Development of the Problem

Since the introduction of flexible endoscopes 30 yr ago, the fibre-optic bronchoscope has become an essential tool of the respiratory physician. Macroscopic examination, biopsy and brushing techniques are common to all forms of endoscopy. However, detailed microbiological examination of lavage fluid is unique to bronchoscopy. Perhaps this is a legacy that we have inherited from our predecessors, who occasionally analysed gastric lavage fluid in their search for tuberculous infection. During the early years of fibre-optic bronchoscopy, cross-infection was not considered to be a major problem (1). However, the increasing use of microbiological examination of bronchoalveolar lavage (BAL) fluid has led to the recognition of contamination as a potential source of both cross-infection and diagnostic confusion (2).

Bronchoalveolar lavage allows the examination of bronchial and alveolar secretions following irrigation with sterile saline (3). The technique has been used for many years to clear purulent or impacted secretions and is the treatment of choice in alveolar proteinosis (4). More recently, analysis of the cellular content of BAL fluid has been used to assess both the nature and activity of interstitial lung disease (5) and may also help in the cytological diagnosis of peripheral tumours. Whilst cell analysis remains a useful research tool (6), its clinical value may become limited following the development of minimally invasive lung biopsy techniques using video thoracoscopy, which has a lower complication rate than open lung biopsy whilst acquiring equivalent diagnostic tissue (7).

Bronchoalveolar lavage is, however, increasingly being used in the management of opportunistic lung disease in immunocompromised patients. The use of immunosuppressive agents and the emergence of HIV infection has led to a substantial rise in the number of opportunistic lung infections which are often life-threatening. Analysis of BAL fluid offers the chance of a rapid microbiological and cytological diagnosis (8,9). However, both bronchoscopy and BAL do have the potential to act as a vector for known pathogens, transmitting them from one patient to another, or acting as a reservoir for environmental contaminants, which may either be pathogenic in immunocompromised patients, or lead to diagnostic confusion or unnecessary treatment in both immunocompromised and immunocompetent patients.

The increasing use of bronchoscopy and lavage therefore requires an effective cleaning and storage process which keeps the bronchoscopes, their accessories and cleaning equipment free from contamination by both pathogenic and environmental organisms.

The Problem

Bronchoscopic contamination has the potential to cause either true or pseudo-infection. True infection occurs when a pathogen acquired from one patient is not removed from the bronchoscope during cleaning, and is subsequently transferred to a second patient, causing a genuine clinical infection.

Pseudo-infection on the other hand is not associated with a clinical illness. It occurs when despite adequate cleaning, the bronchoscope remains contaminated with an organism that is usually not pathogenic and is subsequently identified when the specimen is examined microbologically (10). Repeated contamination of specimens occurring over a period of time is referred to as a ‘pseudo-epidemic’.

Although the potential for true infection is of great concern, there are reassuringly small numbers of cases reported in the literature (11,12) and the evidence for bronchoscopic transmission in some of these cases is tenuous. This is not to suggest that the potential is lower than expected, but rather indicates that most true pathogens are sensitive to current high intensity cleaning guidelines (13,14). Pseudo-infection, whilst not causing a clinical illness, may lead to misdiagnosis and may therefore cause more problems than true infection as it leads to unnecessary treatment of patients with drugs that may cause side-effects (15). The potential for bronchoscopic contamination by organisms capable of causing pseudo-infection is always present, and may be a particular risk for immunocompromised patients. Numerous episodes of pseudo-infection and pseudo-epidemics have fortunately only rarely resulted in the development of genuine infections (16).
## Sources of Contamination

During use, the bronchoscope is subject to contamination from three principal sources: the patient, the environment, and personnel. Once contaminated, the bronchoscope or the equipment used to clean it may then become a reservoir for persistent re-infection, either because the organism is hidden in a site not accessible to disinfection, is resistant to the disinfectant used, or becomes re-inoculated into the bronchoscope or lavage fluid after cleaning.

### PATIENT SOURCES

During bronchoscopy, the bronchoscope is contaminated with nasal and pharyngeal flora in all cases. This may, rarely, cause true infection (2,11,12). When, as is often the case, the patients are being investigated for lower respiratory tract infections, purulent secretions are sucked through the bronchoscope for analysis. Contamination by these pathogens may then provide a source of true infection for subsequent patients. Reported pathogens include Serratia (17), Mycobacterium tuberculosis and atypical mycobacteria (11). Adequate manual cleaning to remove solid debris followed by thorough disinfection will eliminate the majority of viruses, bacteria and fungi (14), although mycobacteria and bacterial spores are more resistant. Fever and pulmonary infiltration are well-described sequelae to bronchoscopy and BAL, but fortunately true infections appear to be rare (2).

### ENVIRONMENTAL SOURCES

Environmental organisms, the most common contaminants, are ubiquitous but are most frequently found in soil or water. They are usually non-pathogenic in immunocompetent hosts. Mycobacteria, especially the rapid growing sub-group of M. chelonei, M. fortuitum (15,18–20) and M. xenopi (21) are most commonly reported. Fungi such as Rhodotorula rubra (22,23) and Blastomyces dermatitidis (10) have also been reported.

### PERSONNEL SOURCES

Personnel associated with bronchoscopy either directly or indirectly are a theoretical but unreported source of contamination. Although a bronchoscopist may have contracted an adenoviral infection from their patients (24), this is not reported as occurring the other way round. Pharmacy staff have, however, been implicated in the transmission of fungal infection to patients through contamination of topical anaesthetic (25).

<table>
<thead>
<tr>
<th>Table 1 Potential reservoirs of infection</th>
</tr>
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<tbody>
<tr>
<td>Bronchoscope and parts</td>
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<tr>
<td>Cracked or dirty biopsy channel</td>
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<tr>
<td>Suction valve</td>
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<tr>
<td>Biopsy channel valve</td>
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<tr>
<td>Biopsy forceps</td>
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<tr>
<td>Cleaning brush</td>
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<tr>
<td>Automated washing machines</td>
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<tr>
<td>Occult mechanical failure of disinfecting cycle</td>
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<tr>
<td>Debris in ports and tubing</td>
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<tr>
<td>Contaminated mains water in rinse cycle</td>
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<tr>
<td>Dilution of disinfectant</td>
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<tr>
<td>Contaminated solutions</td>
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<tr>
<td>Detergent dispenser</td>
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<tr>
<td>Local anaesthetic</td>
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<tr>
<td>Anti-microbial solution</td>
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</tbody>
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### RESERVOIRS

The cleaning, storage and use of the bronchoscope offers many opportunities for reservoirs to be created in sites that may lead to recurrent contamination (Table 1). This requires both the presence of liquid and time in which to allow growth. Although the liquid is usually water, it may also be disinfectant solution, detergent or local anaesthetic.

Eradication of the reservoir sites using aggressive cleaning techniques rather than attempts to eradicate the organism itself usually solves the problem. The bronchoscope and its parts are the main source of contamination. Inadequate storage in a damp condition may lead to Serratia infection (17). The bronchoscope channel may crack or puncture (16) resulting in a biofilm such that only repair or removal of the bronchoscope from service will prevent contamination. Suction valves have also been reported as sources of contamination with M. tuberculosis. Despite initial hand-brushing of suction valves in normal detergent, followed by soaking in 2% glutaraldehyde for 20 min, infection persisted until the valves were autoclaved (26). The design of spring-loaded suction valves may also preclude adequate disinfection of the internal part of valve sleeves (27). Re-assembly of the bronchoscope valves prior to storage may result in inadequate drying, allowing organisms a nidus for growth (23).

In the process of cleaning the bronchoscope, a number of potential reservoirs exist. The first and most widely reported is that of automatic washing machines which have become a well-documented source of contamination (15,18,28–30). Mycobacterium species, principally M. chelonei and M. fortuitum, are the most common contaminants.

Automatic washing machines may lead to contamination because of design faults or mechanical failure.
Many machines recycle detergent and gluteraldehyde, which may result in the holding tanks acting as large reservoirs of contaminated fluid. Some parts of most machines are excluded from contact with gluteraldehyde allowing the easy propagation of a biofilm. Manual inspection and cleaning of these parts of the automatic washer is impossible without returning the machine to the manufacturer. Organic debris may also accumulate around filters (31). These design problems occurring in machines that are primed with mains water contaminated by Mycobacteria have led to a number of well-documented pseudo-epidemics (18,22,28). Bacterial contamination is not unique to the auto-disinfection of bronchoscopes, in one example while investigating a pseudo-epidemic of M. chelonei in outpatient auto-disinfec ting machines used exclusively for gastroenterological examinations on three hospital sites, all were found to be heavily contaminated with M. chelonei (M. Yates, pers. obs.).

Pseudo-infection with Blastomyces dermatitidis has also been reported, apparently due to a failure of the auto-disinfector to remove debris from the sampling port (10). Whilst this may be considered to be a design fault, manufacturers generally recommend manual brushing of all endoscopes to remove debris prior to cleaning.

A mechanical failure has also occurred when a washer disinfectant switch failed after 3 months of use (26), resulting in a bronchoscope not being disinfected at all. This only became apparent following a pseudo-epidemic of M. tuberculosis.

The inner cannula cleaning brush may be a source of fungal contamination. In a reported pseudo-epidemic, the offending brushes were washed in detergent, rinsed in tap water and stored wet in plastic containers between cases (22). Only continual soaking in 2% gluteraldehyde between cases, followed by rinsing with filtered tap water and a further soak in 70% alcohol, eradicated the fungus.

Detergent dispensers have also been shown to harbour M. chelonei and have been responsible for pseudo-infection (19). In this example, the dispenser was routinely rinsed with tap water prior to re-filling. Other solutions involved in bronchoscopy but not related to disinfectant may also act as contamination sources. These have included the local anaesthetic agent, cocaine, which became contaminated by Trichosporon cutaneum during preparation by pharmacy staff (25), and also on a separate occasion when green dye was added to the solution (32). Further confusion may arise when selective growth culture systems become contaminated in the laboratory as has been reported with M. gordonae (28).

Do we Need Automatic Washing Machines?

The presence of reservoirs and contamination in parts of the bronchoscope cannot be avoided. Despite its limitations and the risk of contamination, automation will continue to expand, as the demand for bronchoscopy and BAL increases, yet nursing time and funding limitations remain stringent. Economic and time-management considerations are not the only ones since gluteraldehyde also has a number of well-documented occupational health effects including headaches, contact dermatitis, epistaxis and occupational asthma (33). Since gluteraldehyde must now be used under a fume hood with control of vapour levels, there are increasing demands for automatic disinfection machines, since adequate alternatives to gluteraldehyde are still being evaluated (34).

Solution to the Problem

Environmental contaminants are common, and automation is widely used - how then are we to clean rather than contaminate our bronchoscopes?

THOROUGHLY CLEAN BRONCHOSCOPE AND ACCESSORIES PRIOR TO DISINFECTION

The amount of actual cleaning performed by a machine is limited. Bronchoscopes must be hand-brushed to remove tissues and blood since such products will not be removed during the automatic wash cycle, and if present during the disinfection cycle will be fixed and may subsequently act as a reservoir for contamination. Initial hand-brushing is therefore essential. Suction valves need careful hand-brushing followed by ultrasonic cleaning in order to remove organic matter that tends to collect beneath the 'O' ring. Brushes also need to be cleaned ultrasonically in addition to standard disinfection. Valves should be stored in a dismantled and dry condition.

BE AWARE OF THE LIMITATIONS OF AUTOMATIC WASHING MACHINES

Automation is improving, hardware manufacturers are responding to the difficulties encountered and both water and detergent reservoirs are being removed. Self-disinfecting machines are available, as are machines that air dry following disinfection. Gluteraldehyde concentration and soak times have been well investigated. The British Thoracic Society guidelines (13) recommend a 20-min soak in freshly prepared 2% gluteraldehyde after a careful pre-wash in order to remove M. tuberculosis (36). The rate at which gluteraldehyde degenerates and the degree of dilution that occurs during re-use is uncertain and
may lead to inadequate concentrations of disinfectant (37) which could encourage the growth of gluteraldehyde-resistant mycobacteria (38). Manufacturers of gluteraldehyde recommend fresh solutions every 20 cycles or every 14 days, but this will depend on the ambient temperature, and the amount of water left in the machine at the end of the cleaning cycle, and also the type of gluteraldehyde used (39).

The large amounts of water required in machines may well increase the load of mycobacteria from contaminated water supplies (19). The exclusion of this organism is extremely difficult. Biological filters are expensive, untried, and require high water pressures to work in conjunction with automatic disinfection machines, because of their effects in reducing flow and therefore prolonging cycle times.

The exclusive use of sterile water in the rinse cycle would prove prohibitively expensive. Some inventive manufacturers are currently trialling self-cleansing machines using biological filters in conjunction with ultra-violet light.

Unfortunately, there are no European guidelines developed for or by manufacturers even though there are 30 companies now competing in the market. The American Association for Professionals in Infection Control and Epidemiology have, however, recently published guidelines for infection prevention and control in flexible endoscopy (35).

More often than not, however, manufacturers of automatic machines suggest following gluteraldehyde suppliers' guidelines or endoscope manufacturers' guidelines, and vice versa (40)! There is a need for the standardization of methods for testing the effectiveness of disinfectants and disinfecting machines (41). In the current confusing situation, local microbiological monitoring and advice is essential.

Since the potential for contamination of bronchoscopes, their parts and the cleaning apparatus is inevitable from both human and environmental sources, the following practical guidelines are proposed.

**Practical Guidelines**

**BE AWARE OF THE PROBLEM**

There is often a rapid turnover of staff using an endoscopy unit. They should be made aware of the potential for contaminated equipment and specimens to cause true or pseudo-infection, and should familiarize themselves with cleaning and disinfection protocols. A designated individual should be responsible for ensuring that local guidelines are adhered to.

**TRAIN STAFF IN SIMPLE CLEANING TECHNIQUES**

The importance of simple cleaning of external surfaces and biopsy channels, followed by the dismantling and thorough handwashing and ultrasonic cleansing of forceps, suction and biopsy valves should be emphasized. The removal of all organic debris prior to insertion in ultrasonic cleaners or automatic washing machines is essential. After cleaning, channels should be rinsed with 70% alcohol or sterile water, and all parts dried thoroughly prior to storage or reassembly.

**TEST YOUR AUTOMATIC WASHING MACHINE**

Automatic washing machines should be stripped down and cleaned at regular intervals. Ports and tubing should be checked for contamination, and new machines should be tested to determine how well gluteraldehyde concentrations are maintained with time. A close liaison should be kept between washing machine manufacturers, endoscopists and microbiologists.

**MAINTAIN A HIGH INDEX OF SUSPICION**

Consideration should be given to flushing the bronchoscope with sterile water prior to use. An aliquot of this flushed liquid can then be analysed microbiologically. In this way, any contamination can be detected at an early stage, and the results may prove helpful in the subsequent interpretation of lavage analyses.

**References**

7. Bensard DD, McIntyre RC, Waring BJ, Simon JS. Comparison of video thoracoscopic lung biopsy to open


