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Evidence-based spectrum of antimicrobial activity for disinfection of bronchoscopes

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Summary Processing of bronchoscopes after a physical examination has to eliminate all micro-organisms that could have contaminated the endoscope and that may harm the following patient. The aim of this analysis is to define those micro-organisms that may contaminate the bronchoscope during the examination and that may cause disease in other patients.
Methods: Research of literature and analysis of laboratory data.
Results: During the passage of the respiratory tract the bronchoscope will be contaminated by the physiological flora of oral cavity, nasopharynx, trachea, bronchi, and pulmonary tissues. Whilst the oral cavity, the nasopharynx and the pharynx are the habitat for a great variety of bacteria the lower respiratory tract is virtually free of micro-organisms. However, in ventilated patients trachea and bronchi can become colonized as the result of bypassing the cleansing effect of the ciliated epithelium. In addition all agents that can cause bronchitis or pneumonia in immunocompromised or otherwise healthy individuals are potential contaminants of bronchoscopes. These micro-organisms include bacteria, mycobacteria, yeasts and moulds, enveloped and non-enveloped viruses and rarely parasites.
The bronchoscopic procedure can result in epithelial injury with subsequent bleeding. Therefore, all blood-borne pathogens, e.g. HIV or HBV are also potential contaminants of the bronchoscope.
There are several reports of transmission of micro-organisms due to incomplete or faulty cleaning and disinfection procedures of bronchoscopes. These incidents include nearly all classes of micro-organisms but not parasites or viruses. However, the incubation period of viruses can be long and the association between bronchoscopy and infection may be obscure.
Endospore forming micro-organisms and parasites are not part of the normal flora of the respiratory tract and may rarely cause disease, usually only in severely immunocompromised patients, but transmission of such organisms by bronchoscopy has never been reported.

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Conclusion: The antimicrobial activity of the disinfection process, including chemical disinfectants for endoscopes has to include bacteria, fungi and viruses. Sporicidal activity may be only warranted in specific patient populations, i.e. after bronchoscopy of suspected anthrax patients or before examination of severely immunocompromised patients.

Introduction

Bronchoscopy is performed as a diagnostic procedure, i.e. to inspect trachea and bronchi and/or to obtain tissue or secretion samples, or as a therapeutic procedure to remove foreign bodies, to perform laser photocoagulation, electrocauterization, laser resection, or stent insertion. Thus patients undergoing bronchoscopy are frequently immunocompromised and often suffer from infection.

Reports of increasing dissemination of multiresistant organisms and increasing numbers of health care associated infections caused concern for infections that are associated with medical procedures. In Germany this discussion reached its highpoint when an infection control specialist pointed out that he would not undergo any endoscopic examination himself due to the risk of an infection. [1] Faced with these challenges reassurance is sought that the reprocessing of bronchoscopes is safe.

On the other hand endoscopes are highly sophisticated medical instruments that are difficult to decontaminate. Thus sterilisation procedures like steam sterilisation can be hardly performed without damage to the instrument.

Processing of bronchoscopes after a physical examination has to eliminate all micro-organisms that could have contaminated the endoscope and that may cause harm to the next patient. The aim of this analysis was to define those micro-organisms that may contaminate bronchoscopes during the examination and that may cause disease in subsequent patients.

Methods

The data of a microbiological laboratory that serves a 1,400 bed tertiary care university hospital were analysed for species and frequency of bacterial organisms isolated from the respiratory and pulmonary tract. We analyzed 120 mouth wash solutions, 4,300 throat swabs, 6,420 tracheal secretions and 1,250 bronchial alveolar lavages collected between January 2006 and October 2007. The ten most frequently isolated organisms were summarized as top 10 organisms.

Furthermore a literature review was performed to analyse the potential of the cultivated micro-organisms to cause disease in healthy or immunocompromised patients. In addition, standard manuals of microbiology and infectious diseases were reviewed to collect data on physiological flora and on organisms that are known to cause infections of the respiratory and pulmonary tract. Finally a Medline search using the key words "bronchoscope", "cross infection" and "pseudo outbreak" was performed to identify outbreaks and pseudo-outbreaks in which organisms had been associated with bronchoscopic procedures.

Results

During passage of the respiratory tract the bronchoscope will be contaminated by the normal flora of oral cavity, nasopharynx, trachea, bronchi, and pulmonary tissues.

Whilst the oral cavity is the habitat for a great variety of bacteria, e.g. streptococci, lactobacilli, staphylococci, corynebacteria, and a great number of anaerobes, especially *Bacteroides* spp., the predominant species of the nasopharynx are non-haemolytic and alpha-haemolytic streptococci and *Neisseria* spp. (Tables 1–4). Sometimes potential pathogens such as *Streptococcus pneumoniae*, *Streptococcus pyogenes, Haemophilus influenzae* and *Neisseria meningitidis* colonize the pharynx. [2]

Correspondingly, in clinical specimens of the upper respiratory tract collected in the Heidelberg University Hospitals alpha-haemolytic streptococci (65–78%) and *Neisseria* spp. (26–39%) were the most frequently isolated organisms.

The lower respiratory tract is virtually free of micro-organisms. [2] However, in ventilated patients trachea and bronchi can become colonized as the result of bypassing the efficient cleansing effect of the ciliated epithelium. *Candida albicans*, coagulase-negative staphylococci (CNS), alpha-haemolytic streptococci and enterococci are frequently isolated from tracheal secretions of such patients. [2] This was also reflected in our laboratory results, with *C. albicans* (24–28%) and CNS (21–28%) being the most frequently isolated organisms.

Table 1
Micro-organisms that are part of the normal flora, colonization flora or infectious agents in the respiratory tract: Oral cavity

Normal flora	Micro-organisms identified in the laboratory	Organisms that cause infectious diseases
• streptococci • lactobacilli • staphylococci • corynebacteria • great number of anaerobes, especially bacteroides	*Top 10* • Streptococci (65%) • *Neisseria* spp. (26%) • CNS* (19%) • *Staphylococcus aureus* (19%) • *Candida albicans* (19%) • *Enterococcus* spp. (11%) • *Enterococcus faecalis* (11%) • *Pseudomonas aeruginosa* (9%) • *Candida* spp. (9%) • *Haemophilus parainfluenzae* (6%) *Others* • *Corynebacterium* spp. • *Enterobacter cloacae* • *Haemophilus influenzae* • *Klebsiella oxytoca* • MRSA • *Moraxella* spp. • *Rothia* (*Stomatococcus*) *mucilaginosa* • *Serratia marcescens* • *Streptococcus pneumoniae* • VRE	*Common* • Herpes simplex virus • Coxsackie virus A & B • *Streptococcus pyogenes* • *Candida* spp. *Less common* • Morbillivirus • VZV • EBV • Rubella virus • Echovirus • HIV • *Actinomyces* spp. *Rarely* • Human papillomavirus • *Treponema vincentii* • *Fusobacterium* spp. • *Neisseria gonorrhoeae* • *Treponema pallidum* • Mycobacteria • *Aspergillus* spp. • *Mucor* spp. • *Cryptococcus neoformans* • *Histoplasma* spp.

*CNS: coagulase negative staphylococci; MOTT, Mycobacteria other than tuberculosis

All micro-organisms that can cause infection of the mouth, the pharynx and the larynx, bronchitis or pneumonia in immunocompromised or otherwise healthy individuals are potential contaminants of bronchoscopes, e.g. bacteria, such as pneumococci, *Pseudomonas* spp. or *Chlamydia* spp.; mycobacteria; viruses, such as influenza virus or CMV; fungi, such as *Aspergillus* spp.; or parasites, such as *Toxoplasma* or *Cryptosporidium* (Tables 1–4). [2]

The bronchoscopic procedure can result in epithelial injury with subsequent bleeding. Therefore, all blood-borne pathogens, e.g. HIV, HCV or HBV are also potential contaminants of the bronchoscope.

There are several reports of transmission or pseudo-outbreaks of micro-organisms due to incomplete or faulty cleaning and disinfection procedures of bronchoscopes. [3–63] These incidents include nearly all of the above mentioned classes of micro-organisms. Bacteria were responsible for 26 outbreaks or pseudo-outbreaks reported in the literature, [3–25] mycobacteria were discussed in 22 reports [26–57] and fungi in 6 reports. [58–63] Cross-infections due to parasites or viruses were not reported. However, the incubation period of viruses can be long and the association between bronchoscopy and infection may be obscure.

Endospore-forming micro-organisms are not part of the normal flora of the respiratory tract and may rarely cause disease, e.g. pneumonia due to *Bacillus cereus* in severely immunocompromised patients or respiratory anthrax. No evidence for a transmission of *Bacillus* spp. by bronchoscopy has been reported so far.

Table 5 summarizes the risk of contamination of bronchoscopes compared to the risk of infection due to different organisms and the actual occurrence of cross-infection or pseudo-outbreaks due to the micro-organisms.

Discussion

Bacteria are the most common micro-organisms colonizing and infecting the respiratory tract in immunocompromised as well as in immunocompetent persons. Treatment of an increasing number of immunocompromised patients has led to an uncertainty in the classification of physiological flora, colonization or pathogenic colonization. This may be demonstrated by the tendency of standard text books to omit chapters on physiological flora, e.g. the Manual of Clinical Microbiology 6th edition's chapter 'Indigenous and Pathogenic Micro-organisms of Humans' had been considerably shortened in the 8th edition and has been deleted

Table 2
Micro-organisms that are part of the normal flora, colonization flora or infectious agents in the respiratory tract: Nasopharynx

Normal flora	Micro-organisms identified in the laboratory	Organisms that cause infectious diseases
• non-haemolytic streptococci • alpha-haemolytic streptococci • *Neisseria* spp. *Sometimes* • *Streptococcus pneumoniae* • *Streptococcus pyogenes* • *Haemophilus influenzae* • *Neisseria meningitidis*	*Top 10* • alpha-haemolytic and non-haemolytic streptococci (78%) • *Neisseria* spp. (39%) • *Rothia* (*Stomatococcus*) *mucilaginosa* (29%) • MSSA and MRSA (26%) • CNS (14%) • *Candida* spp. (13%) • *Haemophilus parainfluenzae* (9%) • *Enterococcus* spp. (8%) • *Haemophilus influenzae* (5%) • Enterobacteriaceae (5%) *Others* • *Pseudomonas aeruginosa* • *Streptococcus pyogenes* • *Streptococcus pneumoniae* • VRE • alpha-haemolytic streptococci • *Moraxella* (*Branhamella*) *catarrhalis* • *Acinetobacter baumannii* • *Stenotrophomonas maltophilia* • *Eikenella corrodens* • Aerobic bacilli • *Aspergillus fumigatus* • *Neisseria meningitidis* • *Arcanobacterium haemolyticum* • *Actinomyces viscosus* • *Abiotrophia* spp.	**Pharyngitis** *Common* • Rhinovirus • *Streptococcus pyogenes* • Adenovirus • EBV • Coronavirus • Influenza virus • Streptococci Groups C & G • *Mycoplasma pneumoniae* *Less common* • HSV • Parainfluenza virus • RSV • *Arcanobacterium haemolyticum* *Rare* • Coxsackie virus • CMV • Hantavirus • HIV • Rubella virus • *Borrelia recurrentis* • *Chlamydia pneumoniae* • *Corynebacterium diphtheriae* • *Francisella tularensis* • *Fusobacterium* spp. • *Haemophilus* spp. • Leptospirae • *Treponema pallidum* • *Yersinia enterocolitica* • *Toxoplasma* • *Candida* spp. **Laryngitis** *Common* • Adenovirus • Influenza virus • Parainfluenza virus • Rhinovirus • RSV • *Haemophilus influenzae* Type B *Less common* • *Streptococcus pyogenes* • Enterovirus *Rare* • *Streptococcus pneumoniae* • *Staphylococcus aureus* • *Haemophilus parainfluenzae*

*CNS: coagulase negative staphylococci; MOTT, Mycobacteria other than tuberculosis

in the current, 9th edition.[1,64] On the other hand, nearly all bacteria that were isolated from specimens from the upper or lower respiratory tract in our laboratory have been described as causing agents for pulmonary or respiratory tract infections. Organisms without clinical impact in the respiratory tract may be the majority of CNS, non-pathogenic *Neisseria* spp. or corynebacteria, aerobic bacilli and some rarely isolated organisms like *Abiotrophia* spp., *Raoultella ornithinolytica, Brevundimonas vesicularis, Sphingomonas paucimobilis* or *Comamonas testosteroni*.

As has been demonstrated by several reported outbreaks, bacteria can cause cross-infections associated with bronchoscopes. Therefore it is beyond doubt that the decontamination process

Table 3
Micro-organisms that are part of the normal flora, colonization flora or infectious agents in the respiratory tract: Trachea

Normal flora	Micro-organisms identified in the laboratory	Organisms that cause infectious diseases
None	*Top 10* • *Candida* spp. (24%) • CNS (21%) • Streptococci (20%) • *Enterococcus* spp. and VRE (12%) • MSSA and MRSA (11%) • *Neisseria* spp. (7%) • *Pseudomonas aeruginosa* (6%) • *Escherichia coli* (6%) • *Klebsiella pneumoniae* (4%) • *Stenotrophomonas maltophilia* (3%) *Others* • *Enterobacter* spp. • *Haemophilus influenzae* • *Serratia marcescens* • *Klebsiella* spp. • *Aspergillus fumigatus* • *Enterococcus faecium* • *Citrobacter* spp. • *Streptococcus pneumoniae* • *Acinetobacter baumannii* • *Moraxella* (*Branhamella*) *catarrhalis* • *Morganella* spp. • *Eikenella corrodens* • *Streptococcus pyogenes* • *Burkholderia cepacia* • *Proteus* spp. • *Raoultella ornithinolytica* • *Capnocytophaga* spp. • *Neisseria meningitidis* • *Mycobacterium tuberculosis* • *Nocardia farcinica* • *Brevundimonas vesicularis* • *Bacillus pumilus* • *Bacillus cereus* • *Sphingomonas paucimobilis* • *Comamonas testosteroni* • *Actinomyces odontolyticus*	**Acute infection** *Common* • Adenovirus • Influenza virus • RSV • *Mycoplasma pneumoniae* *Less common* • Rhinovirus • Parainfluenza virus *Rare* • Enterovirus (Coxsackie virus) • *Chlamydia pneumoniae* **Exacerbation of chronic infection** *Common* • *Haemophilus influenzae* • *Streptococcus pneumoniae* • *Moraxella* (*Branhamella*) *catarrhalis* • *Staphylococcus aureus* • *Mycoplasma pneumoniae* *Less common* • Influenza virus • Parainfluenza virus • Rhinovirus • Adenovirus *Rare* • *Pseudomonas aeruginosa* • *Escherichia coli* • *Klebsiella* spp.

*CNS: coagulase negative staphylococci; MOTT, Mycobacteria other than tuberculosis

of bronchoscopes has to effectively eliminate bacteria.

Infection or colonization with mycobacteria is rare compared to other bacteria. Therefore, mycobacteria should be less frequently contaminants of bronchoscopes, however, they can cause severe disease. The comparably high number of incidents of cross-transmissions or pseudo-outbreaks due to mycobacteria demonstrates that there may exist difficulties in eliminating these micro-organisms from bronchoscopes. This can be particularly harmful in case of MDR-TB. In New York State in 1995 inadequate cleaning and disinfection of the bronchoscope after the procedure performed on a patient with MDR tuberculosis led to subsequent transmission of infection to one patient and active MDR-TB in another patient.[32] Apart from the patient's individual flora, water used for rinsing the bronchoscope during the decontamination procedure might be a source of contamination of bronchoscopes with mycobacteria as well. Contamination with *Mycobacterium chelonae* resulting from biofilms in washer disinfectors has been observed.[45,56] The identification of acid fast bacteria resulted in isolation and antibiotic treatment of patients which might be regarded as unnecessary as *M. chelonae* rarely cause invasive disease. Thus, the decontamination procedure has to be not only effective against mycobacteria; secondary contamination with these organisms must be prevented as well.

Table 4
Micro-organisms that are part of the normal flora, colonization flora or infectious agents in the respiratory tract: Bronchi and pulmonary tissues

Normal flora	Micro-organisms identified in the laboratory	Organisms that cause infectious diseases
None	*Top 10* • *Candida albicans* (28%) • CNS (28%) • Streptococci (25%) • *Enterococcus* spp. and VRE (15%) • *Candida glabrata* (8%) • *Neisseria* spp. (6%) • MSSA and MRSA (5%) • *Aspergillus fumigatus* (5%) • *Escherichia coli* (5%) • *Stenotrophomonas maltophilia* (4%) *Others* • *Rothia* (*Stomatococcus*) *mucilaginosa* • *Pseudomonas aeruginosa* • *Haemophilus influenzae* • *Streptococcus pneumoniae* • *Acinetobacter baumannii* • *Legionella pneumophila* • MOTT • *Mycobacterium tuberculosis* • *Corynebacterium* spp. • *Lactobacillus rhamnosus* • *Micrococcus luteus* • *Nocardia farcinica* • *Penicillium* spp. • *Aspergillus flavus* • Aerobic bacilli • *Actinomyces viscosus* • *Trichosporon asahii* • *Achromobacter denitrificans* • *Penicillium marneffei*	**Community-acquired pneumonia** *Common* • *Streptococcus pneumoniae* • *Haemophilus influenzae* • *Legionella* spp. • *Mycoplasma pneumoniae* *Less common* • *Staphylococcus aureus* • *Klebsiella* spp. • Influenza virus • Parainfluenza virus *Rare* • *Escherichia coli* • *Enterobacter* spp. • *Moraxella* (*Branhamella*) *catarrhalis* • *Chlamydia psittaci* • *Chlamydia pneumoniae* • *Coxiella burnetii* • *Pneumocystis jirovecii* **Nosocomial acquired pneumonia** *Common* • *Pseudomonas aeruginosa* • *Staphylococcus aureus* • *Enterobacter* spp. *Less common* • *Streptococcus pneumoniae* • *Klebsiella* spp. • *Escherichia coli* • *Haemophilus influenzae* • *Legionella* spp. • Anaerobic bacteria *Rare* • Viruses • RSV • HSV • Protozoae

*CNS: coagulase negative staphylococci; MOTT, Mycobacteria other than tuberculosis

Table 5
Risk of contamination of bronchoscopes compared to risk of infection due to different organisms

Micro-organisms	Risk of contamination of bronchoscope	Risk of causing infection	Association with bronchoscopic procedures
Bacteria	+++	+++	Yes
Mycobacteria	+	++	Yes
Yeasts	++	+*	Yes
Moulds	+	+*	Yes
Enveloped viruses	++	++	N.D.
Non-enveloped viruses	+	+	N.D.
Spore-forming organisms	(+)	(+)	Yes
Parasites	(+)	+*	N.D.

+++, high; ++, medium; +, low; (+), very low; N.D., not described.
* Infection usually in immunocompromised patients.

Yeasts and moulds cause infections predominantly in immunocompromised patients and only rarely in immunocompetent persons. However, bronchoscopy is performed frequently in even severely immunocompromised patients. As moulds exist ubiquitously in the environment and can contaminate the bronchoscope not only during examination but also during processing of the scope, the decontamination process has to include the elimination of yeasts and moulds.

Viruses are common agents of respiratory infections and blood-borne pathogens can easily contaminate the bronchoscope during bronchoscopic procedures. On the other hand, we could not detect a reported incident of cross-transmission of viruses due to bronchoscopes. A publication bias seems to be unlikely, but some viral infections are very frequent and the source of infection may be manifold, e.g. influenza or RSV. For other viruses the incubation period can be long and the association between bronchoscopy and infection may be obscure, e.g. HCV or HIV. In spite of the lack of demonstrated transmissions due to bronchoscopy, the frequency and the outcome of the viral diseases necessitate the sufficient elimination of viruses during decontamination of bronchoscopes.

Endospore-forming micro-organisms are not part of the normal flora of the respiratory tract and may rarely cause disease, e.g. pneumonia due to *Bacillus cereus* in severely immunocompromised patients or respiratory anthrax, but transmission of such organisms by bronchoscopy has never been reported.[65–67] There is a theoretical risk of transmission of *Bacillus* spp. but the rare occurrence of *Bacillus* spp. in the respiratory tract on one hand and the uncommon occurrence of disease on the other hand may not warrant the inclusion of procedures to eliminate spores in the routine decontamination of bronchoscopes.

Parasites also occur infrequently in the respiratory tract and rarely cause disease, mostly in immunocompromised patients. As for *Bacillus* spp., transmission of parasites due to bronchoscopes has not been reported. Therefore, the necessity of special procedures to eliminate parasites is also questionable.

In conclusion, the antimicrobial activity of disinfection procedures for bronchoscopes has to include bacteria and mycobacteria, fungi and viruses. Sporicidal activity and activity against parasites may be warranted only in special patient populations, e.g. after bronchoscopy of suspected anthrax patients or before examination of severely immunocompromised patients.

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