidence against transmission of HIV by the respiratory route.¹⁵

In assessing the risks from cross infection we have to consider the severity of the consequences of acquiring a particular infection. With limited data on the prevalence of contamination and the likelihood of transmission of infection, this consideration has perhaps received undue emphasis. HIV has provoked a major revision of infection control policies whereas comparative complacency surrounds *Mycobacterium tuberculosis*, for which there is effective treatment, despite its greater prevalence and resistance to disinfection.

The risk of infection is determined not just by the number and nature of contaminating organisms but also by the susceptibility of the recipient host. Immunosuppressed patients are at risk from fungal spores, non-tuberculous mycobacteria, and *Pneumocystis carinii*, which are not normally pathogenic in the immunocompetent patient. These organisms might be encountered in the environment, but the factors contributing to the pathogenesis of *P carinii* and *Mycobacterium avium-intracellulare* are poorly understood.

CROSS INFECTION AND BRONCHOSCOPY

Outbreaks of infection from fiberoptic instrumentation have almost invariably been attributed to inadequate cleansing or inappropriate disinfection of the instrument. Damage to the instrument channels, failure to dismantle the valves during cleaning, and contamination of the rinsing water have also been implicated.^{16,17} Persistent contamination of two bronchoscopes with both *Mycobacterium chelonae* and *Pseudomonas* spp as a result of damage to the biopsy channel has been described.¹⁸ Infection with *M chelonae* developed in two patients, one of whom died; nine patients were transiently colonised and broncho-

Bronchoscopic hygiene

DO	Clean bronchoscope and valves in detergent <i>immediately</i> after use Use 2% alkaline glutaraldehyde* or succine dialdehyde disinfectants† Disinfect equipment for 20 minutes after every case Flush channel with 70% alcohol after rinsing off disinfectant Clean and disinfect equipment <i>before</i> each session Ultrasonicate (10 min) hollow or spring structure accessories Cover aldehyde containers, avoid splashing, and ventilate room Receive hepatitis B vaccine Wear clean gloves Protect eyes and mouth
DO NOT	Reserve equipment for infected cases Add disinfectant to detergent or use disinfectant before detergent Overuse aldehyde disinfectants (use fresh for each session or for less than about 10 procedures)

*Cidex, Asept, or Totacide.

†Gigasept.

scopy samples from 72 patients were contaminated. Prolonged immersion in glutaraldehyde failed to decontaminate the instrument. *M tuberculosis* infection has also been transmitted by a contaminated bronchoscope¹⁹ and contamination of samples with *M tuberculosis* and *M avium-intracellulare* has been described.^{20,21} The disinfectants used were iodophors, cetrimide, and chlorohexidine, which have little mycobactericidal activity. The use of 70% alcohol for disinfection of bronchoscopes has been implicated in the fatal transmission of *Serratia marcescens* and persistent contamination of bronchoscopic samples.^{22,23} No cases of viral transmission by bronchoscopy have been reported.

The true incidence and nature of infectious complications after bronchoscopy is difficult to determine. Retrospective studies are generally inaccurate owing to underreporting and, perhaps, to the long incubation times of several pathogens. Pereira *et al*, in a prospective study of 100 fiberoptic bronchoscopies, found a 6% incidence of pneumonia and a 16% incidence of fever after the procedure.²⁴ In a study of 52 patients undergoing rigid bronchoscopy, Burman *et al* reported the incidence of fever to be 46%, with bacteraemia occurring in one third.²⁵ Where organisms were identified in these prospective studies they were found to have been present in the upper or lower respiratory tract before bronchoscopy.

Prevention of cross infection

Successful infection control depends both on the adequacy of preventative measures (table) and on their application to all cases of infection, recognised and unrecognised. Hepatitis B virus and mycobacteria have hitherto prompted only the selective application of

infection control precautions. This approach is justified, it is claimed, by the apparent lack of cases of iatrogenic cross infection. The devastating consequences of HIV infection and the large number of symptomless infected individuals dictate that the only effective policy of infection control is one that is mandatorily applied to all patients alike.

There are two approaches to the prevention of cross infection in respiratory units: firstly, preventing microorganisms coming into contact with staff and equipment and, secondly, cleaning and disinfection of equipment that becomes contaminated. Endoscopy staff who are not immune to *M tuberculosis* and hepatitis B virus should in addition be protected by vaccination.

BARRIER PRECAUTIONS

Clean gloves should be worn by the bronchoscopist and assistant for each case; contaminated hands are responsible for most nosocomial infections, including those caused by respiratory organisms.^{26,27} Spectacles and a mask will protect the mucosa of the eyes and mouth against contaminated secretions coughed by the patient and should be worn for every case. Although wearing a gown does little to prevent cross infection, it is recommended on the grounds of general cleanliness; it should be changed when visibly soiled.

LUNG FUNCTION EQUIPMENT

Contamination of lung function equipment can be prevented by the use of inexpensive modifications to standard equipment developed recently at the Brompton Hospital. Spirometry is performed with the patient breathing into a disposable polythene bag placed inside a rigid box; air is displaced into the spirometer from the box, the volume and rate being the same as those of the air exhaled. Contamination of the plethysmograph is prevented with a smaller device based on the same principle. Carbon monoxide transfer may be measured by timed rebreathing of test gases from a foil bag sealed with a detachable valve. After use by each patient the bag is discarded and the valve cleaned. A more detailed account and validation of these methods is published elsewhere.²⁸ This system removes the risk of cross infection, allays the fears of patients and staff, and permits accurate lung function tests to be performed on all patients without recourse to screening.

Cleaning and disinfection

Of all infection control measures in the bronchoscopy unit, the most important is thorough cleaning of the equipment. This should be performed immediately after use to remove blood, tissue, and secretions before they dry. Protein presents a physical barrier to disinfectants, particularly those that fix protein. By

competing with microorganisms for active sites protein also chemically neutralises disinfectant. After being cleaned in neutral detergent 10 bronchoscopes used on patients with AIDS were sampled and found to be free of all detectable microorganisms, with reductions of up to 10^8 organisms/ml (Hanson, unpublished data). HIV, present on all bronchoscopes sampled before cleaning, could not be detected after cleaning even with the polymerase chain reaction, which amplifies viral material by up to 10^8 . Further evidence of the efficacy of cleaning is provided by applied experiments with mycobacteria and HIV. Five bronchoscopes were contaminated with human sputum containing a recent isolate of *M tuberculosis* from a patient with AIDS. Cleaning alone reduced contamination by 99.85%–100%, with any remaining detectable organisms inactivated within 10 minutes by 2% alkaline glutaraldehyde. High titre HIV, introduced in serum into five gastroscopes, was reduced in antigen titre after cleaning by 99.98% on one instrument and to undetectable levels on four. Subsequent immersion in 2% alkaline glutaraldehyde for two minutes removed all detectable antigen (Hanson, unpublished data).

Certain items of equipment with hollow lumina or a complex spiral structure, such as biopsy forceps and cytology brushes, cannot be cleaned reliably without the use of an ultrasonic cleaner. Such items should be sonicated in detergent or a proprietary ultrasonic cleaning fluid (*not* disinfectant) for 10 minutes before being cleaned in the usual way.

Several makes of automated washer disinfectors for endoscopes are now available. These do not clean or disinfect endoscopes more thoroughly than can be achieved by hand but they do have several advantages. Most importantly, they ensure that cleaning is always thorough. They reduce exposure of staff to potentially infected material, and, if the disinfectant circuit is plumbed into the main drain, they greatly reduce the amount of glutaraldehyde in the room air. They also release staff from a time consuming manual task for other duties. Weighed against these benefits are their cost and the need to disinfect the washing machine itself to prevent bacterial colonisation of the water pipes. Moreover, the endoscope must still be wiped down and the channel brushed through by hand before it is placed in the machine.

CHOICE OF DISINFECTANT

The choice of disinfectant for use with fiberoptic instruments is greatly limited by the corrosive properties. Phenolics, peroxides, hypochlorites, and iodophors all damage bronchoscope components. Two percent alkaline glutaraldehyde is the disinfectant of choice for fiberoptic bronchoscopes and is now used universally in bronchoscopy units.²⁹ Gigasept (formal-

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dehyde and butan-1,4-dial/2,5-dimethoxytetrahydrofuran) is an acceptable alternative.

In a recent study HIV was inactivated by 2% alkaline glutaraldehyde within two minutes even in the presence of serum. Reuse of 2% alkaline glutaraldehyde for 14 days in our bronchoscopy unit (for about 20 procedures) reduces its active concentration to 1.2%. One per cent alkaline glutaraldehyde also rapidly inactivates HIV but only in the absence of protein: HIV in serum remains infectious for over 15 minutes in 1% glutaraldehyde.³⁰ On bronchoscopes HIV is invariably surrounded by protein, which must be removed by cleaning before disinfection. Increasing the period of disinfection does not compensate for inadequate cleaning.

Few infectivity studies have been conducted on the susceptibility of hepatitis B virus to glutaraldehyde. Bond *et al* showed that transmission of hepatitis B to a chimpanzee was prevented by treating the virus (10^8 chimpanzee infectious doses/ml) with 2% alkaline glutaraldehyde for 10 minutes.³¹ In a similar study the virus was inactivated in five minutes by 1% and 0.1% glutaraldehyde, two chimpanzees being used for each concentration.³² More detailed studies are currently in progress with duck hepatitis B virus as a model, but these chimpanzee studies indicate that hepatitis B virus is not highly resistant to glutaraldehyde.

Studies on the susceptibility of mycobacteria to disinfectants have used diverse methods and test organisms and produced conflicting results.³³⁻³⁵ The most recent studies have shown a 1 log reduction of *M tuberculosis* every 4-6 minutes in 2% alkaline glutaraldehyde.^{36,37} When recent clinical isolates of *M tuberculosis* and *M avium-intracellulare* from patients with AIDS were used, exposure to 2% alkaline glutaraldehyde initially killed organisms rapidly, after which *M tuberculosis* was steadily inactivated at a rate of 1 log every 6.6 minutes and *M avium-intracellulare* at a rate of 1 log every 72 minutes.² The relative resistance of the latter to disinfection has been reported by others, though there may be variation between serotypes.³⁶

Seventy per cent ethyl alcohol is a powerful mycobactericidal agent³⁸ (also Hanson, unpublished data). When used to rinse bronchoscopes after disinfection with 2% alkaline glutaraldehyde it provides an additional safeguard against mycobacteria and leaves the surface of the instruments dry. Because alcohol may damage the components of bronchoscopes the control body should be only wiped in alcohol and not immersed; the insertion tube may be immersed but for four minutes only. Alcohol should not be used as the sole disinfectant.

For how long, then, should bronchoscopes be disinfected? Recommended disinfection times have hitherto been based entirely on in vitro inactivation

rates. In practice virtually all microorganisms are removed from equipment by thorough cleaning, which greatly reduces the inoculum presented to the disinfectant. We may reasonably assume that 20 minutes in 2% alkaline glutaraldehyde will kill virtually all pathogens surviving on a well cleaned bronchoscope.

PROTECTING THE IMMUNOSUPPRESSED PATIENT

The exception to this is *M avium-intracellulare*, and possibly other non-tuberculous mycobacteria. Although these organisms are not pathogenic in the immunocompetent patient, they may cause disease in the immunosuppressed.³⁹ Because they are environmentally ubiquitous they might be thought exempt from infection control precautions. Genetic probing has shown, however, that 73% of *M avium-intracellulare* organisms infecting patients with AIDS are identical at the molecular level; they differ from those isolated from other subjects and from the environment and are likely to be more than "casual opportunists."⁴⁰ Bronchoscopic inoculation of microorganisms into mucosa or lung tissue may be a greater hazard than inhalation or ingestion. Disinfection of equipment *before* use on immunosuppressed patients is therefore advisable; one hour in glutaraldehyde has been suggested as a compromise between what is practical and what is necessary to kill *M avium-intracellulare*.⁴¹ Units performing bronchoscopy on large numbers of immunosuppressed patients may find even this unrealistic. Adequate protection for the immunocompromised should, however, be afforded by thorough cleaning of equipment, disinfection for at least 20 minutes, and rinsing in sterile water or 70% ethanol rather than tap water, which may itself be contaminated with mycobacteria.⁴²

GLUTARALDEHYDE SENSITIVITY

Glutaraldehyde is the disinfectant of choice in bronchoscopy units but there are serious problems with its use. A survey of 43 endoscopy units in the United Kingdom found that 16 units (37%) had encountered problems due to sensitisation of staff.⁴³ Most affected are those with the greatest exposure—that is, the most experienced endoscopy assistants and those who work in units with the fewest staff. These are the very people units can least afford to lose. As the problem is common to all aldehydes, changing the formulation of the disinfectant—for example, to Gigasept—will bring at best only temporary relief. Staff handling aldehydes must protect their skin from splashing; the area of use must be well ventilated and disinfection should be performed in a closed system. The use of a plumbed in washer-disinfector helps greatly in this respect.

MECHANICAL VENTILATORS

Intermittent positive pressure ventilation may be considered appropriate for patients infected with HIV who have potentially reversible respiratory failure or may be instituted in infected patients with rapidly progressive respiratory failure before they are known to be HIV antibody positive. Most intensive care units are equipped with Siemens Servo, Puritan Bennett, or Brompton Manley ventilators. Endotracheal tubes and the external plastic corrugated tubing used with all of these ventilators are disposable. The Siemens Servo ventilators have an expiratory gas circuit that can be easily removed from the ventilator after use on each patient. Sterilisation of these parts in an autoclave or cleaning followed by disinfection in glutaraldehyde for 20 minutes would achieve effective decontamination. The internal gas carrying circuitry of the Puritan Bennett is inaccessible and difficult to disinfect. This should not be necessary, however, even after use on a patient with AIDS as both the inspiratory and the expiratory limbs of the circuit are fitted with bacterial filters that can be removed for autoclaving. Although theoretically such filters will not obstruct viruses, in practice viruses are generally associated with cellular material, which is effectively filtered. The Brompton Manley ventilator does not permit the easy removal of expiratory gas carrying components for autoclaving, though this could be done on occasion if thought necessary.

There is no risk of transmitting HIV by the correct use of continuous positive airways pressure delivered by face mask because of the rapid airflow and the use of disposable valves, humidifiers, and tubing.

It should be remembered that the regular use of disposable and autoclavable components in respiratory circuits is intended to prevent the transmission of respiratory pathogens and that neither HIV nor hepatitis B virus is transmitted by the respiratory route.

Practical implications

Are we preaching a counsel of perfection, out of touch with the realities of providing a bronchoscopy and lung function service in a district general hospital? The diversity of infection control precautions taken by respiratory physicians suggests that the current position is unsatisfactory.⁴⁴ When investigations are performed on patients infected with HIV the adoption of additional precautions is disruptive, time consuming, and expensive; costs increase with increasing numbers of infected patients and are greater overall than for a uniform policy.⁴⁵ Of particular concern is the denial of certain investigations to patients thought to harbour HIV, constituting second class care and reinforcing the stigma of HIV infection.

Universal adoption of the proposals recommended here would avoid these problems but at the following expense:

- 1 Capital expenditure of £3000 for contamination free carbon monoxide transfer factor and spirometry equipment (available from PK Morgan Ltd).
- 2 Bags for transfer factor and spirometry together costing about £2 per patient.
- 3 Sufficient bronchoscopes to allow for 20 minutes' disinfection between patients; busy units will need at least two immersible bronchoscopes. Ninety three per cent of units already have two or more bronchoscopes (S Church, personal communication), but non-immersible models should be replaced where necessary with immersible ones to facilitate adequate cleaning.
- 4 Barrier precautions, which need to become second nature to bronchoscopists, not only for their own protection but to meet increasing public awareness about matters of hygiene.

Conclusion

HIV has brought new interest to the neglected subject of infection control. Efficient control of infection, however, will be achieved not by increased use of newer and better disinfectants but by the routine use of simple barrier precautions, by cleaning equipment well, and by adopting these methods for every patient.

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