

Infection Control in the Bronchoscopy Suite A Review of Outbreaks and Guidelines for Prevention

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The 2000 Institute of Medicine report, *To Err Is Human*, suggests that medical mishaps occur in 2.9 to 3.7% of hospitalizations, resulting in 44,000 to 89,000 deaths yearly in the U.S. alone (1). In this context, March 2002 reports of bacteria transmission via bronchoscopes fostered a groundswell of concern among medical personnel and the public alike (2, 3). With nearly 500,000 bronchoscopies performed each year in the U.S. alone (4), there are fears of significant patient harm.

Most bronchoscopists are familiar with a 1 to 3% rate of immediate, procedure-related complications due to bronchoscopy (5). In contrast, reports of bronchoscopic pathogen transmission have been scattered and largely anecdotal. Under-recognition and under-reporting of such episodes have contributed to a sense of complacency regarding infection control in the bronchoscopy suite. With recent events, renewed attention may be focused on infection control. However, the burgeoning sensation of time-pressure and administrative demands for economic thrift will likely intensify the temptation to “cut corners.”

Bronchoscopic infectious complications include distal spread of organisms within a patient during bronchoscopy, transmission of organisms to subsequent patients via contaminated instruments, accessories or solutions, and transmission of infectious agents to medical personnel or nearby patients. Distal spread of infection is rarely clinically significant, although the exact incidence is unknown (6); it may include contamination of the lower respiratory tract with organisms from the upper respiratory tract, extension of infection within the lung, and hematogenous dissemination to distant organs (6). Distal pathogen spread is a complication of the procedure itself and will not be discussed further here. This article reviews the available evidence regarding transmitted infectious hazards of bronchoscopy. We will also provide guidelines for the prevention of infections associated with bronchoscopes.

PATHOGEN TRANSMISSION BY THE BRONCHOSCOPE

Microbes may be spread to subsequent patients if bronchoscopes or accessories are inadequately disinfected or if contamination occurs after disinfection. Multiple avenues for contamination

have been described (Table 1). Despite this, reports of pathogen transmission via contaminated bronchoscopes have been relatively uncommon considering the large number of procedures performed. To date, the English-language literature includes at least 59 reports, totaling 953+ patients (*see* Tables E2 and E3 in the online supplement). Most reports have described *pseudo-infections*. These occur when, despite disinfection of the bronchoscope, a contaminating organism is isolated from bronchoscopic specimens in a patient with no clinical evidence of disease attributable to that organism. A *pseudoepidemic* or *pseudo-outbreak* occurs when the organism is isolated in bronchoscopic specimens from multiple patients. *True infection* implies development of actual clinical disease in a patient after undergoing bronchoscopy with the contaminated instrument.

Review of the available cases reveals that the data are limited in several aspects. Most of the reports are descriptive series, with few case-control investigations. In many of the episodes, the causality between the clinical scenario, putative offending organism, and ostensible mechanism of contamination is tenuous. Most importantly, because there are no prospective studies of pathogen transmission, the actual incidence is unknown. In light of the unclear significance of the problem, the urgency to intensify infection control recommendations is unclear.

The most recent reports (2, 3) are the first to describe pathogen transmission despite adherence to all current (2003) reprocessing standards. Epidemiologic investigations in both instances implicated loose fittings over the valve stem for the working channel of certain bronchoscope models. In this scenario, effective mechanical cleaning and disinfection would be impossible. In total, there were multiple pseudoinfections and 20 to 43 possible true infections, including up to three deaths, due mainly to *Pseudomonas aeruginosa*. As both series were retrospective, it is difficult to discern the exact number of cases actually attributable to pathogen transmission; for example, DNA fingerprints from many of the clinical isolates described by Srinivasan and coworkers (2) did not match those from the bronchoscopes, and the causality for most of the true infections is unclear. However, even if a minority of the cases were actually due to contaminated bronchoscopes, the notion that they occurred in a setting where infection control guidelines were ostensibly adhered to rigorously is concerning. Presumably, there could have been many other institutions where similar pathogen transmission occurred, unnoticed or unreported.

As demonstrated in Figure 1, reports of contamination (and true infection) have become more frequent over time. Also, in the 1970s and 1980s, diverse bacteria species, such as *Klebsiella* and *Serratia* spp, were frequently implicated; since the mid-1980s, *P. aeruginosa*, fungi and mycobacteria have predominated. These apparent trends may reflect increased awareness, more bronchoscopies, and reporting bias. However, it is also likely that the spectrum of observed organisms has actually changed.

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TABLE 1. HISTORICAL SOURCES OF CONTAMINATION

Ineffective bronchoscope cleaning	Instilled solutions
Inadequate cleaning	Topical anesthesia (cocaine)
Damaged internal channel	Green dye (additive to anesthetic)
Poorly-mated internal components	Atomizer
Reusable suction valve	Disinfectant
Suction channel	Inadequate activity (e.g., iodides)
Biopsy port	Incorrect disinfectant concentration
Accessories	dispensed by automated reprocessor
Sample collection tubing	Contaminated glutaraldehyde
Reuse of stopcocks for bronchoalveolar lavage fluid aspiration	Improper connector to reprocessor
Contaminated reprocessing equipment	Recontamination after disinfection
Automated washer	Rinsing tap water (hospital supply)
Rinsing tank	Contaminated tap water filters
Tubing	Reuse of "sterile water" for rinsing
Filter	Reassembly of valves before storage
Biofilm in reprocessor	Storage in coiled position/in cases
Cleaning brushes	

References for each of these mechanisms can be found in an online version of this table. Please refer to Table E1 in the online supplement.

This shift implies both that disinfection techniques have improved over time and that there are a number of organisms resistant to all but assiduous cleaning and application of powerful disinfectants. The most common mechanisms for contamination have also apparently shifted. Earlier reports frequently described use of ineffective disinfectants or lack of adequate cleaning regimens. More recently, contaminated automated endoscope reprocessors and ostensible breaches in pre-established infection control protocols based on guidelines have been identified.

Environmental or commensal organisms, especially *P. aeruginosa*, *Serratia marcescens*, nontuberculous mycobacteria, and environmental fungi are the most frequently described pathogens. A complete list of all English-language reports of pseudoinfections may be accessed in the online supplement (Table E2). True infections caused by bronchoscopy have been rare; there are 13 well-documented reports involving 21 patients in the English-language literature (Table E3 in the online supplement). Six reports also describe putative bacterial infections due to bronchoscopy, but a paucity of clinical details makes them difficult to interpret. Twenty-eight percent of all discrete reports describe at least one patient with possible true infection, but the proportion of true infections among all affected patients is only 3 to 4% (see Tables E2 and E3 in the online supplement).

In general, these episodes have been detected when astute clinicians or microbiology laboratories observe dramatic or unexpected changes in isolate patterns. Attributable disease due to the contaminating organism can sometimes be traced retro-

spectively back to an index case. Development of molecular techniques such as DNA fingerprinting has enhanced epidemiologic investigations in recent reports (2, 3, 7–9) and should be used routinely in epidemiologic investigations of suspected outbreaks. Review of the larger outbreaks in the past suggests that effective surveillance of microbial isolate patterns is a major determinant of outbreak size; in some instances, epidemic size might have been limited by earlier discovery.

Pseudoinfections may lead to unnecessary worry, unwarranted treatment of isolates, delay in diagnosing real disease, and need for further investigations to exclude infection (6). Although reporting of suspected pseudoinfections to state health departments and the Food and Drug Administration is highly encouraged, they are likely under-reported (10). Another potential type of pseudoinfection that may be increasingly seen in the future is the false-positive polymerase chain reaction assay because improperly cleaned bronchoscopes may harbor amplifiable nucleic acid residues (11).

BRONCHOSCOPE REPROCESSING

Table 2 outlines terms frequently used in disinfection and sterilization practices, as devised by Spaulding (12). There are problems specifically associated with bronchoscopes using this scheme to classify disinfection practices. Is the bronchoscope still a semicritical item when it is used with sterile biopsy forceps or used in a patient with pulmonary hemorrhage? Although

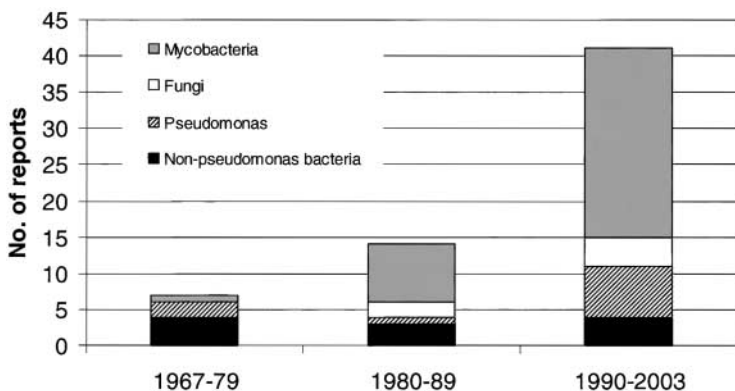


Figure 1. Reports of pathogens by era. Trend in frequency and distribution of reports of bronchoscope transmission of pathogens. Reports include pseudoinfections and true infections.

TABLE 2. REPROCESSING TERMINOLOGY

Term	Definition	Examples
Sterilization	Complete elimination of all forms of microbial life (including bacterial and fungal spores)	Ethylene oxide, autoclaving
Disinfection		
High	Eliminates all organisms except high levels of spores	Glutaraldehyde, orthophthaldehyde
Intermediate	Inactivates MTB, vegetative bacteria, most viruses, and fungi	Ethyl alcohol (70–90%)
Low	Inactivates most bacteria, some viruses, some fungi	Ammonium compounds
Chemical sterilant	Disinfectant capable of destroying spores with prolonged exposure time	Periacetic acid
Instrument classification		
Critical	Penetrates normally sterile space (e.g., bloodstream)	Vascular catheters, surgical instruments
Semicritical	Contacts intact mucous membranes	Bronchoscope
Noncritical	Contacts intact skin	Stethoscope

Definition of abbreviation: MTB = mycobacterium tuberculosis.
Terms adapted from Rutala (12).

sterilization would be most effective in preventing pathogen transmission, flexible bronchoscopes are not easily sterilized. Ethylene oxide gas is effective but requires 24 hours, and luminal penetration may be incomplete if cleaning is inadequate (13). Steam sterilization is quick but damages the fiber-optic parts. From a practical standpoint, sterilization is unnecessary: it is costly, time-consuming and unlikely to confer significant additional protection (14). A summary of recommendations for reprocessing is provided in Table 3.

Factors impeding disinfection are inherent in bronchoscope design: long, narrow working channels (2.6 mm diameter), multiple internal angulations, mated surfaces, springs, and valves. Recent episodes highlight the fact that even careful instrument design may not completely obviate these characteristic risks (2). Effective disinfection necessitates mechanical removal of any biofilms and of encrusted organic material (15). Organic debris

may preclude contact of the disinfectant with micro-organisms or even inactivate some agents (15). Even gas sterilization may not be effective in these circumstances (13). This is not a trivial problem because immediately after routine bronchoscopy, instruments are contaminated with an average of 6.4×10^4 cfu/ml of bacteria (16).

Cleaning Technique

Failure to mechanically clean has been responsible for several episodes of contamination (7, 17). Cleaning should begin immediately after bronchoscopy to prevent drying or hardening of organic debris. All suction ports and attachments should be removed, and instruments should be inspected for damage. Devices that cannot be adequately cleaned, such as biopsy forceps or suction valves, should be either sterilized or disposable (7, 17). The presence of a leak on instrument immersion indicates

TABLE 3. RECOMMENDATIONS FOR BRONCHOSCOPE REPROCESSING

- (1) Inspect the external surface of the bronchoscope for damage and leak testing after each procedure.
- (2) Clean immediately after each use and before disinfection, including wiping external surfaces with detergent and thoroughly brushing all internal channels.
- (3) Discard detergent solutions after each use. Cleaning brushes should be either disposable or thoroughly cleaned with high-level disinfection or sterilization after each use.
- (4) Disinfect with an agent of sufficient microbiocidal intensity at an adequate temperature for sufficient duration. Examples of approved disinfectants include glutaraldehyde, periacetic acid, and orthophthaldehyde. A complete list of approved disinfectants and conditions can be found at www.fda.gov/cdrh/ode/germlab.html.
- (5) Ensure compatibility between the bronchoscope and automated endoscope reprocessors, including the provision of appropriate connectors to provide luminal flow of disinfectant.
- (6) Completely immerse the instrument before disinfection to check for breaches in luminal integrity. Nonimmersible bronchoscopes should be replaced if economically feasible.
- (7) Routinely test disinfectant concentration if using nonprepackaged kits, if the disinfectant is used repeatedly for more than several days.
- (8) Rinse with filtered tap water followed by 70% ethyl alcohol or sterile water after disinfection. Sterile water may be necessary if water supplies are implicated in outbreaks.
- (9) Allow bronchoscopes to dry thoroughly in a designated area before storage. Forced air drying is ideal.
- (10) Store bronchoscope in a hanging position to prevent moisture accumulation.
- (11) Use single-use stopcocks, as reusable ones may be very difficult to clean.
- (12) Reprocess heat-stable parts and accessories, such as biopsy forceps, by mechanical cleaning (e.g. by ultrasonics) followed by autoclaving or sterilization.
- (13) Do not reuse atomizers between patients unless resterilized.
- (14) Ensure regular maintenance and disinfection of automated washers and associated supplies.
- (15) Maintain a log of bronchoscope use as well as automated endoscope reprocessor maintenance and disinfection.
- (16) Provide accessible cleaning and disinfection protocol manuals from bronchoscope and automated reprocessor manufacturers. It is important to contact the manufacturer to ensure compatibility between bronchoscopes and automated reprocessors, with appropriately matched connectors.
- (17) Provide regular staff training sessions, with specific provision of device-specific instructions when new bronchoscope models or reprocessing equipment are introduced.
- (18) Microbiology laboratories should regularly monitor isolates to discern patterns suggesting outbreaks or pseudo-outbreaks. If contamination is suspected, cultures should include bronchoscopes, tap water, and reprocessing equipment.
- (19) Notify the institutional infection control officer, the bronchoscope manufacturer, the CDC, the Food and Drug Administration, and the state health department when infections or pseudoinfections are suspected.

Adapted from References (6) and (28).

a breach in the integrity of the luminal surface; puncture sites and breaches will develop concretions of debris (blood, mucus) that cannot be disinfected. This mechanism has caused several episodes of contamination (18, 19). Cleaning brushes should either be single-use or should be mechanically cleaned and disinfected after each use. Reuse of nonsterilized brushes was the likely cause for a pseudoepidemic of *Rhodotorula rubra* in 30 patients (20).

Disinfection

Disinfection can be done manually or with an automated endoscope reprocessor. If glutaraldehyde is used for manual disinfection, precautions should include adequate ventilation (7–15 air exchanges per hour), personal protective equipment (gloves, goggles), exhaust hoods or fume hoods, and tight-fitting lids on immersion baths (21). Multiple other agents are approved for this purpose, including periacetic acid (a chemical sterilant), orthophthalaldehyde, and hydrogen peroxide formulations. However, hydrogen peroxide may cause oxidant damage to bronchoscopes and is therefore not widely used (21). Antiseptics, such as alcohols and iodides, are not sufficient, and have been responsible for past infections when used alone (22).

All currently approved agents are effective high-level disinfectants in experimental conditions, by definition achieving a greater than 4 log reduction in microbial burden (14). Parenthetically, meticulous cleaning alone achieves a 3.5 to 4 log reduction in organism load (23). The choice of specific disinfectant will likely vary by institution, depending on cost, volume of procedures, use of automated endoscope reprocessors, number of bronchoscopes, and cleaning facilities available. For the practical purpose of achieving high-level disinfection, the choice of agent is probably less important than careful cleaning and assiduous adherence to an appropriate reprocessing protocol (14).

A complete listing of Food and Drug Administration–approved disinfectant formulations, conditions, and maximum reuse time can be accessed online (24). Dilution of solutions to ineffective levels may occur more quickly than the maximum reuse period, however, necessitating periodic testing of solution concentration and pH with commercially available test kits (25). Glutaraldehyde solutions should not be used at concentrations less than 2%. Even with adequate concentration, disinfectants should not be used beyond the listed time frame because spontaneous polymerization of aldehyde groups over time abrogates their microbiocidal activity (21).

Special considerations with automated bronchoscope reprocessing. Automated endoscope reprocessors may contaminate the bronchoscope in several ways. Although the inside of the devices are periodically disinfected, water supply tanks, tubing, and pumps are not in contact with disinfectant. These areas may serve as reservoirs for contaminating pathogens (26). Biofilms on the surfaces of the instrument bath may protect organisms during disinfection cycles; this mechanism has caused several outbreaks (15, 27). Once colonized, disinfection may be impossible, and resorting to manual bronchoscope reprocessing may be necessary (26). Other cases have occurred when routine maintenance or disinfection were not performed (27).

Automated endoscope reprocessors help maintain standards of disinfection, ensure consistency between operators, and eliminate human errors. User manuals should be easily accessible and should provide information on which specific bronchoscope models have been tested for compatibility (6). For example, failure to provide adequate internal channel penetration of disinfectant stemming from use of wrong connectors has caused outbreaks (9). Biologic and chemical markers are available to assess disinfectant strength, pH, and efficacy of decontamination. Provided adequate cleaning and high-level disinfection are achieved

for all devices, bronchoscopists can use the same automated reprocessors that are used for gastroenterologic endoscopes.

Disinfection of hepatitis B, hepatitis C, human immunodeficiency virus, or mycobacteria. To date, there have been no reported instances of bronchoscopic virus transmission, although there is one report each of hepatitis B and hepatitis C transmission via inadequately disinfected gastroendoscopes (28, 29). Prior to reprocessing, human immunodeficiency virus RNA can be isolated from bronchoscopes after use on infected patients (30). However, most viruses, including hepatitis and human immunodeficiency virus are readily neutralized with disinfectants as well as with antiseptic agents such as iodides or ethyl alcohol (21, 31).

The main theoretical risk of virus transmission resides in potential failure to adequately remove biologic debris via mechanical cleaning, thus allowing viruses to escape contact with disinfectants. Failure to clean endoscopes adequately has been shown to preclude effective disinfection of hepatitis B and C viruses (28). Although some authors have suggested intensified disinfection regimens (or sterilization) after bronchoscopy of patients with known viral infections, there is no evidence to support this recommendation. Because serologic status is usually unknown, it is more prudent to simply use adequate precautions for all patients.

As described earlier, mycobacteria have been responsible for a large proportion of reported contamination episodes. All historical tuberculosis (TB) cases have been associated with at least one lapse in standard infection control procedures; thus, it is reasonable to infer that they may have been preventable. Given the absence of supportive case–control studies, however, the level of evidence for this conclusion is low. Disinfection is difficult, especially for nontuberculous mycobacteria because they are both environmentally ubiquitous and the most difficult micro-organisms to eradicate, excepting bacterial endospores (32). Some species (*Mycobacterium xenopi*, *Mycobacterium avium*) tolerate hot water temperatures and are capable of slow growth even in distilled or chlorinated water (33). Although some authors have advocated longer disinfection times following patients with mycobacterial disease or preceding immunocompromised patients, this strategy is unnecessary if all current infection control guidelines are followed (14). Numerous studies have demonstrated that 20 minutes in 2% alkaline glutaraldehyde at 20°C or periacetic acid provides adequate disinfection if cleaning with detergent precedes disinfection (14, 15, 23, 34). Experimental models suggest that even high-level contamination (10^8 cfu/ml of *Mycobacterium gordonae*) is completely eliminated by this regimen (34).

Uncommon infectious agents. Inactivation of prions (including Creutzfeldt–Jakob disease) requires unique decontamination protocols. Because prions resist normal inactivation methods, steam sterilization for at least 30 minutes at 132°C in a gravity-displacement sterilizer is the preferred method. Infectivity is tissue-dependent, with central nervous tissues (e.g., brain, spinal cord, and eye) having the highest risk. Because pulmonary tissues are not suspected to be at risk for transmission of these agents, sterilization of bronchoscopes used in patients with proven or suspected Creutzfeldt–Jakob disease is not necessary.

To date, a total of 23 cases of anthrax have been reported to the CDC following the intentional distribution of *Bacillus anthracis* spores through the U.S. postal system. Eleven cases were inhalational anthrax with five deaths, of which at least one patient underwent a bronchoscopic procedure (35), raising the issue of disinfection. *B. anthracis* is a large, spore-forming encapsulated aerobic, nonmotile toxin producing gram-positive rod. Although anthrax spores are resistant to high-level disinfectants, they are only produced in soils and in dead tissues, not in blood or living tissues. High-level disinfection of bronchoscopes is

therefore adequate for patients with known or suspected inhalational anthrax.

Postdisinfection Handling

Thorough rinsing, including all internal channels, is necessary because retained disinfectants may cause mucositis in subsequent patients (21). Tap water rinsing has caused several outbreaks (15). To avert recontamination, we recommend rinsing with sterile water or with filtered tap water followed by 70% alcohol. Alcohol has excellent antimicrobial properties and will also facilitate drying. Residual moisture in the bronchoscope may serve as a nidus for microbial colonization, even after careful disinfection. After rinsing, inner channels should be dried by insufflating air through the working port.

Instruments should be stored in an upright (hanging) position to prevent accumulation of moisture, and valves should not be reassembled until the next procedure (36). Outbreaks have occurred by both of these mechanisms (37).

Other accessories should be adequately disinfected or sterilized. For example, up to 75% of atomizer lumens and 42% of their fluid reservoirs may be contaminated after a single use (38). Active TB has reportedly developed by this mechanism (8). Reusable instruments, such as biopsy forceps, should be cleaned and sterilized because they penetrate intact mucosa during normal use. Cleaning may be difficult due to multiple crevices and tightly wound coils. Ultrasonication is most efficacious for cleaning these devices (16).

PREVENTION OF OUTBREAKS

Bronchoscopists or associated microbiology laboratories should routinely review pathogen isolates to identify unexpected clusters or trends. Settings with fewer procedures, multiple bronchoscopists sharing the same equipment, no staff or physical area dedicated solely to bronchoscopy, and absence of routine training in disinfection techniques are at higher risk of missing such trends and therefore require especially well-formulated procedures for carrying out isolate surveillance. If investigation of suspected episodes is needed, cultures should include samples from all internal lumens of the bronchoscope, internal surfaces of automated endoscope reprocessors, and tap water if used for rinsing. Brush cultures of the bronchoscope lumens are more sensitive than saline flushes (14).

The issue of periodic surveillance cultures of the bronchoscope, accessories, automated endoscope reprocessors, or tap water supplies remains controversial. Further study is needed in this area. Specific issues which are unclear at present include how often to culture, what items specifically to culture, the fiscal implications of such a strategy, what type of organisms are considered significant and in what quantities. Until evidence is available, we do not recommend routine surveillance cultures.

To our knowledge, until 2003 (2, 3), nosocomial infections had not been reported in any case where all current guidelines were followed carefully. However, adherence to published preventive guidelines is poor (15, 39, 40). For example, an observational study of 26 U.S. facilities revealed that the vast majority of endoscopes and bronchoscopes were improperly disinfected (39). Procedural breaches included omission of any disinfectant, failure to routinely test disinfectant concentration, not cleaning or flushing all ports, failure to time manual disinfection periods, and not fully immersing the endoscope in disinfectant solution. In 78% of facilities, biopsy forceps were not sterilized after each use. As a result, washings from 17 of 71 (23.9%) of gastrointestinal endoscopes were culture-positive for more than 10^5 bacterial cfu/ml. A more recent audit of practice in the UK was equally disturbing—the vast majority of centers did not follow national

guidelines (40). In this survey, for example, 43% of departments did not rinse bronchoscopes with sterile or filtered water after chemical disinfection, despite numerous literature reports of microbial tap water contamination. Hospitals with dedicated endoscopy units and staff training sessions complied more closely with standards.

TRANSMISSION TO PERSONNEL AND BYSTANDERS

Risks of Diagnostic Bronchoscopy

A major advantage of flexible bronchoscopy is that it can be performed without general anesthesia, in an ambulatory suite. However, there is often marked coughing, leading to the possibility of airborne pathogen spread. Three organisms cause infections that result in the requirement that infected patients be placed in airborne precautions: chickenpox and disseminated zoster, rubeola (measles), and pulmonary or laryngeal TB. A six-patient TB outbreak in a renal transplant unit was possibly exacerbated by flexible bronchoscopy and endotracheal intubation of a patient with active pulmonary TB while in the transplant ward (41). Pulmonary fellows-in-training have higher rates of skin test conversions than infectious disease fellows, despite approximately equal exposure to TB (42). This discrepancy may originate in bronchoscopy-associated exposure among pulmonary fellows. Also, analysis of TB skin test conversions after an episode of widespread nosocomial exposure revealed that conversion rates were highest among staff members in close physical proximity during bronchoscopy (43). One report described possible transmission of adenovirus infection to a physician during bronchoscopy on an infected patient (44). However, there are no other well-documented reports of active TB or other infections developing among health care providers after bronchoscopy.

Infection precautions should be in place for every procedure, including full barrier clothing (gowns, gloves, masks, and eye shields), needlestick precautions, and adequate ventilation. The bronchoscopy area should have engineering controls that will allow for negative air pressure, at least 14 air changes per hour, and either discharge of air directly to the outside or monitored high-efficiency particulate air filtration before recirculation. A 1997 survey revealed that 93% of bronchoscopists did not routinely wear protective clothing (40). This finding is alarming because there are well-documented instances of human immunodeficiency virus transmission through mucocutaneous contact with blood and body fluids (45). For patients with suspected or confirmed TB infection, the need for bronchoscopy should be carefully weighed against the risks to staff and bystanders. Where available, we recommend use of a power air-purifying respirator hood, which provides superior protection (6, 46). The N95 particulate respirator is a minimally acceptable alternative (46). Needles should not be used to remove biopsy specimens from forceps: hepatitis B has been transmitted by an accidental stick during this maneuver (29).

Risks of Therapeutic Bronchoscopy

Laser photoresection or endobronchial electrosurgery may liberate infectious pathogens. Intact human immunodeficiency virus or papilloma virus DNA can be isolated from the vapor plume in lesions treated with the carbon dioxide laser or with endobronchial electrosurgery (47, 48). Although there are isolated case reports of laryngeal papillomatosis acquired during laser procedures, population-based surveys have not consistently demonstrated increased risk among laser surgeons (49, 50). However, none of the available evidence in this area is specific to bronchoscopy, and to date, no study has demonstrated intact viral particles or documented transmission due solely to endobronchial ther-

apy. Recommendations to minimize the risk of acquiring laryngo-tracheal papillomatosis include use of tight-fitting masks with small pore sizes and dedicated smoke evacuators. There is a paucity of evidence in this area. Further research is needed to clarify the degree of risk to operators and the efficacy of the safety measures.

Conclusion

True infections and pseudoinfections are notoriously difficult to detect and therefore likely under-recognized. Primary and secondary prevention of potential future outbreaks will require increased vigilance by bronchoscopists, assiduous implementation of reprocessing protocols, and closer collaboration between bronchoscopy personnel, infection control practitioners, and instrument manufacturers. Four major potential avenues for pathogen spread are: failure to follow recommended guidelines for disinfection, organisms harbored in a site inaccessible to cleaning and disinfection, presence of resistant organisms and recontamination of the bronchoscope or accessories after adequate disinfection. Over reliance on automated endoscope reprocessors may instill a false sense of security.

Specific approaches to improve infection control practices include formalized institutional monitoring of isolate patterns to detect trends early, predefined protocols for epidemiologic characterization of suspected outbreaks, and institution of quality control monitoring for all steps in instrument reprocessing. Molecular biology techniques, such as DNA fingerprinting should be used where available when outbreaks are suspected. In contrast, there is no proven role for routine surveillance cultures at present. Quality control for reprocessing procedures and compliance with universal precautions, including monitoring adherence to proper technique, may be especially needed. Finally, design and engineering of bronchoscopes, accessories and reprocessing devices should be attentive to infection control principles, with a focus on streamlining the process of appropriate instrument reprocessing.

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