

INFECTION CONTROL GUIDELINE

for the **Prevention** of
Healthcare-Associated Pneumonia

Professional Guidelines and
Public Health Practice Division

Centre for Communicable Diseases
and Infection Control

Public Health Agency of Canada



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Table of Content

Introductory Statement	5
Executive Summary	8
Part A Overview of Healthcare-Associated Pneumonia and Lower Respiratory Tract Infections	10
A.1. Background.....	10
I. Changing Healthcare Delivery Systems.....	10
II. Definitions of Healthcare-Associated Pneumonia	11
III. Epidemiology of Healthcare-Associated Pneumonia.....	12
A.2. Microbial Agents	17
I. Frequency and Distribution of Organisms Causing Nosocomial Pneumonia in Acute Care	17
II. Early vs. Late Onset Pneumonia in Acute Care	19
III. Organisms Causing Healthcare-Associated Pneumonia in Long-Term Care Facilities	20
IV. Specific Microbial Agents	22
A.3. Diagnosis.....	34
I. Surveillance Definition vs. Clinical Diagnosis.....	35
II. Diagnostic Methods / Strategies	35
III. Diagnostic Issues in Long-Term, Pediatric, and Immunocompromised Patients.....	42
A.4. Role of Respiratory Equipment and Devices.....	44
I. Introduction	44
II. Overview of Mechanical Ventilators and their Accessories	49
III. Risks Associated with Contaminated Respiratory Equipment and Devices.....	51
IV. Special Considerations in Other Settings.....	62
A.5. Healthcare-Associated Pneumonia in Specific Clinical Settings.....	71
I. Introduction	71
II. Non ICU-associated Pneumonia	72
III. Nosocomial Pneumonia in the Critical Care Setting	76
IV. Healthcare-Associated Pneumonia in the Immunocompromised Host.....	79
V. Healthcare-Associated Pneumonia in Other Healthcare Settings	82
VI. Summary of Risk Factors and Prevention Measures for Healthcare-Associated Pneumonia	86
A.6. Surveillance for Healthcare-Associated Pneumonia	98
I. Introduction	98
II. Efficacy and Cost-Benefit.....	99
III. Surveillance in Acute Care Facilities	99
IV. Surveillance in Long-Term Care Facilities	104
V. Surveillance in Home Care.....	106
VI. Surveillance in Ambulatory Care	108
VII. Surveillance and Quality Improvement	109
Part B Recommendations for the Prevention of Healthcare-Associated Pneumonia	111
B.1. Administrative Recommendations for All Healthcare Settings	111
B.2. Recommendations to Prevent Cross-Transmission	112
I. General Recommendations for All Healthcare Settings	112
II. Specific Recommendations for Acute Care Facilities	117
III. Specific Recommendations for Long-Term Care Facilities (LTCF).....	139
IV. Specific Recommendations for Ambulatory Care.....	145
V. Specific Recommendations for Home Care	146
B.3. Recommendations For Modifying Host Risk Factors.....	147
I. General Recommendations for All Healthcare Settings	147
II. Modifications for Long-Term Care and Home Care	154
B.4. Recommendations For Respiratory Equipment, Devices and Procedures	155

I.	General Recommendations for All Healthcare Settings	155
II.	Modifications for Long-Term Care	166
III.	Modifications for Ambulatory Care	169
IV.	Modifications for Home Care	170
B.5.	Recommendations For Environmental Controls	174
I.	Recommendations for Healthcare Facilities	174
B.6.	Recommendations For Surveillance	183
I.	General Recommendations for all Healthcare Settings.....	183
APPENDIX A:	PHAC IP&C Guideline Development Process	186
APPENDIX B:	Public Health Agency of Canada - Guideline Evidence-Based Rating System	188
APPENDIX C:	Possible Sampling Sites for Legionella spp. in Healthcare Facilities.....	189
Glossary of Terms	190
Reference List	194

**The Public Health Agency of Canada's Infection Prevention and Control Guidelines
Program**

Introductory Statement

The Public Health Agency of Canada (PHAC) develops national infection prevention and control guidelines to provide evidence-based recommendations to complement provincial/territorial public health efforts in monitoring, preventing, and controlling healthcare-associated infections. National guidelines support infection control professionals, healthcare organizations and healthcare providers in the development, implementation and evaluation of infection prevention and control policies, procedures and programs to improve the quality and safety of health care and patient outcomes.

The purpose of the PHAC Guideline *Infection Prevention and Control Guideline for the Prevention of Healthcare-Associated Pneumonia* is to provide a framework within which those responsible for developing systems to reduce healthcare-associated pneumonia in all settings may develop policies and procedures that are consistent with national guidelines.

Guidelines, by definition, include principles and recommendations, and should not be regarded as rigid standards. This guideline, whenever possible, has been based on research findings. In some areas, where there is insufficient published research, a consensus of experts in the field has been used to provide recommendations specific to practice.

The information in this guideline was current at the time of publication. Scientific knowledge and medical technology are constantly evolving. Research and revisions to keep pace with advances in the field are necessary.

Target Users

This guideline is intended to assist infection prevention and control professionals and all other healthcare providers responsible for the prevention of healthcare-associated pneumonia in all settings, whether in hospitals, clinics or physician offices.

Guideline Working Group

The Public Health Agency of Canada's Infection Prevention and Control Program developed this guideline with expert advice from a working group. The Guideline Working Group was comprised of members representing pediatric and adult infectious disease/hospital epidemiologist physicians, an intensivist/infectious disease specialist, a respirologist, a

microbiologist, pediatric and adult acute care infection control practitioners, a long term care infection control practitioner, a respiratory therapist from acute care, and a respiratory therapist from home care. The multidisciplinary Guideline Working Group reflected a balanced representation of the regions of Canada.

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Guideline Issuance and Review

This guideline was issued in 2011 and will be reviewed in 2014.

Please refer to Appendix A for a summary of the PHAC Infection Prevention and Control Guideline Development Process.

This document is part of the PHAC series of Infection Prevention and Control Guidelines.

For information regarding the Infection Prevention and Control Guidelines series, please contact:

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Executive Summary

The substantial clinical and financial impact of healthcare-associated pneumonia makes this an important issue for healthcare professionals and healthcare administrators. According to data from the Canadian Nosocomial Infection Surveillance Program, pneumonia is the second most common nosocomial infection overall and the most common infection in intensive care units^(1;2). Additionally, pneumonia is associated with considerable morbidity and mortality⁽³⁻⁵⁾ along with high costs of care⁽⁶⁻⁹⁾.

The Infection Prevention and Control Guideline for the Prevention of Healthcare-Associated Pneumonia presents an overview of healthcare-associated pneumonia and provides evidence-based recommendations intended to prevent both pneumonia and other severe lower respiratory tract infections in settings where health care is provided. It updates and replaces the recommendations of the previous Health Canada guideline, *Prevention of Nosocomial Pneumonia* (1990), and has been expanded to encompass a variety of healthcare settings, including acute care hospitals (adult, neonatal, and pediatric intensive care units (ICUs) and non-ICU areas), long-term and ambulatory care facilities, and home care. This revision contains administrative recommendations outlining the essential infrastructure and resources needed in order for infection prevention and control programs to implement the prevention and control measures recommended in this guideline. Attention is also focused on education, recognizing that all healthcare workers require ongoing education in order to remain current with scientific innovations in the field of infection prevention and control.

The document is intended for use primarily by personnel who are responsible for the surveillance and control of infections in healthcare settings. It emphasizes the importance of *prevention* as a healthcare worker's primary goal in the approach to a patient, resident, or client at risk of pneumonia. This means increasing one's awareness of the risk factors for the development of pneumonia in specific populations (e.g., the immunocompromised patient, the cystic fibrosis patient, the elderly long-term care resident, the home care client) in the specific healthcare settings where it occurs, and practising appropriate preventive measures. To this end, the guideline has been organized to provide information to the user according to specific healthcare settings and their respective "at risk" population(s).

Part A, "Overview of Healthcare-Associated Pneumonia", provides the background for the recommendations that appear in Part B. It includes updated information on the diagnosis, epidemiology, and pathogenesis of healthcare-associated pneumonia in specific clinical settings. There are comprehensive sections on: 1) specific microbial agents causing healthcare-associated pneumonia, including antimicrobial-resistant organisms; 2) the role of respiratory therapy equipment and procedures in healthcare-associated pneumonia with special consideration of long-term, ambulatory and home care; and 3) surveillance/quality assurance for healthcare-associated pneumonia in different healthcare settings. A summary of risk factors and prevention measures related to the patient, the device, the treatment, and the environment completes the overview.

Part B, "Recommendations for the Prevention of Healthcare-Associated Pneumonia", presents control measures to assist in: 1) the prevention of cross-transmission of healthcare-associated pneumonia; 2) the modification of host risk factors; 3) the care of respiratory equipment and devices; 4) surveillance/quality assurance; and 5) maintenance of administrative and environmental controls.

General recommendations have been provided at the beginning of each of the above sections that are applicable to all healthcare settings, i.e., acute care (adult and pediatric), long-term care, ambulatory care, and home care settings. In addition, specific and/or modified recommendations have been provided to augment general recommendations where it is necessary to address issues that are unique to one healthcare setting.

Recommendations are based on the most current literature (see Appendix B for rating criteria). Where scientific evidence was lacking or conflicting, the consensus of the *Working Group for the Prevention of Healthcare-Associated Pneumonia* and the *Infection Prevention and Control Guidelines Steering Committee* was used to formulate a recommendation.

Part A Overview of Healthcare-Associated Pneumonia and Lower Respiratory Tract Infections

A.1. Background

Changing Healthcare Delivery Systems

Guidelines for the prevention and control of infections in the provision of health care services have traditionally focused on the acute care setting. Individuals at risk of acquiring or transmitting infection are now found in all healthcare settings across the continuum of care. In addition, increasingly sophisticated surgical procedures, greater use of invasive devices, and provision of ventilator therapy to increasingly compromised patients present new infection prevention and control challenges. Standards and guidelines should be continually updated to address current issues and provide recommendations for the prevention and control of infections that may be acquired as a result of care or treatment both inside and outside the acute care hospital. In this guideline, issues related to the prevention and control of pneumonia and other lower respiratory tract infections in all healthcare settings will be considered.

The past decade has seen major shifts in the delivery of health care in Canada. Health care restructuring, motivated by changes in the health status and demographics of the population, such as more individuals with chronic illness and an increasingly older population, and the continuing increase in hospital health care costs with the search for cost-effective alternatives to hospital-based treatments, have resulted in the relocation of patient care from acute care hospitals to ambulatory, long-term care, and home care settings⁽¹⁰⁻¹⁴⁾. This trend is expected to continue with advances in information technology that will support more health care delivery in the outpatient setting⁽¹⁴⁾. Movement of patients between and within different healthcare settings is frequent, and the level of acuity and complexity of care provided in all healthcare settings has increased markedly in past years^(10;15-17). These changes have all resulted in an increased opportunity for transmission of infection⁽¹⁸⁾.

Reducing the number of professional staff or the overall staff complement is a common cost-containing measure. However, there are reports in the literature correlating increased nosocomial infection rates with decreases in nurse staffing, or changes in nursing staff ratio or composition⁽¹⁹⁻²²⁾. More specifically related to pneumonia, Kovner and Gergen found an inverse relation between nurse staffing levels and postoperative pneumonia⁽²¹⁾. The mechanism hypothesized for this association is that an increased patient-to-nurse ratio places time constraints on the nursing staff that prevent their implementing proper infection control techniques⁽¹⁹⁾.

Definitions of Healthcare-Associated Pneumonia

Traditionally, nosocomial (hospital-acquired) pneumonia has been defined as an infection of lung parenchyma that develops during hospitalization and was neither present nor incubating at the time of admission⁽²³⁾. This definition does not include cases attributable to health care received in the outpatient setting. The term "healthcare-associated pneumonia" is used in this guideline to encompass hospital-acquired pneumonia as well as pneumonia associated with health care delivered in other settings. When the term "nosocomial" pneumonia is used in this document, it is referring specifically to pneumonia related to inpatient hospitalization. Lower respiratory tract infections other than pneumonia, such as influenza and bronchiolitis due to respiratory syncytial virus, occur in the healthcare setting. These are considered when data are available and recommendations for prevention are warranted.

The criteria used to define pneumonia for surveillance purposes may differ with the type of healthcare setting, according to the characteristics of patients in a particular setting and the resources available for diagnosis. As an example, pneumonia in the elderly may present with few respiratory symptoms and signs but instead manifest as delirium, worsening of chronic confusion, and falls⁽²⁴⁾. Definitions should be relevant to the setting in which they are applied and take into account the type of information generally available⁽¹⁰⁾.

Epidemiology of Healthcare-Associated Pneumonia

1. Infection Rates

Rates of healthcare-associated pneumonia vary widely depending on a number of factors:

- The patient population studied (e.g., age, nature, and severity of underlying illness)
- Type of healthcare setting (e.g., teaching or community hospital, long-term care facility (LTCF))
- Country
- Diagnostic strategies (e.g., testing methods, approaches to surveillance)
- Surveillance definitions, methods, and intensity
- Infection control practices
- Staffing

When published rates of healthcare-associated pneumonia are reviewed, the factors above should be considered to avoid errors in interpretation or comparison of infection rates between non-comparable patients, institutions, or settings^(25;26).

1.1. Acute care hospital (adult and pediatric)

Pneumonia is the second most common nosocomial infection in adults^(1;2;25). In the United States, hospital-wide incidence rates based on clinical surveillance criteria have generally been in the range of 5 to 10 nosocomial pneumonias /1000 discharged adults, with a higher frequency in university-affiliated hospitals than non-teaching hospitals⁽²⁷⁻³²⁾. This is comparable to the overall nosocomial pneumonia incidence rate of 5.7/1000 discharges observed in one Canadian tertiary care hospital⁽³³⁾. Lower respiratory tract infections are responsible for 6% of pediatric nosocomial infections^(34;35).

Pneumonia is the most common nosocomial infection in patients in adult intensive care units (ICU)^(36;37). The great majority of pneumonia cases occur in patients who are intubated and mechanically ventilated. Mechanical ventilation has been associated with a 3 to 21-fold increased risk of nosocomial pneumonia^(31;38;39).

In pediatric and neonatal ICUs (PICU, NICU), lower respiratory tract infections are the second most common nosocomial infection^(34;40;41). They constitute 6% to 27% of all nosocomial infections detected in a PICU setting^(34;35;42-44) and accounted for 12.9% of nosocomial NICU infections in a multicentre point prevalence survey⁽⁴⁵⁾.

Crude rates of ventilator-associated pneumonia (VAP) among adults range from 6 to 52 cases/100 ventilated patients, depending on the population studied and the criteria used for diagnosis⁽⁴⁶⁻⁴⁸⁾. Because crude VAP rates do not adjust for duration of mechanical ventilation, defining rates as the number of cases/1000 ventilator-days is recommended. Tables 1 and 2 summarize data on VAP reported by hospitals participating in the National Nosocomial Infections Surveillance (NNIS) System. NNIS is a surveillance program established by the Centers for Disease Control and Prevention in 1970. Through this system, a number of US hospitals confidentially report their rates of nosocomial infections, including VAP. As Tables 1 and 2 show, VAP rates differ according to the type of unit, often reflecting the type of patients and their risk factors.

Table 1

Ventilator-associated pneumonia rate by ICU type

Type of ICU	# Units	# Ventilator-Days	Pooled Mean Rate
Coronary	59	76 145	4.4
Cardiothoracic	47	98 358	7.2
Medical	92	268 518	4.9
Medical/surgical			
Major teaching	99	320 916	5.8
All others	109	351 705	5.1
Neurosurgical	29	45 073	11.2
Pediatric	52	133 995	2.9
Surgical	98	253 900	9.3
Trauma	22	63 137	15.2
Burn	14	23 117	12.0

Note. Mean rate is calculated per 1000 ventilator-days: National Nosocomial Infections Surveillance System Report, data summary from January 1992 through June 2004, issued October 2004⁽⁴⁹⁾.

Table 2

Neonatal ICU ventilator-associated pneumonia rate

Birth Weight Category	No. of High-Risk Nurseries	Pooled Mean Rate
≤1000 g	102	3.5
1001-1500 g	91	2.4
1501-2500 g	86	1.9
>2500 g	90	1.4

Note. Mean rate is calculated per 1,000 ventilator-days: National Nosocomial Infections Surveillance System Report, data summary from January 1992 through June 2004, issued October 2004⁽⁴⁹⁾.

In a Canadian multicentre study, 177/1,014 adult patients (17.5%) acquired VAP after ICU admission⁽⁵⁰⁾. The risk of VAP increased cumulatively with time, with an overall incidence rate of 14.8 cases/1000 ventilator-days. Although the cumulative risk of ICU VAP increased over time, the daily risk of acquiring VAP decreased after day five. The calculated rates for VAP were 3% per day in the first week of ICU stay, 2% per day in the second week, and 1% per day thereafter. This decreasing rate reflects the higher risk of early VAP in ventilated patients.

1.2. Long-term care facilities

Most of the available data regarding the risk of pneumonia in long-term care facilities come from nursing homes. Pneumonia is the leading cause of death in nursing home residents and accounts for 13% to 48% of all infections in the nursing home setting^(51;52). In the elderly, the attack rate for pneumonia is highest among nursing home residents. Additionally, nursing home residents are the individuals most likely to require hospitalization for their pneumonia.

Marrie et al. found that 33/1000 nursing home residents per year required hospitalization for the treatment of pneumonia, compared with 1.14 /1000 elderly adults living in the community⁽²⁴⁾. Table 3 summarizes data on the incidence of pneumonia among residents of nursing homes.

Table 3

Incidence rates of nursing home acquired-pneumonia

Reference	Year	Incidence Rate
Loeb ⁽⁵³⁾	1999	1.2
Muder ⁽⁵⁴⁾	1998	0.27 – 2.5
Jackson ⁽⁵⁵⁾	1992	1.5

Note. Incidence rate is episodes per 1000 patient-days.

Pneumonia accounted for 4.6% of nosocomial infections in a pediatric LTCF⁽⁵⁶⁾.

1.3. Home and ambulatory care settings

Few infection surveillance programs have been developed for the home care sector.

Therefore, little information is available on the incidence or prevalence of lower respiratory tract infections among patients receiving health care at home. A San Francisco survey revealed that 12% of home care patients had invasive devices in place, nasogastric tubes and tracheostomies representing 10.8% and 2.3% of those devices respectively⁽⁵⁷⁾. This same survey found that 20.6% of home health care patients had some type of infection (including respiratory tract infection) on the day surveyed; one-quarter of these infections occurred during the course of home health care. The potential for healthcare-associated respiratory tract infections in the home is recognized, but the true frequency of these infections is unknown.

The overall incidence of infection in the outpatient setting may be quite low. However, many serious outbreaks have occurred, including several outbreaks of *Mycobacterium tuberculosis* and a large outbreak of Legionnaires' disease⁽⁵⁸⁾. The use of respiratory therapy equipment and devices (e.g., nebulizers and pulmonary function equipment in the respiratory clinic) in the outpatient setting may also present a risk of infection⁽¹¹⁾.

2. Impact of Healthcare-Associated Pneumonia: Human and Economic Burden

2.1. Economic burden

There is evidence that healthcare-associated infections impose a heavy human and economic burden on society and the health care system, as well as on individual patients and their families^(7;8;59-61). Nosocomial pneumonia (NP) costs per infection have been estimated to average \$5000 U.S. per patient⁽⁹⁾. Because the occurrence of healthcare-associated pneumonia is related largely to the patient population and the level of risk within the specific environment where care is provided, the impact will differ for each healthcare setting.

2.2. Acute care hospital

In both adult and pediatric patients, nosocomial pneumonia is a potentially life-threatening complication of hospitalization. Most published studies on the morbidity and mortality associated with NP have been carried out in the adult population. Pneumonia is the most frequent cause of death from nosocomial infections in adults. In a 1980 study by Gross et al. of 200 consecutive hospital deaths, pneumonia accounted for 60% of all deaths attributed to nosocomial infection⁽⁶²⁾. Crude case fatality rates for nosocomial pneumonia average 30%⁽⁶³⁾ with a range from 11% to 73%^(4;5;28;33;64-66). Variation in rates can reflect different patient populations, pathogens, and study methods. Studies examining the impact of VAP on survival and length of stay also report discrepant results. The largest matched case-control study to evaluate the attributable mortality and morbidity of VAP was conducted in several Canadian hospitals between 1992 and 1996⁽³⁾. While VAP was associated with an almost 33-fold increased risk of death, this did not reach statistical significance (relative risk (RR): 32.2; 95% confidence interval (CI): -20.6 to 85.1). These findings are in keeping with other studies that have not consistently demonstrated an increased risk of death due to NP^(5;6;36;67). Factors associated with a greater mortality risk include "high-risk organisms" such as *Pseudomonas* or *Acinetobacter* species, increased severity of underlying disease, inappropriate antimicrobial therapy, and age^(28;38;46;65;68;69). It remains uncertain whether nosocomial pneumonia is an independent predictor of death, over and above the other prognostic factors.

There is substantial morbidity associated with NP^(3;28). Studies report that nosocomial pneumonia increases the length of hospital or ICU stay by 6-20 days^(3;6;9;28;70) with associated additional hospital costs^(8;9). These costs do not address the indirect costs borne by patients, their families, or society.

2.3. Long-term care facilities

Most long-term care facilities are nursing homes, and most information regarding infection comes from these facilities. Nursing home pneumonia is the leading infectious cause of death in residents of long-term care facilities, with mortality rates ranging from 5% to 44%, depending on the resident's functional status^(54;71). Elderly patients hospitalized with nursing home acquired-pneumonia have higher in-hospital mortality (18.6%) than elderly patients hospitalized with community-acquired pneumonia⁽⁷²⁾.

The need for antimicrobial therapy and transfer to hospital represents the best available morbidity outcome markers of infection in long-term care. Pneumonia is the infection most frequently requiring transfer of nursing home residents to hospital, and nursing home residents make up a substantial proportion of patients admitted to hospital for pneumonia⁽⁵⁴⁾. The length of stay (mean of seven days) of nursing home residents with pneumonia is similar to that of elderly patients with community-acquired pneumonia⁽⁷²⁾.

The cost of nursing home infections is poorly defined. In the United States, the estimated cost of nursing home-acquired pneumonia ranges from \$673 million to nearly \$2 billion yearly⁽⁷¹⁾.

2.4. Home care setting

There have been no studies to estimate the costs of infections related to receiving health care in the home or ambulatory setting.

A.2. Microbial Agents

The spectrum of etiologic agents causing healthcare-associated pneumonia is broad and may differ according to the specific facility, type of setting, patient population, time of onset of pneumonia, and the diagnostic methods used^(46;47;73-77). The bacteria, viruses, and fungi that cause healthcare-associated pneumonia originate from a variety of different sources, including the patient's endogenous flora, other patients and visitors, staff, contaminated devices, and the environment. The acuity and severity of the underlying illness, duration of hospitalization, whether endotracheal intubation was performed or not, and prior antimicrobial exposure are major determinants of the infecting pathogens^(23;78).

I. Frequency and Distribution of Organisms Causing Nosocomial Pneumonia in Acute Care

The NNIS system provides the largest database describing the distribution of microorganisms isolated from ventilated and non-ventilated adult, pediatric, and neonatal ICU patients with nosocomial pneumonia (Table 4). *Staphylococcus aureus* and *Pseudomonas aeruginosa* are the most frequently isolated organisms in adult and pediatric patients in NNIS hospitals. Although *S. aureus* is the most common pathogen (16.7%) reported in neonates, coagulase-negative staphylococci (CoNS) are isolated almost as frequently (16.5%)⁽⁴¹⁾. CoNS may be pulmonary pathogens in the neonate⁽⁷⁹⁾ but are not considered a cause of nosocomial pneumonia in older children and adults. Gram-negative aerobic bacteria represent 59% and 67% of isolates in adult and pediatric patients

respectively. Anaerobes are common pathogens in patients who are predisposed to aspiration. In a study of non-ventilated patients, anaerobes were isolated from 35% of pneumonia cases⁽⁷⁴⁾. However, anaerobes have rarely been reported in studies of ventilated patients in whom bronchoscopic sampling with quantitative culture of lower respiratory tract secretions has been performed^(46;80;81).

Table 4

Distribution of organisms isolated from patients with nosocomial pneumonia in adult, pediatric, and neonatal level III ICU patients

Organism	Adult ⁽³⁷⁾	Pediatric ⁽⁴⁰⁾	Neonate ⁽⁴¹⁾
	NNIS 1992-1998 (n = 9877) %	NNIS 1992-1997 (n = 1459) %	NNIS 1986-1993 (n = 2665) %
<i>Staphylococcus aureus</i>	17.0	16.9	16.7
Coagulase-negative staphylococci	2.5	0.9	16.5
Enterococcus	1.8	1.0	4.6
<i>Streptococcus pneumoniae</i>	1.6	3.4	-
Group B Streptococcus	-	0.2	5.7
Other Strep.spp.	-	-	3.3
Other gram-positive bacteria	5.0	-	-
<i>Klebsiella pneumoniae</i>	7.0	5.3	6.0
<i>Pseudomonas aeruginosa</i>	15.6	21.8	11.7
<i>Enterobacter</i> spp.	10.9	9.3	8.2
<i>Escherichia coli</i>	4.4	3.6	5.8
<i>Acinetobacter</i> spp.	2.9	3.1	-
<i>Serratia marcescens</i>	4.3	3.6	-
<i>Citrobacter</i> spp.	4.3	3.6	-
<i>Haemophilus influenzae</i>	-	10.2	1.4

Organism	Adult ⁽³⁷⁾	Pediatric ⁽⁴⁰⁾	Neonate ⁽⁴¹⁾
	NNIS 1992-1998 (n = 9877) %	NNIS 1992-1997 (n = 1459) %	NNIS 1986-1993 (n = 2665) %
Other gram-negative bacteria	15.7	-	-
<i>Candida</i> spp.	7.3	2.0	-
<i>Aspergillus</i> spp.	0.5	0.5	-
Other fungi	2.5	0.7	-
Viruses	0.2	2.5	-
Others	-	-	21.7

II. Early vs. Late Onset Pneumonia in Acute Care

The etiology of bacterial NP varies with the duration of hospitalization before pneumonia develops. Early onset nosocomial pneumonia, occurring during the first four to five days of the hospital stay, is more commonly caused by community-acquired pathogens such as *S. pneumoniae*, methicillin-susceptible *S. aureus* (MSSA), *H. influenzae*, or *Moraxella catarrhalis*^(25;82). This is consistent with aspiration of the oropharyngeal organisms that the patient was colonized with on admission. In contrast, late onset pneumonia (occurring more than four to five days after admission) is usually caused by pathogens such as *Enterobacteriaceae* (*Klebsiella* spp., *Enterobacter* spp., *Serratia* spp.), *P. aeruginosa*, *Acinetobacter* species, or *S. aureus*, including methicillin-resistant (MRSA) strains that colonize the respiratory tract after hospitalization^(47;63;83;84). In one prospective study of nosocomial pneumonia on adult medical and surgical wards at a Canadian tertiary-care hospital, the most frequent pathogens causing nosocomial pneumonia in non-ICU patients during the first seven days of hospitalization were *S. aureus*, *H. influenzae*, beta-hemolytic streptococci, *S. pneumoniae*, and *M. catarrhalis*⁽⁶⁴⁾. After 10 or more days in hospital, *Enterobacteriaceae* and *P. aeruginosa* were the most common pathogens recovered⁽⁶⁴⁾. Patients with late onset pneumonia are more likely than those with early onset pneumonia to have serious underlying disease, previous hospitalization, or prior antimicrobial therapy⁽²⁵⁾.

III. Organisms Causing Healthcare-Associated Pneumonia in Long-Term Care Facilities

Many studies have reported the etiology of pneumonia in the long-term care setting ⁽⁸⁵⁻⁸⁹⁾, but the accuracy of these data is uncertain. Sputum samples that are adequate for culture are difficult to obtain because of poor cough reflex and altered mental status. For example, two Canadian studies of hospitalized long-term care facilities residents reported obtaining adequate samples in only 35%⁽⁹⁰⁾ and 22% of patients⁽⁹¹⁾. Studies also vary considerably in the patients sampled. Some include only patients admitted to an acute care hospital from a nursing home, whereas others include all patients acquiring pneumonia. The criteria for the adequacy of sputum samples, use of blood cultures, and application of specific tests for the diagnosis of viral and atypical pathogens also differ among studies. Consequently, the relative frequency of bacterial pathogens varies widely and may not reflect the general situation. Marrie et al. summarized the bacteriologic results from five studies of healthcare-associated pneumonia in long-term care facilities⁽⁹²⁾ (Table 5).

Table 5

Distribution of bacterial isolates from residents with healthcare-associated pneumonia in long-term care facilities, five studies

Percentage of Patients with the Organism					
Organism	Garb et al. ⁽⁸⁹⁾ <i>n</i> = 35	Marrie et al. ⁽⁹¹⁾ <i>n</i> = 131	Phillip & Branaman – Phillips ⁽⁸⁷⁾ <i>n</i> = 104	Drinka et al. ⁽⁸⁶⁾ <i>n</i> = 56	Chow et al. ⁽⁸⁸⁾ <i>n</i> = 116
<i>Streptococcus pneumoniae</i>	26.0	6.8	29.8	29.0	6.0
<i>Staphylococcus aureus</i>	26.0	5.3	10.5	5.8	1.7
<i>Haemophilus influenzae</i>	6.0	0.8	19.0	23.0	2.5
Other aerobic Gram-negative bacilli	47.0	5.3	23.0	-	17.0
<i>Klebsiella pneumoniae</i>	40.0	-	-	-	16.0

Percentage of Patients with the Organism					
Organism	Garb et al. (89) n = 35	Marrie et al. (91) n = 131	Phillip & Branaman – Phillips (87) n = 104	Drinka et al. (86) n = 56	Chow et al. (88) n = 116
<i>Moraxella catarrhalis</i>	-	-	3.8	17.6	-
Normal flora	-	-	-	23.0	-
Unknown etiology	-	59.0	-	-	72.0

Most cases of pneumonia acquired in long-term care facilities are of unknown etiology. Organisms that commonly cause community-acquired pneumonia, such as *S. pneumoniae*, *H. influenzae*, and *S. aureus*, account for a significant proportion of infections and are predominant in this setting. Additionally, outbreaks of pneumococcal pneumonia have been reported in nursing homes. Aerobic Gram-negative bacilli may cause pneumonia, but the frequency of isolation is variable and frequent colonization of the upper airway with these organisms leads to false-positive results from sputum culture. Anaerobes are rarely a cause of pneumonia in the absence of lung abscess.

“Atypical” organisms, such as *Legionella*, *Chlamydomphila pneumoniae*, and *Mycoplasma pneumoniae*, are not thought to be a common cause of healthcare-associated pneumonia in long-term care residents^(86;91). However, there are reports of outbreaks of *Legionella* infection occurring in long-term care facilities^(93;94), and *C. pneumoniae* has been reported to cause serious morbidity and mortality among residents in nursing homes^(95;96).

Respiratory viruses may cause lower respiratory tract infection in long-term care residents^(91;97). Falsey et al. found that 42% of acute respiratory illnesses during one winter season were viral in origin; respiratory syncytial virus (RSV) (27%) was the most common virus associated with illness, followed by rhinovirus (9%), parainfluenza (6%), and influenza (1%)⁽⁹⁷⁾. Outbreaks of influenza A, influenza B, and RSV have been reported in this setting and can cause considerable morbidity and mortality⁽⁹⁷⁻⁹⁹⁾.

IV. Specific Microbial Agents

1. *Endogenous Respiratory Tract Organisms*

The etiology of healthcare-associated pneumonia is primarily determined by which organisms colonize the oropharynx, as microaspiration is the most common route of pathogen entry. *S. pneumoniae*, *H. influenzae*, *M. catarrhalis*, and MSSA are recognized to colonize the upper respiratory tract and are common causes of community-acquired pneumonia^(29;64;91). The relative prevalence is highly variable, *S. pneumoniae* being isolated in 1% to 35% and *H. influenzae* in 6% to 23% of cases^(47;64;74;100-102), but their roles in NP, particularly in the elderly with chronic lung disease, have been well established. Greenaway and colleagues reported that 38% of bacterial nosocomial pneumonia acquired on the general wards of a Canadian tertiary-care hospital were caused by community-acquired pathogens (*S. pneumoniae*, *H. influenzae*, *M. catarrhalis*, beta hemolytic streptococci)⁽⁶⁴⁾. *S. pneumoniae* and *H. influenzae* have also been implicated in VAP, commonly occurring within the first five days after intubation^(47;77;82;100).

2. *Staphylococcus aureus*

S. aureus has been identified as a common cause of NP in many studies, accounting for 17% of adult⁽³⁷⁾ and 16.9% of pediatric ICU NPs⁽⁴⁰⁾. Taylor and co-workers reported that *S. aureus* was responsible for 27% of bacterial pneumonias (ICU and non-ICU) over a seven year period in a Canadian adult and pediatric tertiary care hospital⁽¹⁰³⁾.

Individuals at risk of acquiring MSSA pneumonia include injection drug users, children, and those with recent influenza⁽¹⁰⁴⁾. In intubated patients, MSSA is seen primarily in early onset nosocomial pneumonia, in which infection is probably from an endogenous source related to community-acquired carriage. These pneumonias usually occur in younger patients, often with a history of cranial trauma or neurosurgery, in whom the reported incidence rates of VAP are as high as 56%⁽¹⁰⁵⁻¹¹⁰⁾.

3. *Enterobacteriaceae*

With late onset NP, a shift occurs from the usual pathogens seen with community-acquired pneumonia to predominantly enteric Gram-negative bacilli (EGNB), which include *Escherichia coli*, *Klebsiella pneumoniae*, and *Enterobacter*, *Proteus*, and *Serratia* species. EGNB rarely colonize the oropharynx and respiratory tract of healthy people. However, the prevalence of colonization with these organisms increases significantly among ill patients⁽¹¹¹⁾. Changes on the epithelial surface of the oropharynx and respiratory tract, induced by the underlying disease, probably facilitate the adherence of these bacteria⁽¹¹²⁾.

Oropharyngeal colonization with EGNB can also occur exogenously from contaminated respiratory therapy equipment and from patient to patient from bacteria on the hands of personnel⁽¹¹³⁾.

In general, EGNB's have been implicated in 20% to 40% of cases of bacterial nosocomial pneumonia⁽²⁵⁾. Although adequate sputum samples for diagnosis are difficult to obtain, aerobic Gram-negative bacilli have also been identified with variable frequency in long-term care residents⁽⁵¹⁾. When diagnostic methods are used that exclude contamination of respiratory specimens by upper airway and oropharyngeal secretions, the isolation rate of EGNB is lower⁽⁸⁰⁾.

4. Environmental Pathogens

Non-fermentative Gram-negative bacilli, such as *Pseudomonas* species and *Acinetobacter* species, have evolved in aquatic environments and have minimal growth requirements. Because of the many potential hospital reservoirs and their inherent resistance to commonly used antimicrobials, these organisms have become significant hospital pathogens. Investigations that use diagnostic techniques capable of distinguishing colonization from true infection have found an increasing role of these pathogens in NP, particularly in ICU patients requiring mechanical ventilation^(46;83;114). French investigators evaluating 135 consecutive episodes of VAP found that *P. aeruginosa*, *Acinetobacter baumannii*, and *Stenotrophomonas maltophilia* were responsible for 39% of episodes of VAP occurring ≥ 7 days of mechanical ventilation. In contrast, only 6 of 34 cases (18%) of VAP occurring within the first six days were caused by these four pathogens. All patients with these organisms had received prior antimicrobials⁽⁸³⁾. These findings are consistent with those of other studies^(46;69).

4.1. *Pseudomonas aeruginosa*

In published NNIS data, *P. aeruginosa* accounted for 21.8% and 15% of pulmonary infections in pediatric and adult ICU patients respectively, and ranked first and second as the most frequently identified pathogen in these two settings^(37;40). Colonization of the respiratory tract often precedes invasive infection with *P. aeruginosa*⁽¹¹⁵⁻¹¹⁷⁾. Gastric colonization may also play a role in pathogenesis⁽¹¹⁸⁾. Respiratory tract and gastric colonization with *P. aeruginosa* may originate from exogenous sources, including contaminated enteral feeds⁽¹¹⁹⁾, respiratory diagnostic equipment⁽¹²⁰⁾, and disinfectants⁽¹²¹⁾; from other patients colonized with *P. aeruginosa*; or from other patients by way of the transiently colonized hands of healthcare workers (HCWs)^(122;123).

Studies to determine risk factors and routes of transmission of *P. aeruginosa* have primarily been undertaken in patients with VAP. In a prospective study by Talon et al. involving 190 mechanically ventilated patients in a surgical ICU, length of hospitalization, previous use of third-generation cephalosporins, and chronic obstructive pulmonary disease, were the most significant predictors of colonization and/or infection with this organism⁽¹¹⁷⁾.

4.2. Acinetobacter species

Acinetobacter spp. are widespread in hospital and out-of-hospital environments. Virtually all soil and water samples yield *Acinetobacter* spp. *Acinetobacter* has been isolated from hospital air, vaporizer mist, tap water faucets, peritoneal dialysis baths, bedside urinals, mattresses, pressure transducers, angiography catheters, and equipment and solutions used for respiratory therapy, including mechanical ventilators^(114;124). This organism colonizes the skin of up to 25% of healthy ambulatory adults, and transient pharyngeal colonization is observed in 7%. It is the most common Gram-negative organism persistently carried on the skin of hospital personnel⁽¹¹⁴⁾.

The respiratory tract is the most frequent site of *Acinetobacter* infection. Pneumonia usually occurs in debilitated ICU patients receiving prolonged mechanical ventilation and broad spectrum antimicrobials^(83;84).

A. baumannii, often resistant to numerous antimicrobial agents, has emerged as an important opportunistic pathogen causing life-threatening infections in patients with altered host defence mechanisms⁽¹¹⁴⁾. It is usually acquired exogenously through cross-transmission, especially in ICUs, where numerous outbreaks have occurred^(114;125-128).

4.3. Burkholderia cepacia

B. cepacia is an important respiratory pathogen in patients with cystic fibrosis (CF)⁽¹²⁹⁻¹³¹⁾. Risk factors associated with acquisition of *B. cepacia* in CF patients include older age, more advanced pulmonary disease, exposure to *B. cepacia* during a previous hospitalization, or a sibling with *B. cepacia* colonization^(132;133). Spread of *B. cepacia* among CF patients has also been associated with frequent social contact in ambulatory care clinics⁽¹³⁴⁾. *B. cepacia* thrives in a moist environment, and hospital outbreaks of respiratory tract colonization and infection in non-CF patients have been associated with inadequate or inappropriate disinfection, reuse of respiratory therapy equipment, and intrinsic or extrinsic contamination of nebulized medications or solutions⁽¹³⁵⁻¹³⁷⁾. Contaminated respiratory therapy equipment may play a role in the transmission of *B. cepacia* among CF patients^(130;138).

4.4. *Stenotrophomonas maltophilia*

S. maltophilia, an opportunistic organism usually of low pathogenicity, has been identified as a cause of nosocomial pneumonia⁽¹³⁹⁻¹⁴¹⁾. Usually, isolation of this organism from the respiratory tract represents colonization⁽¹⁴¹⁾. Risk factors for colonization or infection include hospitalization in an ICU, malignancy, mechanical ventilation, and previous antimicrobial exposure. The single most important predisposing factor for infection with *S. maltophilia* is being immune compromised⁽¹³⁹⁾. Nosocomial outbreaks of respiratory infection and colonization have been linked to contaminated water sources within the hospital^(142;143).

4.5. *Legionella pneumophilla*

L. pneumophilla causes up to 10% of NP and has been responsible for many nosocomial outbreaks⁽¹⁴⁴⁻¹⁴⁹⁾. Nosocomial cases have also been reported in immunosuppressed children^(150;151) and neonates^(152;153). The incidence of Legionnaires' disease may be underestimated because the specialized diagnostic tests required to identify *Legionella* spp. are not performed routinely⁽¹⁵⁴⁾.

Legionella spp. are commonly found in natural and man-made aquatic environments⁽¹⁵⁵⁾. In addition, soil and dust containing dormant forms of *Legionella* can become airborne during soil excavation, which can subsequently contaminate cooling towers or be inhaled by susceptible individuals⁽¹⁵⁶⁾. Cooling towers, heated potable water distribution systems, and locally produced distilled water provide a suitable environment for *Legionellae* to multiply and serve as a source of infection for patients⁽¹⁵⁷⁻¹⁵⁹⁾. The presence of *Legionella* colonization of the water system may be predictive of the occurrence of healthcare-associated *Legionella* infection^(94;148;160). Factors contributing to the proliferation of *Legionella* in these reservoirs are low hot-water temperatures, stagnant water in pipes, sediment in hot-water storage tanks, and the presence of other microbes^(159;161). If all of these factors are not controlled by appropriate maintenance procedures, high-level contamination may result^(159;162;163). During construction and renovation projects, water systems are often disrupted, and the potable water can become contaminated with *Legionella* when the water supply is restored. Contamination may be due to massive descaling in the water pipes as they are repressurized, or the introduction of contaminated soil into the plumbing system⁽¹⁵⁶⁾. Results of routine environmental water cultures from sites sampled within a single water system may be variable, and changes in concentrations of *Legionella* can occur at the same site at different times^(164;165).

Modes of transmission believed to be responsible for healthcare-associated *Legionella* infection include inhalation of aerosols from cooling towers⁽¹⁶⁶⁾, aerosols of potable hot water (e.g., in showers)⁽¹⁶⁷⁾, and aerosolization of tap water used in respiratory therapy devices⁽¹⁶⁸⁾. Microaspiration of *Legionella*-contaminated water, in conjunction with use of nasogastric tubes^(145;147;169) and ice or ice water from contaminated ice machines⁽¹⁷⁰⁾, has also been implicated. A person's risk of acquiring Legionnaires' disease following exposure to contaminated water depends on several factors, including the type and intensity of exposure, and the exposed person's health^(171;172). Patients who are immuno-compromised, critically ill, or taking steroids are at highest risk of infection^(150;171-174). Other factors that can influence the risk of illness following exposure include the extent of *Legionella* colonization of aerosolized water and the virulence properties of the responsible strain. Mortality rates from healthcare-associated *Legionella* infections are approximately 24%⁽¹⁷³⁾.

The incubation period for Legionnaires' disease is usually two to ten days. Therefore, laboratory-confirmed legionellosis that occurs in a patient who has been hospitalized continuously for ten days or more before the onset of illness is regarded as a definite case of healthcare-associated Legionnaires' disease. A laboratory-confirmed infection that occurs two to nine days after admission to a healthcare facility is a possible case of healthcare-associated Legionnaires' disease⁽³⁰⁾. In facilities where as few as one to three cases of healthcare-associated Legionnaires' disease have been identified over several months, intensified surveillance has frequently detected additional cases⁽¹⁴⁹⁾.

5. Antimicrobial-Resistant Organisms

Antimicrobial-resistant organisms (AROs) are primarily hospital-acquired, rather than organisms that the host is colonized with on admission. AROs are more frequently being isolated in nosocomial pneumonia. Prior receipt of antimicrobial therapy, especially with broad-spectrum agents, is a strong risk factor for late onset VAP and pneumonia due to resistant organisms. Numerous studies have demonstrated the potential for AROs to spread rapidly in the hospital setting, causing both colonization and infection^(83;84;105;175;176).

5.1. Methicillin-resistant *Staphylococcus aureus*

The emergence of MRSA has led to an increase in the incidence of nosocomial staphylococcal respiratory tract infections^(105;177). The results of national surveillance in Canadian hospitals have revealed that the rate of MRSA infection increased more than four fold between 1995 and 2000, 24% of infections involving the respiratory tract. In this study, MRSA colonization or infection occurred infrequently in pediatric patients. Adults in critical care units were more likely to have infection with MRSA (odds ratio (OR) 1.5, 95% CI: 1.4 to 1.6; $p < 0.001$) than patients elsewhere in the hospital⁽¹⁷⁷⁾.

Studies comparing the epidemiologic and clinical features of MSSA and MRSA pneumonia in mechanically ventilated patients conclude that patients with MRSA pneumonia are older and significantly more likely to have had a longer duration of mechanical ventilation (greater than six days), prior administration of antimicrobials, use of corticosteroids, pre-existing chronic lung disease, and prior bronchoscopy^(105;107;110). MRSA pneumonia causes greater morbidity and mortality than MSSA pneumonia: mortality directly related to pneumonia is 20 times greater for the MRSA patient⁽¹¹⁰⁾.

MRSA has also been documented as a cause of pneumonia in long-term care facilities. However, serious infections caused by the pathogen occur less often in this environment⁽¹⁷⁸⁾. A retrospective review of MRSA and MSSA infection rates conducted among residents of a Veteran's Affairs facility revealed a transient increase in the overall *S. aureus* infections one year after the introduction of MRSA to the facility. After this peak, infection rates declined to the baseline rates seen before the introduction of MRSA⁽¹⁷⁹⁾. Additionally, MSSA and MRSA infections were similar in terms of the sites involved and the outcomes⁽¹⁷⁹⁾. More information is needed about the impact of MRSA on *S. aureus* infection rates and outcomes in the long-term care setting.

The principal mode of transmission of MRSA is considered to be from one colonized or infected patient to another by means of the hands of transiently colonized HCWs. A report of the largest outbreak to date of MRSA pneumonia or colonization in mechanically ventilated patients suggested that respiratory tract colonization in mechanically ventilated patients could have played a significant role in the spread of the outbreak through environmental contamination and subsequent colonization of healthcare personnel and adjacent patients⁽¹⁰⁵⁾.

5.2. Extended spectrum beta-lactamase (ESBL)-producing Enterobacteriaceae
Bacteria producing ESBLs are identified in the clinical laboratory by their resistance to third-generation cephalosporins and susceptibility to antibiotics combined with beta-lactamase-inhibiting compounds such as clavulanic acid and tazobactam⁽¹⁸⁰⁾. Over the past decade, ESBL-producing *Enterobacteriaceae* have emerged as serious nosocomial pathogens in some facilities, and outbreaks of these organisms have been well documented in adult and pediatric patients in Europe and the United States⁽¹⁸¹⁻¹⁸⁵⁾. The prevalence of ESBLs in Canadian hospitals is low⁽¹⁸⁶⁾.

Outbreaks have usually affected the most seriously ill patients and occurred in ICUs. The risk factors for infection with ESBL-producing organisms are similar to those for other antimicrobial-resistant nosocomial pathogens and include prior antimicrobial administration, prolonged length of hospital stay, stay in an ICU, and increased severity of illness⁽¹⁸⁷⁾. Outbreaks of ESBL have been associated with significant morbidity and mortality^(182-184;186).

5.3. Penicillin-resistant *S. pneumoniae*

Historically, *S. pneumoniae* remained sensitive to benzyl penicillin and was not considered an important hospital pathogen. However, outbreaks due to penicillin-resistant pneumococci are being reported with increasing frequency. These outbreaks often involve children⁽¹⁸⁸⁾ or the elderly in long-term care facilities⁽¹⁸⁹⁾. In these age groups, nasopharyngeal carriage is common. Other patients, staff, and family members may rapidly become colonized by resistant pneumococci after casual contact with infected patients during outbreaks⁽¹⁷⁶⁾. Carriage may persist for several months, with dissemination into the community.

6. *Bordetella pertussis*

Pertussis, a highly communicable infection of the respiratory tract caused by the microorganism *B. pertussis* is a well-recognized cause of disease in young children and infants. Complications are pneumonia, seizures, and encephalopathy, and they occur more commonly in infants younger than six months of age⁽¹⁹⁰⁾. *B. pertussis* is spread by large droplets produced by an infected individual's cough or sneeze.

Although the incidence of pertussis has decreased substantially since the introduction and widespread use of vaccine, a resurgence has been reported over the last two decades in both Canada⁽¹⁹¹⁾ and the United States⁽¹⁹²⁾. This is thought to result from incomplete immunization coverage, the need for multiple doses of vaccine to achieve protection, the less than 100% efficacy of vaccine, and the waning of vaccine-induced protection in those older than six years of age⁽¹⁹³⁾. Infected adolescents and adults can serve as reservoirs for pertussis in young infants who are unimmunized or incompletely immunized⁽¹⁹⁴⁾.

Healthcare facilities have reported nosocomially or occupationally acquired pertussis⁽¹⁹⁵⁻²⁰⁰⁾. Factors contributing to transmission are failure to recognize and isolate infected infants and children, lack of highly sensitive and, rapid diagnostic tools, failure to appreciate that immunity following immunization wanes with time, failure to diagnose, failure to institute control measures rapidly, and failure to recognize and treat disease in HCWs^(201;202).

7. *Aspergillus* Species

Lower respiratory tract infection due to *Aspergillus* sp. is uncommon, but mortality rates are very high in the population of patients who become infected⁽²⁵⁾. *Aspergillus* spp., which are commonly found in soil, water, and decaying vegetation, have been cultured from unfiltered hospital air and ventilation systems^(156;203). Environmental disturbances caused by construction and/or renovation and repair activities (e.g., removing ceiling tiles, running cables through the ceiling, structural repairs) in and around healthcare facilities increase the airborne *Aspergillus* spp. spore counts in the indoor air of these facilities, thereby increasing the risk of healthcare-associated aspergillosis among high-risk patients. Transmission occurs by the airborne route through inhalation of airborne aerosols carrying *Aspergillus* spp. Spores^(156;203-205). A study, in 2000, suggested that hospital water may be a source of nosocomial transmission of aspergillosis⁽²⁰⁶⁾.

Nosocomial respiratory infections caused by *Aspergillus* spp. usually occurs in immunocompromised patients, particularly in patients undergoing chemotherapy for hematologic malignancy, hematopoietic stem or solid organ transplantation, in premature newborns, and in patients with acquired immunodeficiency syndrome (AIDS)⁽²⁰⁷⁻²¹²⁾.

8. Viruses

8.1. Respiratory Syncytial Virus

RSV is the most common cause of lower respiratory tract infection in infants and young children and a major cause of pediatric nosocomial infection. In a multicentre study in Canadian pediatric hospitals, Langley and colleagues reported that 6% of 1516 hospitalized children with RSV had acquired it in hospital⁽²¹³⁾. Infection may be severe with life-threatening pneumonia or bronchiolitis in children who are immunocompromised or have chronic cardiac or pulmonary disease⁽²¹⁴⁻²¹⁶⁾. Immunocompromised adults (especially recipients of hematopoietic stem cell transplant) and those in ICUs, as well as the elderly, are also at risk of severe disease, secondary pneumonia, and death⁽²¹⁶⁻²²¹⁾. Outbreaks have occurred in neonatal intensive care units⁽²²²⁾ and among the elderly in long-term care facilities⁽²²³⁾. Community outbreaks of RSV occur yearly in the winter months and typically last three to five months; nosocomial outbreaks usually parallel disease in the community⁽²²⁴⁾. During community outbreaks, infants and children admitted to a hospital with respiratory symptoms may shed virus for prolonged periods and serve as reservoirs for further transmission⁽²²⁵⁻²²⁷⁾. Virus may be shed for several days before the onset of symptoms and for up to a week afterwards^(35;227). Shedding is prolonged in the neonate⁽²²²⁾ and the child immunocompromised by chemotherapy or immunodeficiency⁽²²⁵⁾. During

community outbreaks of RSV infection, adults admitted to the ICU may already be infected with RSV, putting other patients at risk of nosocomial infection with this virus⁽²¹⁹⁾.

Person-to-person transmission of RSV is by large droplet or contact spread⁽²²⁸⁾. Fomites contaminated by respiratory secretions are also involved, as RSV survives on surfaces for several hours^(35;229). Hospital staff may become infected after exposure in the community or in the hospital and secondarily infect patients or other HCWs^(224;230-232). RSV can be inoculated into the eyes by hands. The eye is an efficient portal of entry⁽²²⁸⁾.

8.2. Influenza

Influenza is an important cause of morbidity and mortality, especially in individuals who are elderly, immunosuppressed, or have chronic underlying disease. Infection is common in children. Morbidity and hospitalization rates among healthy children less than two years of age are similar to those among adults over 65 years of age⁽²³³⁾, but severe disease and death occur primarily in the elderly and in immunocompromised adults⁽²³⁴⁾. Most reported outbreaks have occurred in long-term care facilities^(97;235), but outbreaks have also been reported on pediatric⁽²³⁶⁾, medical, and geriatric wards^(237;238) and in adult⁽²²¹⁾ and neonatal^(239;240) ICUs.

As with most nosocomial viral infections, infections with influenza are seasonal, occurring annually in the winter months, and they follow or parallel outbreaks in the community, which usually last from six to eight weeks⁽²²¹⁾. Outbreaks are often characterized by abrupt onset and rapid transmission^(237;241).

The most important reservoirs of influenza virus are infected persons. Infection may be introduced into a healthcare facility by patients or personnel⁽²³⁸⁾. The period of greatest communicability is during the first three days of illness, but the virus can be shed up to six days before onset of symptoms, and up to seven or more days after illness onset^(227;236). Transmission is by large droplet spread or by contact. Influenza virus also survives for several hours on environmental surfaces⁽²⁴²⁾.

8.3. Parainfluenza

Parainfluenza infections are most common among infants and young children^(243;244). The disease is relatively mild among older children and healthy adults. In long-term care facilities, both residents and staff may be affected and resident deaths have been reported⁽²²³⁾. Outbreaks have been reported on pediatric wards and NICUs⁽²⁴³⁻²⁴⁵⁾. Serious infection and death have resulted from nosocomial infection in immunocompromised

children and adults⁽²⁴⁶⁻²⁴⁸⁾. Parainfluenza type 3 is frequently endemic, with increases in the spring and fall, whereas types 1 and 2 usually cause outbreaks in the fall.

Transmission of parainfluenza virus is by direct and indirect contact and by large droplets⁽²²⁷⁾. Parainfluenza virus also survives for several hours on environmental surfaces⁽²⁴⁹⁾. Viral shedding from the upper respiratory tract occurs one to four days before the onset of symptoms and continues for seven to ten days in most patients with primary infection. Some patients with primary infection continue to have intermittent shedding of virus for three to four weeks⁽²²⁷⁾.

8.4. Adenovirus

Adenovirus is a common cause of lower respiratory tract infection in young children but unusual in older children and adults⁽³⁵⁾. Outbreaks of severe disease have occurred in neonates^(250;251) and in acute and chronic pediatric care centres⁽²⁵²⁻²⁵⁵⁾. For outbreaks in pediatric settings, attack rates of 12%-46% have been reported. Adenoviruses have rarely been reported as a cause of infection in long-term care facilities⁽²²³⁾, but an outbreak among adult residents and staff in a psychiatric chronic care facility has been reported⁽²⁵⁶⁾. Serious adenovirus infections have been reported in immunocompromised pediatric and adult patients, including those having received a transplant⁽²⁵⁷⁻²⁶⁰⁾, and there is increased mortality in these populations. Immunocompromised patients may excrete the virus for prolonged periods, serving as a persistent reservoir for nosocomial transmission.

Unlike the seasonal pattern of other respiratory viruses, adenovirus infection tends to be endemic with sporadic cases occurring throughout the year⁽²⁶¹⁾. Transmission is by direct or indirect person-to-person contact and large droplets, usually through contaminated environmental sources⁽³⁵⁾. Most nosocomial adenovirus outbreaks have involved HCWs who had contact with an identified index case, with subsequent spread to other patients⁽²⁶²⁾.

8.5. Severe acute respiratory syndrome (SARS) – coronavirus

The SARS outbreak brought to the forefront, the potential for transmission of viral respiratory tract infections to HCWs and patients in healthcare settings. This has led to the introduction of the concept of respiratory hygiene and cough etiquette⁽²⁶³⁾.

In March 2003, the world was alerted to the appearance in Asia of a severe acute respiratory syndrome (SARS) of unknown etiology affecting large numbers of HCWs. Within weeks a novel coronavirus, now called SARS-associated coronavirus (SARS-CoV), was identified as the causative agent⁽²⁶⁴⁾. By mid-July 2003, 8437 individuals worldwide had been infected, and there were 813 deaths (9.6%)⁽²⁶⁵⁾.

The epidemiologic and clinical features of SARS have been described in detail⁽²⁶⁶⁻²⁶⁹⁾. In Canada, most of the cases occurred in Toronto and were the result of exposure to SARS-CoV in the hospital setting^(266;267). The median incubation period was six days (interquartile range three to ten days) for prodrome and nine days for cough or dyspnea⁽²⁶⁶⁾. Fever (99%) was the most common symptom with non-productive cough (69%), and myalgia (49%), dyspnea (42%) being less commonly reported⁽²⁶⁶⁾. Admission chest radiography was normal in 25% of SARS patients⁽²⁶⁶⁾. Approximately 20% became severely ill, requiring ICU admission⁽²⁶⁸⁾. Overall mortality was 6.5%⁽²⁶⁶⁾, increasing considerably among patients admitted to the ICU (34%) and among those requiring mechanical ventilation (45%)⁽²⁶⁸⁾. A higher mortality risk was seen in patients with diabetes, other co-morbid illnesses, older age, and bilateral radiographic infiltrates^(266;268). These findings are similar to those reported in the Singapore cohort⁽²⁶⁹⁾.

Compared with adults and teenagers, younger children had a milder clinical course⁽²⁷⁰⁾. Currently, there is no proven therapy for SARS-CoV infection.

For the most part, nosocomial and occupational transmissions of SARS occurred as the result of exposures to patients not suspected of having the infection. Transmission was terminated with the enforcement of strict infection control measures, including use of personal protective equipment (PPE) incorporating masks, gowns, gloves, and face protection^(267;271;272). This highlights the need for a high index of suspicion for SARS in the appropriate setting. Evidence to date suggests that it is spread mainly by respiratory droplets, with the potential for spread through fomites^(267;271). Diarrhea may be present in 24%-38% of patients at some point during their illness^(266;273), and SARS-CoV has been found by polymerase chain reaction (PCR) testing in the intestine or stool of patients with SARS⁽²⁷³⁾. The role of enteric shedding in the hospital transmission of SARS has yet to be demonstrated.

A case-control study comparing the use of PPE by infected and non-infected HCWs in Hong Kong's Prince of Wales Hospital demonstrated that staff who used masks, gowns, and complied with hand hygiene were less likely to acquire SARS (no cases in HCWs using non-paper masks) than those who did not use them⁽²⁷⁴⁾. In multivariate analysis, only the use of masks was significant in affording protection, and there were no differences in infection risk between the use of surgical masks and respirators⁽²⁷⁴⁾. These measures may be insufficient where aerosol-producing procedures are performed. Nine HCWs caring for a patient around the time of respiratory failure and intubation were found to have suspected or probable SARS, despite what was thought to be the use of recommended PPE⁽²⁷⁵⁾. However, other factors may have contributed to these transmissions. The source patient had copious respiratory secretions and may have been a "super-spreader", or an individual likely to carry a high viral load. Such patients may be more able to contaminate their environment and those in their environment. Additionally, investigation determined that many of the infected HCWs did not have a clear understanding of how to remove their PPE without contaminating themselves⁽²⁷⁵⁾. For that reason, aerosol-producing procedures (e.g., non-invasive ventilation, sputum induction, administration of nebulized medications) need to be limited, and the focused infection control education for HCWs needs to be emphasized.

9. Uncommon Pathogens

9.1. Chlamydomphila (formerly Chlamydia) pneumoniae

C. pneumoniae is assumed to be transmitted from person to person by means of infected respiratory tract secretions. *C. pneumoniae* has been reported to account for 7%-10% of cases of community-acquired pneumonia among adults^(276;277) and up to 28% of pneumonia cases among school-age children^(278;279). It is infrequently documented as a cause of acute lower respiratory tract infection in infants⁽²⁸⁰⁾. *C. pneumoniae* is rarely a cause of healthcare-associated infection but has been implicated in outbreaks⁽⁹⁵⁾ and sporadic cases⁽⁹⁶⁾ of pneumonia in long-term care facilities.

9.2. Mycoplasma pneumoniae

M. pneumoniae is a common cause of respiratory infections in adults and school-age children, causing approximately 15%-20% of all community-acquired pneumonia^(277;278). Transmission occurs by means of respiratory droplets, requiring close contact with an infected person. The incubation period is roughly two to four weeks⁽²⁸¹⁾. Several institutional outbreaks of healthcare-associated *M. pneumoniae* have been reported in closed communities, such as long-term residential facilities⁽²⁸²⁾ and hospitals^(283;284).

9.3. *Pneumocystis jiroveci* (formerly *carinii*) (PCP)

P. jiroveci is an organism of low virulence found in the lungs of humans and a variety of animals. It is a major cause of pneumonia in the immunocompromised host with deficient cell-mediated immunity, particularly in persons with human immunodeficiency virus (HIV) infection, patients receiving immunosuppressive therapy for organ transplantation or cancer, and children with congenital immunodeficiency syndromes^(285;286).

Animal model studies have demonstrated that *P. jiroveci* is communicable and that airborne droplets are the most likely source of transmission⁽²⁸⁶⁾. Outbreaks of PCP in the healthcare setting have been reported, and epidemiologic studies suggest that person- to- person spread by the respiratory route may occur^(285;287-289). However, because carriage of *P. jiroveci* is difficult to detect, and cultures and antibody tests are not available, evidence of healthcare-associated infection is circumstantial.

A.3. Diagnosis

Diagnosing healthcare-associated pneumonia, especially VAP, may be difficult, as other conditions may mimic its clinical and radiographic findings^(25;26;290;291). The definitions and use of diagnostic tests differ depending on whether the goal is surveillance for incidence rates of pneumonia or a definitive diagnosis for individual patient management⁽²⁹²⁾.

The diagnosis of pneumonia is based on a combination of findings obtained by history, clinical examination, microbiologic and immunologic testing, and radiography. However, common symptoms of community-acquired pneumonia such as fever, productive cough, chest pain, and dyspnea, may be absent or obscured by underlying disease in hospitalized patients who have pneumonia⁽²⁹²⁾. This is particularly an issue with ventilated patients. Colonization of the upper respiratory tract with pathogenic bacteria occurs in more than 50% of hospitalized patients. Consequently, isolation of bacteria, the most common nosocomial pathogens, from tracheal aspirates could be the result of either colonization or infection^(293;294). Chest radiographic abnormalities representing non-pneumonic infiltrates are frequently observed, and fever and leukocytosis may be the result of underlying illness or other infections^(295;296). All these factors contribute to the potentially poor specificity of a clinical diagnosis of NP. Chest radiography remains an important component in the evaluation of hospitalized patients with suspected pneumonia, although it is most helpful when findings are normal, generally ruling out pneumonia⁽²⁹⁷⁾. When radiographic infiltrates are evident, they may be falsely attributed to pneumonia rather than to non-infectious causes, such as pulmonary embolus with infarction, recurrent aspiration, pulmonary hemorrhage, pulmonary edema, or acute respiratory distress syndrome⁽²⁹⁵⁾.

I. Surveillance Definition vs. Clinical Diagnosis

Infection control personnel need a reproducible, reliable, and accurate definition of healthcare-associated pneumonia to perform surveillance and investigate outbreaks. Ideally, they should be able to identify pneumonia on the basis of common clinical and laboratory findings. For epidemiologic purposes (e.g., calculating incidence rates), a definition applicable to all patients over prolonged time periods should be used⁽²⁵⁾. The Centers for Disease Control and Prevention (CDC) definitions of nosocomial pneumonia have been widely used for infection control surveillance in the hospital setting. The definitions rely predominantly on clinical criteria, such as fever, leukocytosis, and the development of purulent sputum, in combination with the presence of new or progressive pulmonary infiltrates on radiography, a suggestive Gram stain, and cultures of sputum, tracheal aspirate, pleural fluid, or blood⁽²⁹⁸⁾.

Definitions of healthcare-associated pneumonia for infection control surveillance are fully discussed in Section A.6 of this document. Definitions that require the performance of specialized diagnostic tests not widely available in most healthcare settings are problematic. However, specialized tests may provide a more accurate diagnosis for patient care and are discussed below. It is important that the strengths and limitations of the various diagnostic tests are understood, so that infection rates can be appropriately interpreted and compared.

II. Diagnostic Methods / Strategies

1. Bacterial Pneumonia

Although the clinical criteria traditionally used for the diagnosis of pneumonia, coupled with Gram stain and/or cultures of sputum or tracheal specimens, appear to have reasonable clinical accuracy for bacterial pneumonia, their sensitivity and specificity are variable^(294;299-305). Non-quantitative culture of expectorated sputum or endotracheal secretions is the simplest and most frequently used test in the investigation of pneumonia. These cultures may establish etiology, but not diagnosis. This is especially true in mechanically ventilated patients, since the lower respiratory tract frequently becomes colonized within hours of intubation, and so the pathogens isolated could be present as a result of either colonization or infection^(144;292;294;302-306). Lack of specificity in the clinical context can lead to over-diagnosis of pneumonia, resulting in unnecessary antimicrobial treatment, which could promote the development and spread of AROs and contribute to a poor outcome from pneumonia^(307;308). Blood cultures are positive in only 8% to 20% of cases and, therefore, are of limited use in making a diagnosis of NP or identifying the responsible organism. The value of routinely obtaining blood cultures for diagnosing VAP has been questioned⁽³⁰⁹⁻³¹¹⁾.

A variety of invasive and non-invasive diagnostic techniques have been investigated over the past decade to improve the diagnostic accuracy of VAP⁽³¹²⁻³²²⁾. The advantages and disadvantages of these techniques are summarized in Table 6. Invasive fiberoptic bronchoscopic techniques, e.g., quantitative cultures of protected specimen brush (PSB) and bronchoalveolar lavage (BAL) specimens have been used to increase specificity and improve diagnostic accuracy of respiratory tract cultures⁽³⁰⁷⁾. BAL is the sequential installation and aspiration of physiologic solution into a lung subsegment through the bronchoscope to sample the alveolar surface distal to the bronchoscope. PSB involves brushing a small portion of the distal airway. The rationale for bronchoscopy is to minimize contamination of culture samples with organisms that colonize upper respiratory tract secretions. Since contamination will still occur to a certain degree, quantitative cultures are used to distinguish between bacteria colonizing the respiratory tract and those infecting the lungs. The suggested criteria for diagnosing pneumonia are $\geq 10^3$ cfu/mL for PSB and $\geq 10^4$ cfu/mL for BAL⁽³⁰⁷⁾.

The reported sensitivities and specificities of these methods range from 47% to 100% and 82% to 100% for BAL, and 30% to 100% and 60% to 100% for PSB respectively⁽³²³⁻³²⁵⁾. While specificity is generally improved, sensitivity is lowered, increasing the number of true NPs that may be missed. Bronchoscopy is an invasive and costly technique that is not always readily available. The complications of bronchoscopy include hypoxemia, bleeding, and arrhythmia, and the complications of PSB include pneumothorax.

Non-invasive, quantitative strategies as alternative diagnostic methods have also been investigated. These include non-bronchoscopic or "blind" (blind catheterization of the distal airways through the endotracheal tube) BAL, mini-BAL, PSB, or tracheal specimens^(304;315;316;319;326;327). They are comparable to bronchoscopically obtained BAL and PSB in sensitivity and specificity^(323;328). The utility of bronchoscopy in the diagnosis of nosocomial pneumonia therefore remains controversial. Studies have failed to conclusively demonstrate that the use of invasive diagnostic tests ultimately results in improved patient outcomes⁽³²⁹⁻³³¹⁾.

Table 6**Advantages and limitations of methods used for the diagnosis of nosocomial pneumonia**

Reference	Method	Advantages	Disadvantages
Craven & Steger 1997 ⁽²⁵⁾	Transthoracic aspirates	Good sensitivity and specificity	Complications frequent (i.e., pneumothorax) False negatives do occur
Marquette, Copin, et al. 1995 ⁽³⁰⁵⁾ Wunderink 2000 ⁽³⁰¹⁾ Chastre, Trouillet, et al. 2000 ⁽²⁹⁷⁾ Reimer & Carroll 1998 ⁽³³²⁾	Sputum with Gram stain	Non-invasive Relatively inexpensive Often easy to obtain Gram stain and culture easy to perform	Poor sensitivity for immunocompromised patients or unusual organisms Presence of potential pathogen suggestive but not diagnostic Poor specificity, especially in patients on ventilators or in long-term care
Marquette, Copin, et al. 1995 ⁽³⁰⁵⁾ Craven & Steger 1998 ⁽³³³⁾ Sanchez-Nieto, Torres, et al. 1998 ⁽³²⁹⁾ Ruiz, Torres, et al. 2000 ⁽³³⁰⁾	Quantitative endotracheal aspirates	Non-invasive Simpler, less expensive to perform than bronchoscopic or nonbronchoscopic BAL or PSB More readily available Good correlation (>65%) with bronchoscopic BAL and PSB	Threshold for diagnosis of VAP varies among studies Requires quantitative bacteriology
Grossman & Fein 2000 ⁽³²³⁾ Torres & el-Ebiary 2000 ⁽³²⁴⁾ Baughman 2000 ⁽³²⁵⁾ Chastre & Fagon 1994 ⁽³⁰⁷⁾	Bronchoscopy with PSB or BAL and quantitative culture	Better specificity for diagnosis PSB specificity 95% and sensitivity 67% BAL specificity 82% and sensitivity 73% Results may decrease unnecessary antimicrobial use and emergence of AROs	Sensitivity may be less than clinical diagnosis Prior treatment with antimicrobials decreases sensitivity Relies on quantitative bacteriology Bronchoscopy is costly and not always available Bronchoscopic techniques are invasive and may have complications Not possible in the most severely ill patients

Reference	Method	Advantages	Disadvantages
Kollef et al. ⁽³¹⁶⁾ Campbell ⁽³²⁸⁾ Papazian et al. ⁽³¹⁹⁾	Nonbronchoscopic PSB, BAL, mini-BAL	May be done by non-physician health professionals Noninvasive Less expensive than bronchoscopy Similar specificity and sensitivity to PSB and BAL Appears to have comparable diagnostic yield	Quantitative cultures are more costly than routine cultures Procedure requires skilled personnel
Meduri 1995 ⁽³³⁴⁾	Open lung biopsy	Tissue obtained to establish diagnosis Unusual pathogens detected	Risk due to surgical procedure False negatives do occur

PSB, protected specimen brush; BAL, bronchoalveolar lavage; VAP, ventilator-associated pneumonia; ARO, antibiotic-resistant organisms - Adapted with permission from Craven DE, Steger KA. Hospital-acquired pneumonia: perspectives for the health care epidemiologist. *Infect Control Hosp Epidemiol* 1997;18(11):783-795.

As noted, comparison of non-invasive, non-directed quantitative endotracheal aspiration (QEA) and bronchoscopy with PSB and BAL has demonstrated well-correlated results⁽³²⁹⁾. This is consistent with earlier studies indicating that the use of QEA in conjunction with the clinical diagnosis of VAP provides more specificity than does clinical diagnosis alone and compares favorably with diagnosis by bronchoscopy^(305;320). The merits of this method include its ready availability, ease of use, and cost-effectiveness. Whether this diagnostic strategy results in improved patient outcomes remains to be seen.

Open lung biopsy is considered the definitive pulmonary diagnostic procedure. However, its use is generally reserved for those patients who do not improve with initial therapy and have negative findings, or who need the most rapid and specific diagnosis⁽³³⁴⁾. Biopsy cultures may be negative in the presence of histologic evidence of pneumonia.

Quantitative culture and microscopic examination of respiratory specimens are the most accurate methods when attention is paid to the quality and collection of specimens⁽³³⁵⁾. To maximize diagnostic accuracy, specimens should be collected before the start of antimicrobial therapy or before changes are made to a failing regimen. The sensitivity of any diagnostic test is decreased by previous antimicrobial therapy⁽³¹⁷⁾.

Specimens should be transported expeditiously to the laboratory, ideally within 30 minutes but certainly within two hours, to avoid the inhibition of growth of fastidious organisms and overgrowth of colonizing organisms⁽³³⁶⁾. Microscopic analysis of the sample to evaluate its quality (i.e., the presence of polymorphonuclear cells and absence of squamous epithelial cells) is important. Rapid processing to prevent loss of viability of pathogens and/or overgrowth of contaminants in these unpreserved specimens should be performed^(335;337).

2. Viruses

A high degree of suspicion is key to the diagnosis of viral pneumonia, as viral pathogens are often not included in the differential diagnosis. Clinical findings associated with viral infections are non-specific. Chest x-rays frequently show diffuse alveolar or interstitial infiltrates⁽²²¹⁾. The diagnosis in a specific patient is facilitated by knowing what viruses are circulating in the community at a given time.

Viral isolation in cell culture remains the standard method for diagnosing infection with viral respiratory pathogens⁽³³⁸⁾. Specimens for virus isolation should be collected as soon as possible after the onset of symptoms. Although some individuals may shed virus for weeks, the amount of virus present is generally greatest early in the illness⁽²²⁶⁾. Nasopharyngeal washings are a more reliable means of recovering virus than nasal and throat swabs, although less convenient for both the HCW and the patient⁽³³⁸⁻³⁴⁰⁾. Unfortunately, virus isolation generally takes several days and in some cases may take more than two weeks. This limits its value in making therapeutic and infection control decisions^(221;340). Also, even under optimal conditions, viral cultures may be falsely negative. Multiple cultures or confirmation by serology increases the reliability of the culture results.

Enzyme-linked immunosorbent assays (ELISA) and immunofluorescence tests for rapid antigen detection of respiratory viruses, including influenza A and B, RSV, and parainfluenza virus (PIV), are now commercially available. These tests tend to lack sensitivity (though not specificity) when compared with cell culture and are best used in combination to maximize the positivity rates⁽³³⁸⁾. Reported sensitivities for ELISAs range from 57%⁽³⁴¹⁾ to 98%⁽³⁴²⁾ for RSV and 75%^(341;343) to 90%⁽³⁴⁴⁻³⁴⁶⁾ for influenza A. Monoclonal antibody pools for respiratory viruses used in both direct and indirect immunofluorescence assays demonstrate varying sensitivity, depending on the virus: 28%-79% for PIV^(347;348), 65%-92% for RSV^(341;349), 40%-65% for influenza A^(341;343;348), and 58% for adenovirus⁽³⁵⁰⁾. Molecular methods for the rapid detection of respiratory viruses are being evaluated and have demonstrated good sensitivity and specificity when compared with conventional viral cell culture techniques⁽³⁵¹⁻³⁵³⁾. The accuracy of these techniques depends on the technical expertise of the laboratory and the quality of the sample submitted for testing.

The optimal specimen may vary for different detection methods, so the laboratory should be consulted prior to collection. Rapid test methods have proven to be useful and cost-effective in reducing the rate of nosocomially transmitted respiratory viruses by facilitating cohorting and eliminating unnecessary isolation of patients^(354;355).

Serologic assays are available for most of the viral respiratory pathogens. A diagnosis of viral infection is established by a four fold or greater rise in virus-specific antibody between sera collected in the acute and convalescent stages. Serum specimens in the acute stage should be obtained as soon as possible after the onset of symptoms, and sera in the convalescent stage should be collected two to three weeks later. Antibody response may not occur in all infections and is particularly unreliable in young infants because of maternal antibody⁽³⁴⁰⁾. Serologic testing is generally not useful for the "real time" diagnosis of infection for infection control purposes.

3. *Legionella*

It is not possible to distinguish between *Legionella* and other types of bacterial pneumonia by chest radiographs. Specialized diagnostic laboratory tests are essential for the diagnosis of Legionnaires' disease. Many laboratories will look for *Legionella* only when specifically requested. *Legionella* pneumonia may be confirmed by one or a combination of the following methods: isolation of the organism by culture on selective media from respiratory secretions or tissues, microscopic visualization of the bacterium in respiratory secretions or tissues by immunofluorescent microscopy, serology (four fold rise in antibody titre in paired acute and convalescent specimens of serum by use of an indirect immunofluorescent antibody test), and, for detection of *L. pneumophilla* (subgroup 1 only), urinary antigen detection^(144;149;356).

None of the laboratory tests for *Legionella* are 100% sensitive. Therefore, the diagnosis of legionellosis is not ruled out even if one or more of the tests are negative. Currently, the most specific test is culture isolation of *Legionella* spp. from any respiratory tract specimen. Direct fluorescent antibody stain is also highly specific, and sensitivity has ranged from 25% to 75%⁽³⁵⁷⁾. The commercially available test for *Legionella* antigen in urine has a high sensitivity (90%) and specificity (99%). However, this test can only reliably detect serogroup 1 of *L. pneumophilla*⁽³⁵⁸⁾. For other groups, the sensitivity is 50%-80%⁽³⁵⁹⁾. DNA amplification by PCR of *Legionella* has been reported from patients with pneumonia, but clinical experience has not shown PCR to be more sensitive than culture⁽³⁵⁷⁾.

4. *Bordetella pertussis*

Culture isolation of *B. pertussis* from nasopharyngeal aspirates or nasopharyngeal swabs remains the “gold standard” for laboratory diagnosis of pertussis. While the specificity of this method is very high, its sensitivity is generally poor and varies with previous antibiotic therapy, duration of illness prior to specimen collection, patient immunization status, specimen transport, and laboratory expertise^(360;361).

Direct fluorescent-antibody (DFA) testing is used as a more rapid tool to provide a presumptive diagnosis. However, several investigations have documented a poor sensitivity (38%) and false positivity as high as 85%^(360;362;363). A monoclonal antibody (BL-5) showed improved sensitivity and specificity (65.1% and 99.6% respectively) in comparison with culture results⁽³⁶⁴⁾ but needs to be further investigated in clinical studies.

PCR is a rapid, sensitive technique taking 2½ hours⁽³⁶⁵⁾ to two days for results compared with three to seven days for culture. It is superior in detecting infection in vaccinated patients, patients who have received antimicrobial therapy, and patients who are at late stages of the disease^(360;366). On the other hand, the sensitivity of PCR appears to decrease with age, decreasing from 70% in children under age one year to 50% in children between one and four years old⁽³⁶⁷⁾. PCR is more technically sophisticated and expensive than culture⁽³⁶⁸⁾.

5. *Aspergillus*

Diagnosis of *Aspergillus* lower respiratory tract infection is usually difficult⁽³⁶⁹⁾. Invasive tests, such as bronchoscopy with BAL or lung biopsy, are often needed to discriminate between airway colonization and tissue invasion⁽²⁵⁾. Demonstration of *Aspergillus* by microscopic examination and culture of tissue provides the most conclusive diagnosis. The appearance of fungal hyphae in a smear or biopsy indicates a filamentous fungal infection but not specifically *Aspergillus*. *Aspergillus* may be isolated from air-containing tissues, such as lung or sinus, where it may be a colonizer, and does not invade tissue, or it may be cultured as a result of laboratory contamination⁽³⁷⁰⁾. However, a positive sputum culture from a febrile patient with profound neutropenia and acute leukemia is strongly suggestive of the diagnosis⁽³⁷¹⁾. Blood, cerebrospinal fluid, and bone marrow specimens from patients with aspergillosis are almost never positive^(144;370). High-resolution computed tomography (CT) scan is an important diagnostic tool for invasive pulmonary aspergillosis⁽³⁷²⁾. In neutropenic patients, lesions that are specific for invasive fungal disease may be detected very early in the course of infection.

Galactomannan is a component of the fungal cell wall and an exoantigen of *Aspergillus*^(373;374). In an attempt to improve early diagnosis and treatment of invasive aspergillosis, detection of galactomannan antigen in serum has been intensively studied⁽³⁷⁵⁻³⁷⁸⁾. Most reports have used a sandwich ELISA for the rapid detection of *Aspergillus* galactomannan antigen in serum, with a reported sensitivity and specificity of 50%-90% and 81%-93% respectively⁽³⁷³⁾.

III. Diagnostic Issues in Long-Term, Pediatric, and Immunocompromised Patients

1. Long-Term Care

Pneumonia in long-term care residents often does not present with the typical features of fever, cough, and sputum production. Residents 65 years and older tend to have fewer symptoms than do younger adults, even after severity of illness and comorbid conditions have been controlled for⁽⁵⁴⁾. With the onset of pneumonia, continuing care residents may present with a decline in mental status and an insidious or non-specific deterioration of general health. Worsening confusion, changes in activity level, or a fall may be the only presenting features^(51;52;379).

Studies have demonstrated inconsistent approaches to the diagnosis and treatment of infections in long-term care facilities. Physicians may not be readily available to evaluate residents. Chest radiographs are usually not obtained, since long-term care facilities may lack ready access to radiologic services. Chest radiographs may be difficult to interpret because of the pre-existing condition of the resident⁽⁹²⁾. Laboratory services may not be easily accessible. Issues that can compromise the quality of the specimen include difficulty in obtaining it⁽⁵¹⁾, the lack of skilled personnel to obtain specimens, and delayed transport and subsequent processing. Since the clinical presentation in this population may not initially suggest a diagnosis of pneumonia, careful clinical evaluation and chest radiography supplemented by appropriate laboratory studies where indicated are necessary for diagnosis and appropriate management⁽³⁷⁹⁾.

2. Pediatrics

The optimal method for diagnosing nosocomial pneumonia in children remains to be established. In general, the diagnosis of nosocomial pneumonia is based on clinical changes with corroboration by chest radiographic findings. Clinical findings suggestive of pneumonia in children include an increase in respiratory rate or effort, cough (new or significant change), wheezing, change in the amount or consistency of sputum production or tracheal secretions, decreased oxygenation, changes in requirements for assistance with oxygenation and ventilation, and fever⁽⁴⁴⁾.

In neonates, apnea may also be an early sign of nosocomial pneumonia⁽³⁸⁰⁾. As for adult patients, relying on clinical and chest radiographic findings in hospitalized children will usually overestimate the true incidence of nosocomial pneumonia⁽⁴⁴⁾. In addition to the conditions found in adults, congenital heart disease, and bronchopulmonary dysplasia may be confused with lower respiratory tract infection in children⁽³⁸¹⁾.

Sampling of lower respiratory tract secretions in children to determine the etiologic agent of bacterial pneumonia may be impossible. Young children may not cough and rarely produce a sputum specimen adequate for evaluation, since they swallow most sputum. Older children may be instructed on proper technique to produce sputum, or induced sputum may be obtained by nebulized saline. Bronchoscopy or blind BAL has been used in some centres to obtain samples directly from the lower respiratory tract and limit contamination of upper airway flora. Some of these approaches in infants and children, particularly those who are critically ill, may be medically contraindicated or may not be feasible (i.e., small airway size in infants may preclude use of bronchoscopic equipment)⁽⁴⁴⁾. Lung biopsy may be required, especially in the immunocompromised child. If pleural effusion is present, culture of fluid obtained by needle aspiration or chest tube may yield the etiologic agent. Percutaneous thin needle lung aspiration has been used in some centres, but expertise with this technique is limited.

3. The Immunocompromised Host

Immunosuppressed patients may have few clinical symptoms and signs suggestive of NP. Even with extensive bacterial infection in the lung parenchyma, the neutropenic patient may not be able to mount sufficient inflammatory response to create a density that can be seen on the chest radiograph. In addition, pulmonary infiltrates may not be due to infection. It is often difficult to establish the etiology of an infectious episode in the immunocompromised patient, because the range of potential pathogens is broader, including organisms that are otherwise considered normal flora, and opportunistic pathogens. Some organisms are not

generally detected by the usual non-invasive diagnostic methods. In these patients, accuracy in the diagnosis of nosocomial pneumonia may be improved by using “invasive” diagnostic methods, such as fiberoptic bronchoscopy in addition to blood cultures and, where appropriate, pleural fluid examination⁽³⁸²⁻³⁸⁵⁾. Most investigators agree that the technique of BAL is of greatest value in establishing a bacterial or non-bacterial cause of infection in the immunocompromised host. It will reliably diagnose *P. jiroveci* pneumonia (PCP)⁽²⁸⁶⁾. Open lung biopsy may be required, especially if the definitive diagnosis of cytomegalovirus (CMV) or filamentous fungi is to be made.

A.4. Role of Respiratory Equipment and Devices

I. Introduction

Devices that bypass first-line host defences and/or facilitate the entry of bacteria into the lung have been identified as risk factors for the development of pneumonia^(23;38;68). These include respiratory therapy devices used for treatment (e.g., ventilation, medication delivery), diagnosis (e.g., bronchoscopes, pulmonary function tests), and administration of anaesthesia. Devices may become colonized with organisms and deliver contaminated fluids and aerosols to respiratory mucous membranes and the lower respiratory tract. Equipment with the same function and purpose may pose different risks, depending on its components, configuration, age, or model.

Routes of transmission for the pathogens most commonly associated with respiratory equipment and devices are as follows^(18;168):

- **Airborne (droplet nuclei)**

Droplet nuclei are small particles (< 5 µm) that can remain suspended in the air for extended periods of time. They may be generated by patients (e.g., sneezing, coughing) or devices (e.g., nebulizers). Aerosolized particles greater than 0.3 µm are considered capable of carrying pathogens.

- **Direct or indirect contact**^(18;113)

Fluids that may be contaminated with organisms include secretions, saliva, sputum, blood, or condensate in aerosol tubing or the ventilator circuit. Transmission of pathogens in fluid occurs when the fluid physically moves, flows, or spills from one area to another. Contact of hands or equipment with contaminated fluid is thought to be a common mode of transmission.

Transmission may be from device to patient⁽³⁸⁶⁻³⁹⁰⁾, from one patient to another^(391;392), or from one body site to the lower respiratory tract of the same patient by hand or device⁽³⁹³⁻³⁹⁵⁾. Fluid-containing devices, such as nebulizers with a reservoir and humidifiers, can allow growth of hydrophilic bacteria that can be aerosolized during device use⁽³⁹⁶⁻³⁹⁸⁾. Bacteria such as *Pseudomonas* spp., *B. cepacia*, *Legionella* spp., *Flavobacterium* spp., and nontuberculous mycobacteria are capable of multiplying to high concentrations in water^(168;399-401). These organisms may directly enter the lower respiratory tract as aerosols generated during use of a contaminated device^(168;386;397;398).

Fluid-containing respiratory devices are the major environmental reservoirs for the pathogens that cause NP. However, virtually all devices used for respiratory airway care have been linked to nosocomial respiratory infections or implicated as potential environmental reservoirs. These include mechanical ventilation bags, ventilators, aerosolized medications, bronchoscopes, laryngoscope blades, and suction catheters, among others. Outbreaks associated with specific respiratory therapy devices are summarized in Table 7.

Table 7

Outbreaks of infection/colonization associated with respiratory therapy equipment and devices

Source of Contamination	Organism	Year	Reference
Delivery room resuscitators	<i>Salmonella</i> sp.	1955	Rubenstein et al. ⁽⁴⁰²⁾
Neonatal resuscitation equipment	<i>Pseudomonas aeruginosa</i>	1965	Bassett et al. ⁽⁴⁰³⁾
Manual ventilation balloons	<i>Bacillus cereus</i>	2000	Van Der Zwet et al. ⁽⁴⁰⁴⁾
Aerosol solution	<i>Klebsiella pneumoniae</i>	1967	Mertz et al. ⁽³⁸⁸⁾
Ultrasonic nebulizer	<i>Serratia marcescens</i>	1969	Ringrose et al. ⁽³⁸⁷⁾
Saline vials/ultrasonic nebulizer	<i>Serratia marcescens</i>	1969	Cabrera ⁽⁴⁰⁵⁾
In-line humidifier water	<i>Acinetobacter</i> sp.	1980	Redding & Walter ⁽⁴⁰⁶⁾
Tap water used in jet nebulizer	<i>Legionella pneumophilla</i>	1982	Arnou et al. ⁽¹⁶⁸⁾

Source of Contamination	Organism	Year	Reference
Small-volume medication nebulizer	<i>Serratia marcescens</i>	1987	Botman & Krieger ⁽⁴⁰⁷⁾
Medication nebulizer	<i>Legionella pneumophilla</i>	1991	Mastro et al. ⁽⁴⁰⁸⁾
Inhalation nebulizer device	<i>Burkholderia cepacia</i>	1993	Takigawa et al. ⁽⁴⁰⁹⁾
Nebulized albuterol solution	<i>Burkholderia cepacia</i>	1995	Hammill et al. ⁽¹³⁵⁾
Medication nebulizer	<i>Burkholderia cepacia</i>	1996	Pegues et al. ⁽¹³⁷⁾
Nebulized mouthpieces	<i>Pseudomonas aeruginosa</i>	1996	Cobben et al. ⁽³⁹⁰⁾
Nebulized albuterol solution	<i>Burkholderia cepacia</i>	1996	Reboli et al. ⁽⁴¹⁰⁾
Multi-dose albuterol vials, nebulizer assemblies	<i>Burkholderia cepacia</i>	2001	Ramsey et al. ⁽³⁹³⁾
Nebulizer solution/tube	<i>Burkholderia cepacia</i>	1999	Okazaki et al. ⁽⁴¹¹⁾
Cool mist room humidifier	<i>Acinetobacter</i> spp.	1985	Gervich & Grout ⁽⁴¹²⁾
Cool mist room humidifier	<i>Legionella pneumophilla</i>	1985	Kaan et al. ⁽⁴¹³⁾
Wall oxygen humidifier	<i>Pseudomonas</i> sp.	1980	Redding & Walter ⁽⁴⁰⁶⁾
Ventilator temperature probe	<i>Acinetobacter calcoaceticus</i>	1990	Cefai et al. ⁽⁴¹⁴⁾
Ventilator temperature sensor	<i>Burkholderia cepacia</i>	1993	Berthelot et al. ⁽⁴¹⁵⁾
Ventilator temperature probe	<i>Pseudomonas cepacia</i>	1993	Weems ⁽⁴¹⁶⁾
Ventilator temperature probe	<i>Sphingomonas paucimobilis</i>	1996	Lemaitre et al. ⁽⁴¹⁷⁾
Ventilator thermometer	<i>Burkholderia cepacia</i>	1986	Conly et al. ⁽¹³⁶⁾
Contaminated quivers used to store suction tubing	<i>Pseudomonas aeruginosa</i>	1994	Jumaa & Chattopadhyay ⁽⁴¹⁸⁾
Tracheal suction catheter	<i>Pseudomonas aeruginosa</i>	1983	Hilton et al. ⁽⁴¹⁹⁾

Source of Contamination	Organism	Year	Reference
Tracheal irrigant solution	<i>Pseudomonas picketti</i>	1984	Gardner et al. ⁽⁴²⁰⁾
Suction bottles, suction catheters	<i>Acinetobacter</i> spp.	1999	Pillay et al. ⁽⁴²¹⁾
Ventilator, in-line suction catheter	<i>Stenotrophomonas maltophilia</i>	1999	Alfieri et al. ⁽⁴²²⁾
Ventilator circuits (contaminated intake port, washer/decontaminator)	<i>Bacillus cereus</i>	1993	Bryce et al. ⁽⁴²³⁾
Ventilator circuits, resuscitation bags	<i>Acinetobacter calcoaceticus</i>	1988	Harstein et al. ⁽⁴²⁴⁾
Ventilator probes (ineffective disinfection/sterilization)	<i>Acinetobacter anitratus</i>	1990	Contant et al. ⁽⁴²⁵⁾
Ventilator tubing (malfunctioning pasteurization machine)	<i>Flavobacterium meningosepticum</i>	1993	Pokrywka et al. ⁽⁴²⁶⁾
Ventilator condensate in expiratory water trap	<i>Klebsiella pneumoniae</i>	1993	Gorman et al. ⁽¹¹³⁾
Aerosol exposure during disconnection of intubation tube	<i>Pseudomonas aeruginosa</i>	1999	Smulders et al. ⁽⁴²⁷⁾
Ventilator circuits (inadequately dried after processing)	<i>Bacillus cereus</i>	1999	Gray et al. ⁽⁴²⁸⁾
Ventilation equipment	<i>Acinetobacter</i> spp.	1998	Dealler ⁽⁴²⁹⁾
Respirator	<i>Serratia marcescens</i>	1975	Richards & Levitsky ⁽⁴³⁰⁾
Wright Respirometer	<i>Acinetobacter calcoaceticus</i>	1980	Cunha et al. ⁽³⁹⁴⁾
Ventilator spirometer	<i>Acinetobacter</i> spp.	1980	Irwin et al. ⁽³⁹¹⁾
Spirometer	<i>Mycobacterium tuberculosis</i>	1980	Hazaleus et al. ⁽⁴³¹⁾
Peak flow meter	<i>Acinetobacter calcoaceticus</i>	1994	Ahmed et al. ⁽¹²⁴⁾
Laryngoscope blade	<i>Pseudomonas aeruginosa</i>	1993	Foweraker ⁽⁴³²⁾

Proper cleaning and sterilization or high-level disinfection of reusable equipment is essential to prevent infections associated with respiratory therapy, bronchoscopy, and anaesthesia. Devices or parts of devices, such as those used on the respiratory tract, that come into direct or indirect contact with mucous membranes but do not ordinarily penetrate body surfaces are categorized as “semi-critical” in the Spaulding classification (Table 8). The infection risk with the use of these devices is less than that associated with the use of “critical” devices that penetrate normally sterile tissues⁽⁴³³⁾. Therefore, semi-critical devices may be subjected to high-level disinfection rather than sterilization⁽⁴³⁴⁾.

When a device needs to be rinsed after it has been chemically disinfected, sterile water has been recommended because tap or locally prepared distilled water may harbour microorganisms that can cause pneumonia^(161;399;435;436).

Table 8

Sterilization and disinfection of respiratory equipment and devices according to infection risk categories (Spaulding Classification)

Category	Description	Device	Recommended Processing
Critical	Devices that enter the bloodstream or sterile tissue	Bronchoscope biopsy forceps and specimen brushes	Sterilization
Semi-critical	Devices that directly or indirectly contact mucous membranes	Bronchoscopes and accessories Oral, nasal and tracheal airways Ventilator breathing circuits Bubbling or wick humidifiers Exhalation valves Small-volume medication nebulizers Large-volume nebulizers/mist tents Large-volume room-air humidifiers Pulmonary function testing mouthpieces, tubing, connectors Resuscitation bags Laryngoscope blades Stylets Air-pressure monitor probes CO ₂ and O ₂ analyzer probes Temperature probes Respirometers Suction catheters Anesthesia devices or equipment: • face masks or tracheal tubes	High-level disinfection

Category	Description	Device	Recommended Processing
		<ul style="list-style-type: none"> • inspiratory and expiratory tubings • y connectors • right angle connectors • reservoir bags • humidifier and tubing 	
Non-critical	Devices that touch only intact skin but not the mucous membranes or do not contact the patient	Exterior surface of ventilator	Low / intermediate level disinfection

II. Overview of Mechanical Ventilators and their Accessories

This section provides a brief overview of standard mechanical ventilators and their operation. It does not provide a description of specific models of ventilators. There are some features common to all mechanical ventilators, while others are more common on older or newer models. Intermittent positive-pressure ventilation (IPPV) refers to machine-delivered breaths. All other terms used, such as synchronous intermittent mandatory ventilation or pressure control, are simply means of delivering the breath. In almost all cases, IPPV is accompanied by a positive end-expiratory pressure (PEEP), which is a set pressure at an elevated baseline above atmospheric pressure. Continuous positive airway pressure (CPAP) refers to PEEP when all breaths are spontaneous. Each of these modalities may be applied invasively, through an endotracheal or tracheostomy tube, or non-invasively through a face mask (NIPPV) or nasal mask (NCPAP). The commonly used term “BIPAP¹” is an abbreviation of bi-level positive airway pressure or the inspiratory and end expiratory pressure used in NIPPV/PEEP.

Most mechanical ventilators used in hospitals are electrically powered machines with pneumatic (gas-powered) components. Mechanical ventilators used for transporting patients may be either battery or pneumatically powered. They are attached to a source of oxygen and may be attached to a source of compressed air by means of a high pressure hose (50 pounds per square inch). Gas entering the machine is fed through a series of internal filters to ensure that it is pure before it reaches delicate components. Once the gases have been mixed, and their pressures lowered, they are fed through a bacterial filter (reusable or disposable) and enter the circuit or tubing attached to the patient.

¹ Not to be confused with the term “BiPAP®” which is a brand name of a device able to provide BIPAP.

The circuit is wide bore, corrugated, and may be either reusable or disposable. All gas are to be heated and humidified before reaching the patient. This may be accomplished in two ways. The first is to pass the gas through a water heater/humidifier, which may be of the wick or bubble type. Sterile water is added by opening the system and filling with bottled water, a manually operated water feed system, or by automatic drip systems. Water traps are strategically placed in the circuit to catch condensate or rain-out. Some heater/humidifiers use heated wires within the circuit to prevent condensate from forming. Heated wires may be located on both the inspiratory, and expiratory limbs or just the inspiratory limb. All heater/humidifiers require some method of measuring gas temperature. A sensor is usually placed close to the patient Y-connector.

The second method of humidification is to use a heat moisture exchanger (HME). This device is placed at the patient "Y" connector and traps heat and humidity to be released during the next inspiratory phase. No extra heat or humidity is required when this system is in place. Some HMEs incorporate a filter.

All mechanical ventilators require a system for measuring tidal volume. Newer machines have built-in devices for measuring volume. This usually involves having the gas feed through a pneumotach or flow sensor for measurement. To maintain the integrity of the pneumotach, most machines will filter the exhaled gas as it re-enters the machine. These bacterial filters may be reusable or disposable. Portable and some neonatal ventilators do not filter the exhaled gas. Portable ventilators tend to be used in long-term care and home settings, as well as for transport in acute care. On older model machines used in acute care settings, a spirometer may be placed in line or at the end of the expiratory tubing to measure each breath. These may be hand held or machine mounted.

Other items that may be included in the patient circuit of some older models are oxygen analyzers. Many newer machines have analyzers in the internal components. As humidity affects the accuracy of most analyzers, oxygen analyzers will be found before the humidifier on the inspiratory limb.

In some facilities, end-tidal carbon dioxide monitor connectors may also be added to patient circuits. These connectors are added as close to the patient connection as possible. Some models will measure carbon dioxide at the connector, and others use suction to extract a small volume of exhaled gas for analysis at the monitor. All connectors may be disposable or reusable. Tubing for extracting measured gas is usually disposable, because the very small diameter makes it difficult to clean.

III. Risks Associated with Contaminated Respiratory Equipment and Devices

1. Components of Mechanical Ventilation

1.1. Mechanical ventilators

The internal components of mechanical ventilators are not considered a source of contamination of inhaled air⁽⁴³⁷⁾. The use of high-efficiency bacterial filters (main-line) between the ventilator and the main breathing circuit is an industry standard to eliminate contaminants from the driving gas and prevent retrograde contamination of the machine by patients^(438;439).

1.2. Ventilator circuits and humidification (humidifiers and heat moisture exchangers)

Contamination of ventilator circuits during clinical use is very common. Pathogenic bacteria have been found in 60% to 80% of circuits⁽⁴⁴⁰⁾. Once mechanical ventilation has been initiated, the circuit quickly becomes colonized with organisms from the patient's oropharynx. It becomes contaminated first and most heavily at sites nearest the patient^(23;440;441). Early studies by Garibaldi et al. and Feeley and co-workers did not show that a filter placed between the inspiratory phase circuit and the patient prevented infection^(442;443). Use of bacterial filters and water traps on the expiratory limb of the mechanical ventilator circuit may help prevent contamination of the ventilated patient's immediate environment⁽⁴⁴⁴⁾. To date, filters have not been demonstrated to prevent healthcare-associated pneumonia.

Current methods for humidification of the ventilator circuit do not pose a significant risk of pneumonia to ventilated patients. Humidification is achieved by wick-type or bubble-through humidifiers that produce insignificant, if any, aerosolization under normal operating conditions, and are heated to temperatures that limit the growth of bacterial pathogens. Both types of large-capacity heated humidifiers may incorporate completely closed feed systems that automatically maintain appropriate water levels in the reservoir. These closed-feed systems minimize the risk of microbial contamination of the reservoir^(29;440).

The relation between the frequency of ventilator tubing changes and the incidence of nosocomial pneumonia has been investigated by several groups⁽⁴⁴⁵⁻⁴⁵⁰⁾. No benefit in terms of reducing infection has been demonstrated by routinely changing ventilator circuits. Two randomized trials^(448;449) found that when circuits were changed when visibly soiled or mechanically defective they were associated with rates of VAP similar to or modestly lower than rates occurring with frequent or regularly scheduled changes. This conclusion has been supported in a systematic review of the literature⁽⁴⁵¹⁾.

Condensate forms in the tubing because of differences in temperature between the inspiratory phase gas and the ambient air within the tubing; condensate formation increases if the tubing is unheated. The technique of handling and disposing of the condensate that forms on the inspiratory-phase tubing of the ventilator circuit does pose a risk of pneumonia in patients undergoing mechanical ventilation with humidification^(29;452). This condensate rapidly becomes colonized with the patient's oropharyngeal flora, and, if not appropriately drained, contaminated fluid may be accidentally washed directly into the patient's trachea when the tubing is manipulated. In addition, inappropriate disposal or handling of contaminated condensate may lead to contamination of environmental surfaces and the hands of HCWs⁽²⁹⁾. Heated wire circuits decrease condensate formation by elevating the temperature of the inspiratory phase gas with a heated wire in the inspiratory phase tubing.

The HME, which provides passive humidification (i.e., electricity and active heating elements are not required), is placed between the ventilator circuit and close to the patient's airway. It eliminates the need for a humidifier by recycling heat and moisture exhaled by the patient. Since a humidifier is not used, no condensate forms in the inspiratory tubing of the ventilator circuit and bacterial colonization of the tubing is minimized. Several clinical studies have compared rates of NP among patients receiving humidification from a heated humidifier versus an HME^(441;453-458). These studies suggest that VAP rates are similar for the two groups of patients. Only one study demonstrated a significant advantage of HMEs over heated humidification in terms of development of VAP. Kirton et al. found that the rate of nosocomial pneumonia in the HME group (7%) was half that of the heated humidifier group (16%) ($p < 0.05$)⁽⁴⁵⁸⁾.

Manufacturers state that HMEs should be changed every 24 hours, but there are no clinical data to support this recommendation. Studies have suggested that the same HME can be safely left in place for longer than 24 hours without adverse patient outcomes^(457;459-461). Resistive changes often occur in the first several hours of use, and do not appear to increase during subsequent days of use unless the device is grossly contaminated with secretions. Extended use has not been associated with an increase in VAP or problems with secretions. Heat and moisture exchangers equipped with microbiologic filters appear to be effective in reducing circuit contamination, but their benefit compared with HMEs without microbiologic filters is unknown because of the lack of clinical trials comparing the two products^(440;441;462).

1.3. Medication delivery devices (nebulizers)

Nebulizers are devices that produce an aerosol (a suspension of liquid particles or droplets in a gas). Small-volume jet nebulizers for administration of medications, most commonly bronchodilators, are capable of generating bacterial aerosols⁽³⁹⁸⁾. Small-volume jet nebulizers can become contaminated by reflux of tubing condensate from the inspiratory tubing of the breathing circuit and may then lead to NP by direct introduction of pathogenic bacteria into the lung^(398;463). Small-volume jet nebulizers have been associated with nosocomial pneumonia, including Legionnaires' disease, resulting from either contaminated medications (particularly those in multidose vials) or contaminated tap water used to rinse the reservoir. In an outbreak of *B. cepacia* among patients receiving aerosolized albuterol treatments, Hammill and co-workers traced the source of the epidemic to extrinsically contaminated medication nebulizer reservoirs and in-use bottles of albuterol⁽¹³⁵⁾. In another outbreak of 13 cases of *L. pneumophilla* serotype 3 NP, the investigators found that the hospital potable water system was contaminated with the same serotype, and traced the epidemic to contaminated tap water used to rinse small-volume jet nebulizers⁽⁴⁰⁸⁾.

The use of metered dose inhalers to deliver drugs is increasing because of convenience and cost. Another potential advantage is that these devices pose little risk of producing contaminated aerosols⁽⁴⁴⁰⁾.

1.4. Manual ventilation bags (resuscitation bags)

Contaminated manual ventilation bags have been linked to outbreaks of respiratory infection and colonization with *Acinetobacter calcoaceticus* and *Bacillus cereus*^(404;424;464). Bags are particularly difficult to clean and dry between uses. The exterior surface, connecting ports, and interior surface of manually operated ventilation bags routinely become contaminated during use. Microorganisms in secretions left in the bag may be aerosolized and/or sprayed into the lower respiratory tract of patients. In addition, the exterior surface may serve as a reservoir for pathogens transmitted from patient to patient on the hands of HCWs⁽⁴⁶⁵⁻⁴⁶⁸⁾.

1.5. Ventilator spirometry

In 1980, two case reports linked cross-transmission of *A. calcoaceticus var. anitratus* in mechanically ventilated patients to the use of ventilator spirometers. Irwin et al. reported 17 cases of infection traced to contaminated spirometers. The outbreak was halted following discontinuation of spirometer use and increased emphasis on hand hygiene by HCWs⁽³⁹¹⁾. Cunha et al. described a similar outbreak of nosocomial pneumonia in ten patients. Wright respirometers, attached to the patient's endotracheal or tracheostomy tubing, were shown to be the common source of the outbreak. Control measures included rigorous hand hygiene and the measurement of volume with the respirometer from the ventilator tubing instead of directly from the endotracheal or tracheostomy tubing⁽³⁹⁴⁾.

Spirometry performed in pulmonary function laboratories is discussed in Section A.4, IV., 3.2.

2. Other Respiratory Equipment and Procedures

2.1. Large-volume nebulizers (including room humidifiers)

Nebulizers with large-volume (>500 mL) reservoirs used to provide humidification to the respiratory tract, pose the greatest risk of infection to the patient. Examples of these include aerosol nebulizers driven by a pressurized gas source (pneumatic nebulizers) or ultrasonic nebulizers that use high-frequency vibrations to convert water to an aerosol, which is then carried to the patient by a blower motor. Large-volume nebulizers have been associated with NP secondary to contamination of their reservoirs. In 1968, Ringrose and colleagues reported an outbreak of *Serratia marcescens* respiratory tract colonization and infection, which they traced to contamination of the liquid reservoir of an ultrasonic nebulizer. Evidence was also seen of patient-to-patient transmission of *S. marcescens* from the hands of HCWs⁽³⁸⁷⁾. Reservoirs can become contaminated by the hands of personnel, nonsterile fluid added to the reservoir, or inadequate sterilization or disinfection between uses⁽⁴⁶⁵⁾.

Some devices referred to as "humidifiers" (e.g., room humidifiers) aerosolize water droplets and are actually nebulizers. Room-air humidifiers that create aerosols (e.g., vaporizers, spinning disk, and ultrasonic nebulizers) are difficult to disinfect adequately and have been implicated in outbreaks of infection^(412;413;469). There is no evidence of clinical benefit from room-air humidifiers used in hospitals. Wick-type humidifiers, marketed for home use and not for hospital use, do not pose the same risk of aerosol transmission of pathogens⁽⁴⁶⁵⁾.

However, the water in humidifiers is a source of pathogens and can pose a risk of transmission of infection from the hands of the caregiver.

2.2. Suction catheters

Tracheal suction catheters can introduce microorganisms into the mechanically ventilated patient's lower respiratory tract. Two types of suction catheter system are now available: the open, single-use catheter system and the closed, multi-use catheter system. The main advantages attributed to the closed, multi-use catheters are lower costs and decreased environmental cross-contamination⁽⁴⁷⁰⁾. Costs may be significantly lower, since Kollef et al. have shown that, notwithstanding the manufacturer-recommended daily catheter changes, the catheter can remain unchanged for an indefinite time without increasing the patient's risk of healthcare-associated pneumonia⁽⁴⁷¹⁾. In terms of single and multi-use catheters, results of studies differ. Two published trials and other available data suggest that the risk of nosocomial pneumonia is similar for patients managed with either the closed or open suction system^(451;470;472). However, a prospective randomized trial concluded that the incidence rate of VAP was reduced with the use of a closed suctioning system⁽⁴⁷³⁾.

2.3. Suctioning of the respiratory tract

Suction involves the application of negative pressure (vacuum) to the airways through a collection tube (a flexible catheter or suction tip). Secretions or fluids are removed from the upper airway by using a rigid tonsillar, or Yankaur suction tip.

Access to the lower airway is via introduction of a flexible suction catheter through the nose (nasotracheal suctioning) or an artificial airway (endotracheal suctioning).

Occasionally, suctioning has led directly to nosocomial infections. Hilton et al. reported that the withdrawal of a suction catheter across the patient's face resulted in serious eye infections, most frequently due to *P. aeruginosa*⁽⁴¹⁹⁾. The authors also demonstrated contamination of the environment during tracheal suctioning of patients with copious secretions. Pillay and co-workers identified contaminated suction catheters and suction bottles as the source of an outbreak of multi-drug resistant *Acinetobacter* spp. infection in a neonatal unit. Newborns had received oral suctioning as part of their immediate resuscitation in the neonatal admission room. Before the outbreak, suction catheters were temporarily reused after cleansing with alcoholic chlorhexidine solution, as the hospital supply of suction catheters had been limited for financial reasons⁽⁴²¹⁾. Van Dyke and Spector reported transmission of herpes simplex virus (HSV) type 1 from a physician with herpes labialis to an infant during suctioning for meconium aspiration⁽⁴⁷⁴⁾.

Suction collection units can lead to nosocomial infections either by producing aerosols containing potential bacterial pathogens or by serving as an environmental reservoir⁽⁴⁷⁵⁾. Transmission to patients can occur through contamination of the hands of HCWs during manipulation of the suction unit or through retrograde spread to the patient undergoing suction. Contaminated suction units that generate aerosols along with other environmental reservoirs, have led to outbreaks of infection in both adults and neonates^(402;403;476).

2.4. Provision of oxygen by mask or cannula using a humidifier

Oxygen therapy devices pose much less risk than other in-use equipment; however, cannulas, masks, tubing, gas lines, and bubble-through humidifiers used to deliver oxygen from a wall unit can become contaminated⁽⁴⁶⁵⁾. Under normal conditions, humidifiers are not indicated for oxygen flows less than 4 L/min in adult patients^(465;477). If the patient is breathing through a normal upper airway, bacterial contamination of the gas should pose minimal risk of lung infection. Filters in the gas line between the flow meter and delivery device have not been shown to reduce the incidence of pneumonia⁽⁴⁶⁵⁾. Devices used for humidification operated at flow rates of ≥ 5 L/min have been shown to produce microaerosols capable of transmitting disease^(478;479). Nosocomial Legionnaires' disease has been associated with contaminated water in oxygen bubble humidifiers⁽⁴⁸⁰⁾. Reusable oxygen humidifiers likely become contaminated by hand contact during reassembly or when being refilled with sterile water after disinfection⁽⁴⁸¹⁾. Contamination has also resulted from using tap water in the water reservoir of an oxygen humidifier⁽⁴⁸⁰⁾. Two Canadian studies reported contamination rates of 10% when reusable oxygen humidifiers were cultured. In contrast, contamination rates for pre-filled, sterile disposable humidifiers used on multiple patients for a period of 30 days were negligible^(481;482). These results are similar to the results of earlier studies that focused on multiple patient use of disposable humidifiers^(483;484).

2.5. Sputum induction for specimen collection

Sputum induction involves short-term application of hypertonic saline (3%-7%) aerosols to the airway to assist in mobilizing pulmonary secretions for specimen collection. Aerosols are generated using ultrasonic nebulizers or large-volume jet nebulizers⁽⁴⁸⁵⁾.

Microorganisms can be transmitted to patients from contaminated equipment or solutions in the nebulizer⁽³⁹⁶⁾, and many outbreaks of infection traced to nebulizers have been reported^(168;387;405;407). In addition, microorganisms can be transmitted from the patient to the HCW or to patients in the vicinity in the form of droplet nuclei. Tuberculosis transmission occurred when sputum or cough induction procedures were performed in an open clinic area and on a hospital ward^(486;487). An Airborne Infection Isolation Room (AIIR) with an adequate number of air exchanges per hour and additional protection of the HCW from exposure (e.g., respiratory protection) may limit the transmission of infection during these high-risk procedures⁽⁴⁸⁸⁾.

2.6. Anaesthesia equipment

Outbreaks of NP linked to anaesthesia equipment were reported before the implementation of routine cleaning and disinfection or sterilization of anaesthesia equipment components likely to become contaminated with pathogens during use^(489;490). In 1977, Du Moulin and colleagues concluded that organisms do not survive inside the anaesthesia machine, and therefore its internal components (e.g., gas sources, outlets, gas valves, pressure regulators, flowmeters, vaporizers) are not an important source of bacterial contamination of inhaled gases⁽⁴⁹¹⁾. The most commonly used anaesthetic breathing circuit for adults and older children is a circle system, which contains the following components: two one-way valves, inspiratory and expiratory tubing, oxygen and carbon dioxide monitors, reservoir bag, carbon dioxide absorber, mechanical ventilator and circuit, pressure release valve, and y-connector to join the circuit to the face mask or endotracheal tube. Bacteriologic studies have demonstrated that all portions of the anaesthesia breathing circuit, particularly those parts closest to the patient, may become contaminated during patient use⁽⁴⁹²⁻⁴⁹⁴⁾. If proper infection control techniques, including single-use items or disinfection of equipment between patients, are implemented, studies indicate that the anaesthesia breathing circuit does not appear to be a source of transmission of organisms to the patient's airway^(433;491;495;496).

Combined HME and high efficiency (> 99.999%) breathing circuit bacterial filters are commercially available⁽⁴⁴⁰⁾. Many groups have demonstrated a marked reduction in the recovery of bacteria from anaesthetic breathing circuits by the use of bacterial filters at the y-piece or on the inspiratory or expiratory sides of the patient circuit^(493;497;498). Although filters effectively prevent transfer of bacteria from the patient to the anesthesia machine and from the machine to the patient, controlled studies have not shown the benefit of filters in reducing nosocomial pulmonary infections when used in anesthetic circuits that have been either sterilized or cleaned and dried before use on each patient^(442;443). A study by van Hassel and colleagues with over nine years of surveillance for postoperative lower

respiratory tract infections found that infection rates were 0.2% and 0.1% following regional and general anesthesia respectively. No bacterial filters were used in the breathing circuit. Their findings suggest that the role of bacterial filters in the prevention of nosocomial pneumonia would be negligible⁽⁴⁹⁹⁾.

Since experimental evidence suggests that anaesthesia breathing filters effectively remove microbial contaminants from the inspiratory gas of anaesthesia breathing circuits^(493;497;498), it has been suggested that the use of a filter placed between the circuit and the patient may allow the anaesthesia breathing circuit to be used multiple times without disinfection or disposal^(493;500;501). In other words, rather than changing the circuit between patients, the filter is changed between patients. Theoretically, this prevents contamination of the circuit from the patient and contamination of the patient from the circuit. Because the filter is less expensive than the circuit, this alternative strategy would be expected to reduce the costs associated with infection control. In a survey of Canadian healthcare facilities, Alfieri and colleagues reported that 29% of the respondents (24/83) do not change anaesthetic tubing between patients. Facilities that do not change tubing between patients use a HME and/or HME with filter. Nineteen of the 24 facilities reported changing the filter between patients⁽⁵⁰²⁾.

The practice of changing only the filters on the anaesthetic circuitry between patients means that the same tubing and connectors are used case after case. The external surfaces of the corrugated tubing are touched frequently by contaminated hands or gloves of caregivers and may come into direct contact with the patient. The surfaces are difficult to wipe clean because of their configuration and may contribute to cross-contamination of patients. While there is no published evidence that documents the harm of this practice, a theoretical possibility exists.

Few studies have evaluated this practice in the clinical setting. With the exception of a study by Vezina et al., most investigations have had small samples and the results are varied^(498;503-505). Vezina and colleagues evaluated the *in vivo* bacterial filtration efficacy of a breathing filter in a clinical anaesthesia setting. Of 2001 filters studied, bacteriologic cultures were positive on the patient side of 104 filters. In two of these cultures the same bacteria were found on both the circuit side and the patient side of the filter. Therefore, data indicate a clinical effectiveness of 99.9% (95% CI: 99.60% to 99.99%), and an *in vivo* filtration efficacy of 98.08% (95% CI: 92.54% to 99.67%). The practice of using a sterile breathing filter while reusing the anaesthesia breathing circuit might fail and result in contamination of the breathing circuit in fewer than one in every 250 cases. This study was

limited to bacterial filtration efficacy, and the results cannot be extrapolated to viruses, fungi, or mycobacteria. The authors suggest that it would be premature to conclude that use of a breathing filter allows the reuse of anaesthesia breathing circuits between patients without a high level disinfection or sterilization⁽⁵⁰⁶⁾.

Bronchoscopes

Use of contaminated bronchoscopes may lead to colonization or infection. Use of contaminated scopes may also result in pseudoepidemics in which cultures obtained at the time of bronchoscopy represent colonization of the scope rather than colonization or infection of the patient. Outbreaks associated with flexible bronchoscopy are summarized in Table 9.

Table 9

Pseudoepidemics and infections associated with flexible bronchoscopes

Source of Contamination	Organism	Year	Reference
Biopsy suction valve	<i>Pseudomonas aeruginosa</i>	1978	Hussain ⁽⁵⁰⁷⁾
Suction valve	<i>Mycobacterium avium</i>	1989	Wheeler et al. ⁽³⁸⁹⁾
Suction valve; faulty wash/disinfect switch in automated scope washer	<i>M. tuberculosis</i>	1993	Bryce et al. ⁽⁵⁰⁸⁾
Biopsy channel; disinfection failure	<i>Serratia marcescens</i>	1975	Webb & Vall-Spinosas ⁽⁵⁰⁹⁾
Inner channel	<i>P. aeruginosa</i>	1982	Sammartino et al. ⁽¹²⁰⁾
Punctured suction channels	<i>M. chelonae</i>	1983	Pappas et al. ⁽⁵¹⁰⁾
Failure to properly clean suction channel prior to disinfection	<i>P. aeruginosa</i>	1994	Kolmos et al. ⁽⁵¹¹⁾
Suction channel	<i>Rhodotorula rubra</i>	1995	Hagan et al. ⁽⁵¹²⁾
Incorrect connectors joining suction channel to automated scope washer	Imipenem-resistant <i>P. aeruginosa</i>	2001	Sorin et al. ⁽⁵¹³⁾
Tub water; cleaning brushes	<i>Rhodotorula rubra</i>	1989	Hoffman et al. ⁽⁵¹⁴⁾

Source of Contamination	Organism	Year	Reference
*Terminal rinse with contaminated tap water	<i>M. chelonae</i>	1990	Nye et al. *(515)
Terminal rinse with contaminated tap water	<i>M. xenopi</i>	1993	Sniadack et al. (516)
Terminal rinse with contaminated tap water	<i>Legionella pneumophilla</i>	1997	Mitchell et al. (517)
*Failure of automated scope disinfecting machine (biofilm inside machine)	<i>M. chelonae</i>	1992	Fraser et al. *(518)
*Faulty automated scope washer	<i>P. aeruginosa</i>	1997	Blanc et al. *(519)
Failure to replace biopsy port cap before reprocessing in automated reprocessor	<i>M. tuberculosis</i> <i>M. intracellulare</i> Imipenem-resistant <i>P. aeruginosa</i>	1999	Centers for Disease Control and Prevention (520)
Faulty automated scope washer	Multidrug-resistant <i>P. aeruginosa</i>	2000	Schelenz & French (521)
Failure of automated scope washer (biofilm inside machine)	<i>M. chelonae</i> <i>Methylobacterium mesophilicum</i>	2001	Kressel et al. (522)
*Disinfection failure	<i>Proteus</i> spp.	1977	Weinstein et al. *(523)
*Plastic tubing; disinfection failure	<i>M. intracellulare</i>	1982	Dawson et al. *(524)
Disinfection failure	<i>M. tuberculosis</i>	1983	Nelson et al. (525)
Failure to properly clean scope	<i>Blastomyces dermatitidis</i>	1992	Nicolle et al. *(526)
*Contaminated green dye added to cocaine for topical anesthesia	<i>M. gordonae</i>	1979	Steere et al. *(527)
*Automatic aspiration adaptor	<i>M. tuberculosis</i>	1988	Prigorine et al. *(528)

Source of Contamination	Organism	Year	Reference
Dust created during renovation	<i>Sporothrix cyanescens</i>	1990	Jackson et al. ⁽⁵²⁹⁾
Contaminated bronchoscope	Multidrug-resistant <i>M. tuberculosis</i>	1997	Agerton et al. ⁽⁵³⁰⁾
Reuse of single-use stopcocks	<i>Aureobasidium</i> spp.	2000	Wilson, Everts, et al. ⁽⁵³¹⁾

*Denotes pseudoepidemic.

Adapted with permission from Spach DH, Silverstein FE, Stamm WE. Transmission of infection by gastrointestinal endoscopy and bronchoscopy. *Ann Intern Med* 1993;118(2):117-128⁽⁵³²⁾.

Both endogenous and exogenous organisms cause infections related to bronchoscopy. An example of endogenous infection includes pneumonia resulting from aspiration of oral secretions in a sedated patient. The exogenous microorganisms most frequently associated with transmission during bronchoscopy have been Gram-negative bacteria or mycobacteria. These organisms were transferred by bronchoscopes or accessories contaminated by patients who previously underwent bronchoscopy or by the inanimate environment. The factors most commonly associated with transmission have related to inadequacy of manual cleaning, exposure of surfaces to the disinfectant, or rinsing and drying; use of automated reprocessors that have become contaminated; use of an inappropriate disinfectant; and use of improper connectors between the scope and reprocessor^(520;533;534).

Outbreaks have also been traced to bronchoscopes contaminated with environmental organisms through airborne spread, rinses with non-sterile tap water, contact with contaminated transport cases, or use of non-sterile brushes for cleaning.

These outbreaks highlight the paramount importance of appropriate equipment cleaning and disinfection. Manufacturers' instructions for both the scope and reprocessor are to be closely adhered to. Special attention should be directed to damaged equipment, which may provide protected reservoirs for growth of microorganisms and lead to cross-transmission despite adequate cleaning and disinfection.

IV. Special Considerations in Other Settings

Delivery of respiratory services and care outside the acute care setting is expanding rapidly⁽⁵³⁵⁾. These settings include ambulatory care, long-term care, rehabilitation facilities, and the home.

Respiratory care services commonly provided in these settings are continuous oxygen therapy, mechanical ventilation, aerosol drug administration, and airway care. These services can be provided for a period of months or years and, in some cases, for the lifetime of the client or resident. The management of individuals with tracheostomies in both long-term care facilities and in the home is an accepted practice. Home respiratory care clients or long-term care residents are at particular risk of respiratory tract infections because of underlying pulmonary diseases and the presence of devices such as tracheostomy tubes that bypass host upper airway defences.

There are no controlled trials of most infection prevention strategies in these settings. Infection control recommendations are usually based on extrapolations from hospital practice. Major areas of concern are tracheostomy care (e.g., changing of inner cannula, site care, suctioning) and disinfection of respiratory care equipment (e.g., ventilators, humidifiers, nebulization equipment, oxygen delivery systems).

1. Long-Term Care Facilities

In long-term care facilities, respiratory equipment may be similar to that found either in the home or the acute care setting. Residents may be admitted to facilities with equipment used at home and may continue to perform self care (e.g., suctioning). On the other hand, because long-term care facilities accept individuals who are at high risk of acquiring infections, and equipment may be used on multiple patients, cleaning and disinfection procedures for respiratory equipment used in this setting should be as rigorous as those performed in the hospital setting. Equipment management in long-term care facilities has to consider the specific circumstances of its use, especially whether used for one or many residents. An investigation of a case of Legionnaires' disease in a LTCF in Quebec revealed that the most likely source of infection was a portable oxygen condenser that contained a water tank to provide humidification⁽⁵³⁶⁾. The tank was full of non-sterile water, was rinsed with hot tap water, and was occasionally cleaned, but never disinfected. This example highlights the need for careful adherence to standardized infection control procedures for equipment cleaning and disinfection in this setting.

2. In The Home

2.1. Disinfectants

The home environment should be a much safer setting than inpatient or ambulatory care facilities. However, certain pieces of equipment require cleaning and disinfection or sterilization. Among the products recommended for home disinfection are household bleach, 70% isopropyl alcohol, or 3% hydrogen peroxide⁽⁵³⁷⁾. Commercial white vinegar (acetic acid) has been used to disinfect respiratory therapy equipment in the home; a concentration of acetic acid greater than or equal to 1.25% is required^(397;538;539).

New products that are appropriate for the disinfection of semi-critical items have been developed. A premixed, ready to use chemical that contains 7.5% hydrogen peroxide is currently on the market. Its effectiveness is similar to that of 2% gluteraldehyde⁽⁵⁴⁰⁾. Serious eye damage may result from contact with 7.5% hydrogen peroxide, so safety glasses are required while handling the product⁽⁵⁴⁰⁾.

Ortho-phthalaldehyde (OPA) is a relatively new product that has demonstrated excellent microbicidal activity^(541;542). OPA has potential advantages compared with gluteraldehyde: it has excellent stability over a wide pH range of 3-9 and does not require activation.

2.2. Tracheostomy care

Site care: Outside the hospital setting, invasive ventilatory support always involves application of positive pressure via a tracheostomy tube⁽⁵³⁵⁾. The goal of tracheostomy site care is to maintain a clean site in order to prevent infection^(538;543). Sterile techniques should be used for new tracheostomy tubes, but a clean rather than a sterile technique may be used if the tracheostomy tube is more than one month old⁽⁵⁴⁴⁾.

Inner cannula care: Inner cannulas used in the home are normally reusable. Reported methods for cleaning and disinfecting tracheostomy inner cannulas include cleaning with soap and water followed by soaking in 3% hydrogen peroxide or alcohol, or boiling for 15 minutes. Maintenance of suction canisters may be carried out by daily emptying and mechanical cleaning with soap and water followed by weekly disinfection of the system and tubing^(538;544).

Suctioning: Suctioning (oral, nasal, tracheal tube) is considered a clean rather than sterile procedure^(538;543). Sterile distilled and/or recently boiled tap water may be used to flush the catheter. Water from the tap should not be used because of the possibility of contamination⁽⁵⁴⁵⁾. Home cleaning and disinfection of tracheal suctioning catheters have been shown to effectively decrease bacterial growth, thus allowing for reuse⁽⁵⁴⁶⁾. In the same study, 3% hydrogen peroxide was found to be extremely effective in clearing residual mucus from tracheal suction catheters. In addition, the combination of cleaning-disinfection procedures (flushing with 3% hydrogen peroxide, soaking in 100°C (boiling) soapy water overnight, flushing with boiling water, allowing to air dry, and wiping the outside of the catheter with 70% alcohol) was effective in eliminating bacterial growth from the exteriors of 98% and the interiors of 91% of catheters.

2.3. Ventilator and equipment care

Ventilator circuits: For patients receiving assisted ventilation in the home, cleaning of the ventilator circuits is important. Several circuits should be provided, and the circuits (including tubing, manifold, and humidifier) not in use should be cleaned with soap and water, soaked in one of the products recommended for home disinfection, and thoroughly dried before being stored^(538;547).

Evidence is lacking to support an optimal plan for changing and reprocessing ventilator circuits and ancillary equipment in the home. Studies in the hospital setting have found that the less often a circuit is entered, the less likely contamination is to occur^(441;448;451).

Masks and headgear used in NIPPV and in NCPAP require routine cleaning and disinfection.

Solutions and medications: Sterile solutions are preferred for use in aerosol delivery devices (humidifiers and nebulizers). If tap water is used as a diluent or for humidification and nebulization, it should be boiled, stored in a container that has been boiled, stored in the refrigerator, and discarded after 24 hours. Unboiled tap water should not be used in aerosol treatments because it may contain bacteria, minerals, and molds^(544;547).

Oxygen delivery equipment and humidification: If the system for delivering oxygen in the home is made up only of the oxygen source (cylinder, reservoir, or concentrator), the tubing, and the cannula or mask, the tubing and cannula or mask should be discarded when they appear soiled⁽⁵⁴⁷⁾.

If the oxygen is humidified by being bubbled through a bottle of water, it will require different care. Studies conducted in the hospital setting demonstrate that, in practice, oxygen humidifiers are rarely contaminated⁽⁵⁴⁸⁾. Contaminated humidifiers for oxygen are rarely a cause of pneumonia because they do not generate aerosols. However, it is reasonable to take simple steps to avoid the possibility of build-up of large concentrations of bacteria in these reservoirs. Giordano et al. suggest that for home equipment, if the humidifier is pre-filled (comes from the supplier with the water already in it), it may be used down to the minimum effective water level and then discarded. If the humidifier requires filling, the water should be poured out, the reservoir rinsed well, and the water replaced each day. The humidifier should be cleaned and disinfected after 72 hours (three days) of use⁽⁵⁴⁷⁾. Under normal conditions, humidifiers are not indicated for oxygen flows <4L per minute in adult patients⁽⁴⁶⁵⁾.

Small-volume medication nebulizers: Home nebulizer therapy is frequently used for the delivery of medications by aerosol. Clients in the home report long term use of disposable units⁽⁵⁴⁹⁾.

A potential risk of home nebulizer therapy is microbial contamination of the nebulizer device with subsequent aerosolization and transmission of microorganisms to the client's respiratory tract from contaminated units. Although respiratory infections in the home have not been documented, repeated use of improperly reprocessed nebulizers is a recognized source of NP⁽⁴⁰⁷⁾. Most studies have been performed on equipment used by clients with CF. In 1987, Pitchford et al. conducted a prevalence study to determine whether aerosol equipment used at home by 36 patients with CF could provide a reservoir for *Pseudomonas* species. *P. aeruginosa* was recovered from 20% of aerosolization masks, 17% of nebulizers, and also from medication syringes, connective tubing, and saline solutions. Only one patient had the corresponding organism in his sputum. Nebulizers that were repeatedly reused for more than one month were more likely to be contaminated. All contaminated nebulizers and masks that were not cleaned or were rinsed only with tap water were more likely to be contaminated than those cleaned with soap or another agent⁽⁵⁵⁰⁾.

Transmission of Gram-negative bacilli from nebulizers to patients in the home setting was first demonstrated by Wexler and colleagues, who isolated these organisms from 5 of 20 patients who were not colonized with them before nebulization⁽⁵⁵¹⁾. The authors concluded that more frequent changes of disposable parts and adequate disinfection, followed by rinsing and thorough drying, would decrease the likelihood of significant contamination of the reservoir cup. Hutchinson et al. examined all plastic parts and tubing of home-use

nebulizers of 35 CF patients⁽⁵⁵²⁾. Sixty-nine percent of nebulizer circuits were contaminated with Gram-negative bacilli. The antibiotic chamber was the most frequently contaminated part of the circuitry (21 of 24 chambers), followed equally by the T-piece and mouthpiece. The administration and exhaust tubing were the least contaminated parts. The same strain of *B. cepacia*, as confirmed by DNA typing, was isolated both from the nebulizer and the sputum of one patient. Most nebulizers had been in use for at least three months, and although most patients rinsed their nebulizer after every use, very few dried the unit⁽⁵⁵²⁾. Studies of nebulizer contamination continue to demonstrate the importance of adequate cleaning, disinfection, and drying of devices used for home treatment^(138;553).

Large-volume nebulizers (including room humidifiers): Nebulizers with large-volume (>500mL) reservoirs used to provide humidification to the respiratory tract, pose the greatest risk of infection to the patient. Examples of these are aerosol nebulizers driven by a pressurized gas source (pneumatic nebulizers) or ultrasonic nebulizers that use high-frequency vibrations to convert water to an aerosol, which is then carried to the patient by a blower motor. Large-volume nebulizers have been associated with nosocomial pneumonia secondary to contamination of their reservoirs⁽³⁸⁷⁾. Reservoirs can become contaminated by the hands of clients and caregivers, nonsterile fluid added to the reservoir, or inadequate disinfection between uses⁽⁴⁶⁵⁾. All equipment should be cleaned and disinfected using the products recommended for home disinfection.

Room humidifiers that produce a fine spray of water droplets are frequently used in the home and often contaminated with pathogens that can cause infection^(478;543). Further, humidifiers are very difficult to clean and disinfect adequately. They may pose significant risk to immunocompromised patients, especially those who have multiple invasive devices that can be contaminated by the mist from the humidifier. Only those humidifiers that produce a spray of fine mist (water droplets) cause a problem; those that work by simple evaporation are safer⁽⁵⁴³⁾. Wick-type humidifiers, marketed for home use and not for hospital use, do not pose the same risk of aerosol transmission of pathogens⁽⁴⁶⁵⁾.

3. Ambulatory Care (outpatient diagnostic facilities, clinics, physicians' offices and emergency departments)

Innovative medical technologies allow many diagnostic and therapeutic procedures to be done in the ambulatory care setting. Currently, there are few recommendations or guidelines for infection prevention and control in this setting.

Although the incidence of infection may be quite low in the ambulatory care setting, numerous outbreaks, some serious, have occurred in facilities that provide care for non-hospitalized patients⁽⁵⁸⁾. The major factors accounting for most outbreaks in this setting are:

- inadequate disinfection and sterilization
- absent or inappropriate use of barrier precautions
- inadequate hand hygiene

3.1. Bronchoscopy outpatient facilities

Reports have implicated inadequately cleaned and disinfected bronchoscopes as the cause of outbreaks of pseudo-pneumonia^(514;554) in the outpatient setting. Despite these reports, endoscopy suites often do not reprocess scopes properly. High-level disinfection of endoscopes used for patients presumed not to have an infection may be neglected while special cleaning and disinfection procedures, including sterilization, are used for endoscopes used for patients known to be infected by agents such as HIV, hepatitis B virus, or *M. tuberculosis*⁽⁵⁸⁾. Policies and procedures for cleaning and disinfecting scopes in an outpatient endoscopy suite are not different from those needed in the hospital or inpatient setting. The appropriate procedures are to be followed carefully for two main reasons: 1) patients undergoing endoscopy may be particularly vulnerable to infection when exposed to contaminated equipment, and 2) endoscopes, which are semi-critical instruments requiring high-level disinfection (at a minimum), are complex in their design and difficult to clean⁽⁵⁸⁾. Adequate facilities (i.e., workflow space, traffic flow, negative pressure ventilation, temperature, and humidity) for performing procedures and equipment reprocessing should be available. Where there are not adequate facilities for reprocessing on site, consideration should be given to the use of disposable scopes or sending reusable ones to a facility having appropriate reprocessing resources⁽⁵⁵⁵⁾.

In 2001, a survey of single-use medical devices (SUMeDs) in Canadian acute care facilities found reuse is occurring across Canada, despite the absence of a reuse committee in most hospitals and without written reuse protocols for most items⁽⁵⁵⁶⁾. In this study, commonly reused respiratory SUMeDs included ventilator circuits and oxygen nasal prongs. The number of reused SUMeDs per institution seems to have increased substantially since the

last Canadian survey in 1986⁽⁵⁵⁷⁾. With the increased impetus for cost containment, the pressure to reuse single-use items might be greater in the outpatient setting than in the inpatient setting. Examples of single-use respiratory care items that are often reused in the outpatient setting are mouthpieces for pulmonary function machines, nebulizers, inhalers, face masks, and bag-valve masks.

Reports of infection or pseudo-infection associated with the reuse of single use-devices are rare⁽⁵⁵⁸⁾; however, sporadic contamination or contamination with a common pathogen can easily go undetected, particularly in the outpatient setting, where ongoing surveillance for infection may be limited. Wilson and colleagues have reported a pseudo-outbreak of *Aureobasidium* spp. lower respiratory tract infections caused by reuse of single-use stopcocks during bronchoscopy⁽⁵³¹⁾.

Plastic stopcocks labelled for single use were reprocessed in an automated bronchoscope disinfection machine and reused on different patients during BAL. Culture of the stopcocks after they had been supposedly disinfected yielded a heavy growth of *Aureobasidium* spp., while culture of fluid from the automated disinfection machine was negative. No patient was judged to have true infection due to *Aureobasidium* spp. either before or after bronchoscopy. Had this pseudo-outbreak not been caused by an unusual opportunistic organism it might never have been discovered. No quality assurance system had been in place to ensure the sterility and function of the reprocessed stopcocks.

3.2. Pulmonary function testing facilities

Basic tests of pulmonary function measure lung volumes and capacities, flow rates of gases through the airways, and the ability of the lungs to diffuse gases. Spirometry is the most commonly performed pulmonary function test (PFT) in the ambulatory setting⁽⁵⁵⁹⁾. The types of instruments used for testing have changed over the years. Older style machines use volume-collecting devices such as bellows, dry rolling pistons, or water-sealed bells (closed system). As the patient inhales and exhales into these devices, contamination of the equipment is possible, with a theoretical risk of infection. Newer machines use heated wire thermistors and transducers. These devices actually measure flow and calculate volume (open system). Exhaled gas is not collected.

Reports implicating PFT equipment in the transmission of infection are extremely rare. In 1981, Hazaleus et al. reported one case of a tuberculin skin test conversion among 22 patients who underwent pulmonary function testing with the use of a dry-seal spirometer within 12 days of its use by a patient with active pulmonary tuberculosis⁽⁴³¹⁾. There is also circumstantial evidence that implicated contaminated PFT equipment in the increased prevalence of *B. cepacia* among CF patients at one centre⁽⁵⁶⁰⁾. Although microorganisms have been recovered from parts of in-use PFT equipment, a relation between equipment contamination and transmission of infection has not been documented. Studies from Rutala et al.⁽⁵⁶¹⁾ and Burgos et al.⁽⁵⁵⁹⁾ found bacterial contamination of PFT equipment following testing. They demonstrated bacterial contamination of mouthpieces, proximal tubing, water, and the spirometer bell, but no transmission of potentially pathogenic microorganisms from the equipment to the patient or vice versa. These results are similar to those reported by Depledge and colleagues in an earlier study⁽⁵⁶²⁾. Hiebert and Okenson confirmed the absence of detectable nonpathogenic *E. coli* after aerosolizing this organism into standard spirometry tubing and culturing proximal air samples after five or ten minutes of inoculation⁽⁵⁶³⁾. These data suggest that disinfection of mouthpieces and tubing may be sufficient to maintain PFT equipment free of bacterial colonization.

Kirk and co-workers have demonstrated a high efficiency (99.9%) of filters in removing exhaled bacteria after spirometry. They suggest that the use of antibacterial filters may prevent bacterial contamination of spirometers and may also have antiviral properties⁽⁵⁶⁴⁾. Waßer et al. demonstrated that filters reduced the bacterial burden of the spirometer from 45 200 to 50 cfu.⁽⁵⁶⁵⁾ On the other hand, Leeming et al. noted that the efficacy of two commercially available filters was only 67%, when colony counts of expirates were compared with and without a filter in place⁽⁵⁶⁶⁾. Given the few reports of nosocomial transmission of infection from PFT, it is not surprising that there are no convincing reports of reduction of transmission with the use of filters.

In the absence of evidence for infection transmission during PFT, the need for regular use of filters in PFT equipment has not been established^(30;567). However, some spirometric equipment, particularly equipment incorporated into multipurpose testing systems, employs valve manifolds situated proximally to breathing tubes. These valving arrangements provide internal surfaces on which deposition of expired aerosol nuclei is likely. Given their complexity, they may be difficult to disassemble and disinfect between subjects. Since some studies have shown that in-line filters remove microorganisms from the expiratory air stream and thus prevent their deposition⁽⁵⁶⁴⁾, it has been suggested that their use may be

indicated in this setting⁽⁵⁶⁷⁾. The use of in-line filters does not eliminate the need for regular cleaning and decontamination of PFT equipment.

3.3. Cystic fibrosis clinics

Patients with CF have frequent clinic visits. Respiratory therapy measures during these visits include PFT, bronchodilators, and airway clearance techniques. Techniques used to clear the airway may include chest physical therapy by hands, forced expiratory technique and autogenic drainage, positive expiratory pressure (PEP) using a PEP mask, high-frequency oscillation using flutter devices, high-frequency chest compression using a non-stretch inflatable vest that covers the patient's entire torso (ThAIRapy vest), and/or intrapulmonary percussive ventilation, which uses a pneumatic device to deliver pressurized gas to the respiratory tract, usually via a mouthpiece. These may be combined with bronchodilator therapy through a nebulizer⁽⁵⁶⁸⁾.

In the hospital or the clinic setting, contaminated respiratory therapy equipment is a potential route of cross-infection for CF patients. There have been particular concerns about the potential role of PFT equipment in the transmission of infectious microorganisms in this group of patients^(134;562). In one study, an unusually high incidence of *B. cepacia* was noted in a population of 500 CF patients⁽⁵⁶²⁾. Although the environmental investigation was not described and the origin of the outbreak was not determined, spirometers and other equipment in the pulmonary function laboratory were reported to be contaminated. In a CF outpatient clinic in which patients were affected by the same highly transmissible strain of *B. cepacia*, mouthpiece filters used by colonized patients became heavily contaminated during spirometry. However, the organism was not cultured from the spirometer hand piece or from the wooden arms of a chair gripped by each of the patients during spirometry⁽¹³⁴⁾. Although a link between PFT equipment and colonization was not demonstrated in these studies, certain patient care practices in the pulmonary function laboratory were believed to have increased the risk of patient colonization. Practices included inadequate hand hygiene, insufficient care in handling solutions used in nebulizers, and inadequately processing equipment that touched mucous membranes.

Burdge and co-workers examined risk factors for nosocomial acquisition of *B. cepacia* in adult patients with CF in the healthcare setting. The authors concluded that the only identifiable risk factor was treatment with a room humidifier or nebulizer (60% of colonized patients received treatment compared with 5% of non-colonized controls). The reservoirs of the large-volume nebulizers consistently grew *B. cepacia* following therapy⁽¹³⁰⁾. These results strongly suggest that respiratory therapy equipment may have been the source of

infection in study patients. Although studies have not been conducted specifically in the clinic setting, aerosolization masks, nebulizers, medication syringes, connective tubing, and saline solution used at home by patients with CF have been found to be contaminated unless adequately cleaned, disinfected, and thoroughly dried^(138;550-553).

Ensor and colleagues have demonstrated that *B. cepacia* is disseminated into the immediate environment by adult CF patients receiving physiotherapy in hospital⁽⁵⁶⁹⁾. Humphreys and colleagues performed air sampling in outpatient clinic waiting areas and treatment areas where PFT was carried out. Only two of 29 air samples were positive for *B. cepacia*, both with very low counts. Although the authors believed that there was little risk of transmitting *B. cepacia* during outpatient clinics under normal circumstances, they introduced segregation to minimize that risk⁽⁵⁷⁰⁾.

Although a link between respiratory therapy equipment and infection has not been confirmed, there is evidence that CF patients acquire pathogens from other CF patients and from the contaminated environment. Measures to prevent person-to-person transmission in pulmonary function laboratories and other clinic areas for patients with CF have been suggested⁽⁵⁷¹⁾ and include use of a disposable in-line filter for each patient undergoing PFT, use of disposable mouthpieces, emphasis on hand hygiene for patients and families, chest physiotherapy performed in different rooms with only one patient in the room, and segregation of patients with *B. cepacia* from each other.

A.5. Healthcare-Associated Pneumonia in Specific Clinical Settings

I. Introduction

Healthcare-associated pneumonia is associated with a spectrum of presentations and with multiple etiologic agents. The approach presented in this section of the guideline is to discuss the pathogenesis and characteristics of pneumonia within the specific clinical settings where it occurs: on adult and pediatric hospital wards and critical care units, in long-term care facilities, ambulatory care settings, and the home. The ward setting forms the common denominator for patients who acquire NP. A patient with few or no risk factors may acquire pneumonia on a general medical or surgical ward as a result of aspiration (macro or micro) of oropharyngeal secretions. Critically ill patients requiring admission to the ICU are exposed to additional risks within that setting. Although ICUs provide a level of patient care that often cannot be provided elsewhere, the risk of infection is elevated because of the invasive devices and interventions that are the hallmark of modern ICU care. Immunocompromised patients represent another subset of patients with unique

characteristics and both endogenous and exogenous factors that increase their risk of healthcare-associated pneumonia.

Knowledge of the intrinsic and extrinsic risk factors, as well as pathogenic mechanisms, enables infection prevention and control personnel and other healthcare providers to identify patients at increased risk of healthcare-associated pneumonia, allowing them to target surveillance and implement prevention measures. Prevention measures should be aimed at reducing colonization, aspiration, and exposure to respiratory pathogens. This section of the guideline describes the pathogenesis and characteristics of healthcare-associated pneumonia in patients, residents, and clients within various settings across the continuum of health care. At the same time, risk factors for respiratory tract colonization and healthcare-associated pneumonia in all settings have considerable overlap and may be broadly classified as follows:

- patient-related
- device-related
- treatment-related
- environment-related

Risk factors will be summarized by these classifications with a discussion of preventive strategies.

Non ICU-associated Pneumonia

1. Adult

Healthcare-associated pneumonia in the adult non-critical care setting occurs primarily in patients hospitalized with underlying diseases or those recovering from surgery, notably abdominal or thoracic⁽³¹⁾. In a study of nosocomial pneumonia on general medical and surgical wards in a Canadian tertiary care hospital, Greenaway et al. reported that of 92 episodes of pneumonia, 75 (81%) were acquired on surgical wards and 17 (19%) were acquired on medical wards⁽⁶⁴⁾. In a similar study by Everts and co-workers in Australia, 80 (63%) of 126 patients with NP had undergone surgery within two weeks of admission to the study⁽⁶⁶⁾.

For pneumonia to occur in any setting, at least one of the following three conditions must occur: 1) significant impairment of host defences, 2) introduction of an inoculum of sufficient size into the lower respiratory tract to overwhelm the host's defences, or 3) the presence of highly virulent organisms^(112;572). There are several well-recognized routes of entry into the lower respiratory tract, including microaspiration of oropharyngeal secretions

colonized with pathogenic bacteria, gross aspiration of gastroesophageal secretions, inhalation of an infected aerosol, hematogenous spread from a distant site of infection, direct extension from an infected site, and direct inoculation into the airways of intubated patients from ICU staff. Translocation of bacteria from the gastrointestinal tract has also been hypothesized as a mode of inoculation but has not been confirmed⁽⁵⁷³⁾.

The majority of cases of nosocomial pneumonia result from microaspiration of colonized oropharyngeal secretions. While microaspiration is a frequent event occurring in as many as 45% of healthy adults⁽⁵⁷⁴⁾, the determinants of pneumonia are the number of pathogenic bacteria aspirated and the virulence of the organisms that enter the lung, overcoming host defences. Persons with abnormal swallowing, such as those who have a decreased level of consciousness, respiratory/gastrointestinal tract instrumentation or disease, as well as patients who have just undergone surgery, are particularly at risk of aspiration^(38;575;576).

In contrast to healthy people, hospitalized patients tend to have higher rates of oropharyngeal colonization with bacterial pathogens. Johanson and colleagues demonstrated colonization with Gram-negative bacilli in 6% of normal subjects compared with 35% of moderately ill patients and 73% of critically ill patients⁽¹¹¹⁾. The increased ability of Gram-negative bacilli to adhere to the host's oropharyngeal epithelial cells appears to be pivotal in establishing successful colonization. The potential mechanisms include impaired immune function, damage to epithelial surfaces, impaired mucociliary clearance, proinflammatory enzymes, and fibronectin-reducing proteases⁽⁵⁷⁷⁻⁵⁷⁹⁾. The shift in the colonizing organisms is not immediate, but, rather, occurs over time. It is influenced by a number of factors, including underlying disease, severity of illness, and other risk factors. Colonization by Gram-negative organisms increases markedly in patients with coma, hypotension, acidosis, azotemia, alcoholism, diabetes mellitus, leukocytosis, leukopenia, pulmonary disease, and nasogastric or endotracheal tubes, and in patients given antimicrobial agents⁽⁵⁸⁰⁻⁵⁸²⁾. Gross aspiration of large volumes of material is a less common cause of NP, but when it occurs can include both oropharyngeal and esophageal/gastric contents.

Factors that might be expected to increase the risk of nosocomial pneumonia are those that increase the frequency of aspiration, enhance oropharyngeal or gastric colonization, increase the quantity or pathogenicity of microorganisms inoculated, impair local respiratory tract defences, and/or impair systemic immunity.

Most published studies describe the characteristics of patients with NP acquired in both the ICU and on wards and risks specific to the ward^(33;38;102). However, characteristics that have been specifically identified for ward patients are age over 70 years, increased severity of underlying illness, immune suppression, malnutrition, coma or other causes of impaired consciousness, prolonged hospitalization, and the presence of certain comorbid conditions. Greenaway and colleagues found that medical nosocomial pneumonia patients were older than surgical patients (73 ± 14 compared with 61 ± 17 years; $p = 0.017$); hospitalized longer before the onset of pneumonia (60 ± 152 compared with 15 ± 19 days; $p = 0.021$); and had higher mortality ($7/15$ compared with $10/70$; $p = 0.009$). Notably, chronic obstructive pulmonary disease was present in only 27% of ward patients as compared with 64% of NP on general wards and in the ICU^(38;64). Everts and co-workers also found that adult general medical patients who developed nosocomial pneumonia were older than surgical patients and more likely to have neurological diseases⁽⁶⁶⁾.

Postoperative patients, particularly those who have undergone thoracic or upper abdominal surgery, are at particularly high risk of nosocomial pneumonia. In the 1970s, the Study of the Efficacy of Nosocomial Infection Control (SENIC) revealed that 74% of patients with NP had had prior surgery, and the risk of pneumonia was 38 times greater for patients who had undergone thoracoabdominal operations⁽³¹⁾. Other risk factors for postoperative pneumonia are low serum albumin, high risk classification according to the American Society of Anaesthesiology, a history of smoking, longer preoperative stays, longer operative procedures, and thoracic or upper abdominal sites of surgery⁽³²⁾. Bacterial pathogens may enter the airway during intubation or after extubation. Sedation, an anaesthetized airway after extubation, vomiting, supine position, and head and neck, abdominal, and thoracic surgeries are all significant risk factors for aspiration⁽⁵⁸³⁾. Postoperative atelectasis, retained secretions, and pain may all increase the risk of nosocomial pneumonia by impairing the host's ability to clear bacteria and secretions effectively⁽⁵⁸⁴⁾.

2. Pediatric Ward

Nosocomial lower respiratory tract infections represent a significant concern to those caring for hospitalized infants and children because of their frequency and potential severity. Risks for children also depend in part on the child's underlying health and ability to withstand

infection, and on the environment. Nosocomial infection risks in pediatrics differ according to patient unit and medical service^(34;43;585;586). In general, infection risk is lowest in normal newborn nurseries and then progressively increases on pediatric medical-surgical wards, in PICUs, and is the highest in NICUs⁽³⁵⁾. Respiratory tract infections account for a significant portion of nosocomial infections in the pediatric medical-surgical population. NNIS data from 1978-94 showed that pneumonia accounted for 15.6% and 17.2% of cases of nosocomial infection in pediatric surgery and general pediatric services respectively⁽³⁵⁾. The rate of nosocomial respiratory tract infection varies with age. Rates have been reported as 0.59% for children younger than 23 months of age, and 0.1% for older children⁽³⁴⁾.

On pediatric wards, acquisition of exogenous pathogens accounts for lower respiratory tract infections than intubation or ventilation. Most infections are viral⁽⁵⁸⁷⁾. In a large series of nosocomial pediatric infections, Ford-Jones et al. found that viruses were responsible for 46% of infections in which a pathogen was identified⁽³⁴⁾. The epidemiologic patterns of these nosocomial viral infections mirror those seen in the community in terms of frequency, season, age affected, and severity of illness. The most frequent agents are respiratory syncytial, influenza, and parainfluenza viruses. Their importance results from the severity of disease produced in young children, which are magnified in those hospitalized with certain chronic conditions^(216;587). Pediatric wards are particularly suited to the transmission of community pathogens. Infants and toddlers constitute a large proportion of the patients admitted. They frequently harbour infectious organisms and may shed respiratory viruses even if asymptomatic^(35;216;587). In symptomatic children, viral shedding is abundant and prolonged. Young children are also highly susceptible to many infections, as they have not yet developed immunity. Close proximity of large numbers of infectious and susceptible hosts favours transmission.

Behavioural characteristics of young children, such as incontinence or inadequate hygiene, frequent mouthing of hands and objects, drooling and direct contact between children during play, facilitate the spread of infection. Basic care requires frequent hands-on contact from healthcare personnel and parents. All patients, staff, and visitors are potentially susceptible to these viruses, since reinfections occur throughout life. However, infections in older children and adults tend to be mild, and these may not be recognized as sources of transmission. Shared bedrooms, toys, and playrooms, and visiting siblings contribute to risk transmission^(35;216;587;588).

As is the case in adults, most bacterial NP in children occurs by aspiration of bacteria that colonize the oropharynx or upper gastrointestinal tract. Children who have either altered swallowing mechanisms or anatomic abnormalities that prevent adequate protection of their airway are at increased risk of aspiration. Specific conditions or situations associated with an increased risk of aspiration are tracheoesophageal fistula, gastroesophageal reflux, cleft palate, anaesthesia, neuromuscular blockade, primary and secondary myopathies, and central or peripheral nervous system disease associated with swallowing⁽⁵⁸⁹⁾.

II. Nosocomial Pneumonia in the Critical Care Setting

1. Adult

The incidence of nosocomial pneumonia is highest in the ICU, and it is here that it carries the greatest mortality⁽⁵⁹⁰⁾. The patients at greatest risk of NP are those who are managed with endotracheal intubation and mechanical ventilatory support. Additional risk factors for nosocomial pneumonia in the ICU setting include the severity of the patient's underlying diseases, widespread use of antibiotics, and the large number of invasive procedures performed. The reason for this increased incidence of pneumonia appears to relate more to the need for intubation and mechanical ventilation than simply residing in the ICU, since the median rate of pneumonia occurring among mechanically ventilated patients is reported to be 34.4 cases per 1000 ICU days in burn ICUs versus a median rate of 3.2 cases per 1000 ICU days among non-ventilated trauma ICU patients⁽⁵⁹¹⁾. Studies have shown that the risk of pneumonia is lower in patients managed with non-invasive ventilation compared with intubated patients who are mechanically ventilated⁽⁵⁹²⁻⁵⁹⁴⁾.

As with all NP, the pathogenesis of pneumonia acquired in the ICU usually requires two important processes to take place: bacterial colonization of the respiratory tract and the aspiration of contaminated secretions into the lower airway^(595;596). The presence of invasive medical devices is a major contributor to these processes and the subsequent development of VAP. Nasogastric tubes predispose patients to gastric reflux and increase the potential for aspiration. The endotracheal tube plays an important role in the development of pneumonia by serving as a barrier to host defences (such as mucociliary clearance or cough)⁽⁵⁹⁷⁾ and allowing contaminated secretions to pool just above the endotracheal cuff, an area not reached by suctioning devices, with subsequent aspiration into the lower tracheobronchial tree⁽⁵⁹⁸⁾. Leakage of these bacteria around the endotracheal cuff, along with local trauma and tracheal inflammation from the endotracheal tube, increases colonization and reduces the clearance of organisms and secretions from the lower respiratory tract⁽⁵⁹⁹⁻⁶⁰²⁾. Additionally, since the cuff and endotracheal tube are foreign objects, they may become colonized with bacteria that grow in a biofilm and may be embolized into the lower

respiratory tract during suctioning⁽⁶⁰³⁻⁶⁰⁵⁾. Investigations of modification to the material composition of endotracheal tube surfaces and the deposition of anti-adherent coatings to prevent pathogen adherence are ongoing^(606;607).

In intubated patients, bacteria from the hands of HCWs or from contaminated respiratory therapy equipment may be directly inoculated into the endotracheal tube. Outbreaks of infection due to *P. aeruginosa* and *K. pneumoniae* caused by transmission of pathogens from the hands of HCWs have been described^(113;122). Neiderman and colleagues found that *Pseudomonas* species, which readily bind to respiratory epithelial cells, colonize the tracheobronchial tree without first appearing in the oropharyngeal secretions of intubated patients, presumably entering the lung through direct inoculation^(608;609).

In addition to the oropharynx, the stomach has also been considered to be a reservoir of Gram-negative bacteria that cause VAP^(595;601;610-614). This has not been confirmed by all investigators^(116;596). In healthy individuals, the stomach is usually sterile when the gastric pH is <2 because of the potent bactericidal activity of hydrochloric acid. However, when gastric pH increases from normal levels to >4, organisms are able to multiply to high concentrations⁽⁶¹⁵⁻⁶¹⁷⁾. An increase in gastric colonization occurs with advanced age, achlorhydria, various gastrointestinal diseases, and malnutrition, and in patients receiving enteral feeding, antacids, and histamine-2 (H₂) blockers^(118;611;617;618). Gastric alkalization with tube feed, antacids, or H₂ blockers leading to an increased risk of nosocomial pneumonia has been demonstrated in some, but not all, studies^(50;116;611;617-622).

Cook and Kollef summarized the results of 12 cohort studies that evaluated risk factors for ICU-acquired pneumonia⁽⁶²³⁾. Neurologic conditions were associated with ICU-acquired pneumonia, and the risk of lung infection was higher in patients treated with mechanical ventilation than in those breathing without assistance. In addition, the risk of VAP appeared to be higher in patients with chronic lung disease and acute respiratory distress syndrome, and as the duration of ventilation increased. Manipulation of the airway and/or ventilator circuit may predispose to aspiration and subsequent VAP. VAP was associated with several risk factors: reintubation, tracheostomy, frequent ventilator circuit changes, low intracuff pressure, failed subglottic suctioning, and patient transport. Other risk factors emphasize the role of the gastrointestinal tract in the development of pneumonia, such as the presence of a nasogastric tube, enteral feeding, supine positioning, witnessed aspiration, and stress ulcer prophylaxis with gastric pH-altering agents. The authors also observed that many risk factors in this population are patient-specific characteristics and not modifiable (e.g., male

sex, advanced severity of illness), and others may represent epiphenomena associated with the diagnosis or management of lung infection (e.g., recent bronchoscopy, aerosol therapy).

2. Pediatric

2.1. Pediatric intensive care unit (PICU)

Patients admitted to PICUs are at increased risk of infection⁽³⁵⁾. The increased risk of infection in these children results primarily from exposure to mechanical ventilation^(43;624). Although less well studied, mechanisms of pathogenesis of VAP in the child are expected to be similar to those in the adult⁽⁶²⁵⁾. Routes of inoculation include aspiration (mostly bacterial), inhalation (*Legionella* species, *Aspergillus* spp., influenza virus, or *M. tuberculosis*), inoculation of mucous membranes with large droplets (RSV and other respiratory viruses), or secondary to blood stream infection (bacterial)⁽³⁵⁾.

Many of the risk factors in the development of NP previously identified in adult patients, such as severe underlying cardiopulmonary disease, immunosuppression, depressed sensorium, and prior thoracoabdominal surgery, are present in pediatric patients and place them at similar risk of infection⁽⁴⁴⁾. Study performed in a Canadian PICU identified specific risks for bacterial nosocomial pneumonia and tracheitis⁽⁶²⁶⁾. With the use of multivariate analysis, three independent risk factors for bacterial NP were identified: immunodepressant drugs, immunodeficiency, and the use of neuromuscular blockade. High association of risk factors with each other prevented some factors, such as mechanically assisted ventilation and intubation, from reaching statistical significance. Singh-Naz and colleagues found that variables significantly associated with the development of nosocomial infection in critically ill children were operative status, device utilization ratio, antimicrobial therapy, parenteral nutrition, and length of stay before onset of infection⁽⁵⁸⁶⁾.

2.2. Neonatal intensive care unit (NICU)

Patients in NICUs have the highest risk of infection of any pediatric setting⁽³⁵⁾. This results from prematurity, low birth weight^(627;628), immunologic immaturity^(41;629), and exposure to invasive devices and procedures. Endotracheal intubation is a major risk factor for pneumonia in NICUs^(628;630). In a study of incidence and outcome of pneumonia in neonates, Webber et al. reported that pneumonia developed in 10% of all ventilated babies⁽⁶²⁸⁾. Outbreaks have occurred after exposure to contaminated resuscitation and respiratory therapy equipment^(404;464;631;632).

Early onset pneumonia may develop in hospitalized neonates as a result of infection with organisms acquired perinatally from their mother's vaginal flora and is most often due to group B streptococcus⁽⁶²⁸⁾. Other perinatally acquired pathogens from the mother's genital tract are *Ureaplasma ureolyticum* and *Chlamydia trachomatis*. Such perinatally acquired pathogens will not be addressed further in this guideline.

III. Healthcare-Associated Pneumonia in the Immunocompromised Host

The immunocompromised host is a person who has one or more defects in the body's normal defence mechanisms and is thus predisposed to infections, often life threatening, that would not otherwise occur⁽⁶³³⁾. The number and types of immunocompromised hosts are constantly increasing because of our aging population and medical advances that have prolonged survival in those who previously would have died from their underlying disease⁽⁶³⁴⁾.

Pulmonary infections are an important problem in immunocompromised patients. For patients with neoplastic diseases, nosocomial infections of the respiratory tract have been reported to account for approximately 30% of all nosocomial infections⁽⁶³⁵⁾. Velasco and colleagues reported that nosocomial pneumonia was the most common infection among patients in an oncology ICU, constituting 28.5% of all nosocomial infections⁽⁶³⁶⁾. Respiratory tract infections occur most commonly in patients with leukemia/lymphoma and those with solid tumours of the lung and head and neck regions⁽⁶³⁷⁾. Pannuti and colleagues identified 55 cases of NP (20%) in 275 bone marrow transplant patients within 100 days of transplantation⁽⁶³⁸⁾. Nosocomial pneumonia is also a frequently encountered complication in solid organ transplant recipients. Pulmonary infections have been documented to occur in up to 40% of patients after heart^(639;640) or liver transplantation⁽⁶⁴¹⁾. Fifty-one percent of all pulmonary infections (36/71) in heart transplant recipients in one report were nosocomial in origin⁽⁶⁴⁰⁾. A multicentre surveillance study conducted by the Centers for Disease Control and Prevention (CDC), from 1989 to 1995, reported that pneumonia was responsible for 15% of the 530 nosocomial infections identified in 2,541 HIV-infected patients⁽⁶⁴²⁾.

The most important risk factor for infection in the immunocompromised individual is severe neutropenia, especially if prolonged⁽⁶⁴³⁾. As with the immunocompetent host, most bacterial NPs occur by aspiration of bacteria colonizing the oropharynx or upper gastrointestinal tract of the patient. The compromised host rapidly acquires altered oropharyngeal and upper respiratory tract flora, becoming colonized with predominantly Gram-negative organisms. Chemotherapy further contributes to colonization by inducing mucosal damage and ulceration, facilitating tissue invasion. Another major factor is hospitalization and exposure

to hospital flora, which include multiresistant Gram-negative bacilli and fungi⁽⁶⁴³⁻⁶⁴⁵⁾. Pulmonary infections in the immunocompromised host may also be hematogenous in origin.

Patients with impaired cell-mediated immunity may also acquire pneumonia following reactivation of a latent pulmonary focus of infection. Corticosteroids or a primary malignant process may impair cell-mediated immunity. Infections in this setting include tuberculosis, atypical mycobacterial infection, *Pneumocystis carinii* pneumonia, and viral infections such as CMV and herpes simplex⁽⁶⁴³⁾.

Aspergillus spp. are a cause of severe illness and mortality in highly immunocompromised patients, e.g., patients undergoing chemotherapy and/or transplantation (including hematopoietic stem cell transplant (HSCT) and solid organ transplant) and patients with advanced HIV infection⁽⁶⁴⁶⁻⁶⁴⁸⁾. Host factors and environmental exposures are both associated with increased risk of invasive pulmonary aspergillosis (IPA). Severe and prolonged neutropenia is the most important host risk factor for IPA⁽⁶⁴⁹⁾, and HSCT recipients are at highest risk because they experience the most severe and prolonged degree of neutropenia⁽⁶³⁸⁾. Autologous and allogeneic transplant recipients are severely neutropenic for up to four weeks after transplantation⁽⁶⁵⁰⁾. However, reports have cited *Aspergillus* infection occurring after engraftment, usually associated with graft-versus-host disease and administration of high doses of steroids. The risk for HSCT patients may extend over the entire year after transplantation⁽⁶⁴⁶⁾. Hospital environmental sources associated with outbreaks of IPA include building construction/and or renovation projects^(204;651;652) bird droppings in air ducts supplying high-risk patient areas⁽⁶⁵³⁾, and contaminated fireproofing material⁽⁶⁵⁴⁾.

Legionella infection may occur in immunocompromised patients, transplant recipients having the highest risk⁽⁶⁵⁵⁾. Among patients undergoing surgical procedures at one institution where legionellosis was documented, renal transplant recipients had an attack rate of 50%, whereas the general hospital population experienced an attack rate of only 0.4%⁽¹⁷⁴⁾. The source of post-transplantation legionellosis in all studies where an environmental link was sought was the hospital's potable water distribution system⁽⁶⁵⁵⁾.

The major viral respiratory pathogens in immunocompromised hosts are CMV, varicella-zoster virus, HSV, and adenovirus. NP in immunocompromised hosts can result following exposure to individuals with RSV and influenza virus, and severe disease has been reported in pediatric organ transplant recipients^(225;656;657) and adult HSCT patients^(217;658). These two viruses have emerged as important pathogens in past years, causing outbreaks in some settings⁽⁶⁵⁹⁾. Among immunocompromised patients, adenoviruses often become disseminated and then cause serious disease, with a 60% mortality rate^(258;260). Nosocomial acquisition of adenovirus infection in transplant patients has been suggested. In one report, several patients with similar adenovirus strains were found to be temporally clustered⁽²⁵⁹⁾.

Profound immunosuppression raises the possibility of patients acquiring potentially pathogenic microorganisms from sources of little concern in other hosts, such as uncooked foods and water. Fresh fruits and vegetables, and flowers and plants are normally colonized by free-living microorganisms such as *Pseudomonas* spp.⁽⁶⁶⁰⁾, and institutional water sources are potential sources of microorganisms such as *Pseudomonas* spp., *Legionella* spp., and saprophytic mycobacteria. Personal items may become colonized with bacteria and fungi⁽⁶⁶¹⁾ and be difficult to clean, although their role in increasing the risk of infection is not well studied. By the time the patient returns home, the immune system has been partially restored, but environmental sources remain potential problems.

Prevention of infection is one of the most important objectives for compromised patients because of their increased susceptibility to hospital-acquired organisms. Defensive strategies must take into account not only effectiveness but also cost. The pathogenesis and risk factors for pneumonia in the immunocompromised individual are similar to those in the normal host, therefore the measures recommended for prevention of healthcare-associated pneumonia in this guideline are applicable to this group of patients. In addition, interventions to prevent specific infections in the compromised host may be required^(662;663).

IV. Healthcare-Associated Pneumonia in Other Healthcare Settings

1. Long-Term Care

The pathogenesis of pneumonia in the elderly is believed to result largely from aspiration of endogenous organisms colonizing the oropharynx^(86;90;664-666). The occurrence of pneumonia is related directly to the virulence of the colonizing pathogens, the size of inoculum aspirated, and the degree of impairment of host defences⁽⁶⁶⁷⁾. Ineffective clearing of mucus from the respiratory tract makes older people more vulnerable to pneumonia secondary to aspiration, and this is especially true for those with coexistent illnesses such as stroke, dysphagia, gastroesophageal reflux disease, aspiration, or sedative hypnotic medication use^(51;668-670). Aging-related physiologic changes in lung function and host immunity, such as alterations in cell-mediated and humoral immunity and qualitative changes in T-cell function, also predispose the elderly to pneumonia. Many elderly people have underlying conditions that increase susceptibility to pneumonia, including diabetes, chronic pulmonary disease, and heart disease^(671;672).

Only a few studies have specifically examined risk factors for lower respiratory tract infection in long-term care facilities^(53;669;673-676). Profound debility⁽⁶⁷³⁾, bedfast status^(53;674;675), urinary incontinence⁽⁶⁷⁴⁾, and deteriorating health status have been consistent risk factors^(669;673). In addition, studies have identified chronic obstructive lung disease⁽⁶⁷⁵⁻⁶⁷⁷⁾ and tracheostomy⁽⁶⁷⁵⁾ as risk factors for pneumonia. Factors associated with aspiration, including difficulty swallowing oral secretions^(53;669), inability to take oral medications⁽⁵³⁾, and nasogastric tube feeding⁽⁶⁷³⁾, increase the risk of pneumonia. Table 10 illustrates the relative degree of risk for a variety of factors for nursing home acquired pneumonia according to interpretation of the published literature^(51;52).

Table 10

Risk factors for pneumonia among nursing home residents

Risk Factor	Degree of Risk in Nursing-Home Acquired Pneumonia
Activities of daily living dependence	+++
Age	+++
Alcoholism	+
Aspiration	+++

Risk Factor	Degree of Risk in Nursing-Home Acquired Pneumonia
Bed-fast state	+++
Body positioning	++
Broad-spectrum antibiotic use	++
Bronchial asthma	+
Cardiac disease	+
Cerebrovascular accident	+++
Cognitive impairment	+++
Dental caries	++
Difficulty with oropharyngeal secretions	+++
Dysphagia	+++
Feeding tube	+++
Frailty	+++
Incontinence	+++
Immunosuppression	+
Institutionalization	+++
Malnourishment	++
Pulmonary disease	++
Sedative-hypnotic drug use	+++
Tracheostomy	++
Tobacco	+

+, low risk; ++, intermediate risk; +++, high risk

Residents of long-term care facilities may acquire organisms from exogenous sources as well. Patients with indwelling urinary catheters and pressure sores are often colonized with multiply resistant bacteria^(178;678;679). These microorganisms may be spread from resident to resident, most commonly on the hands of HCWs. The relatively confined environment of the nursing home, with susceptible individuals residing in close proximity, provides conditions for the spread of respiratory pathogens such as influenza⁽⁶⁸⁰⁾, RSV⁽⁶⁸¹⁾, and *M. tuberculosis*⁽⁶⁸²⁾.

2. Ambulatory Care

Many diagnostic and therapeutic services previously delivered only in hospitals have been shifted to the outpatient setting. However, the delivery of health care in the ambulatory care setting differs from that in the acute care facility. The patient mix and interactions are varied, and the patients' clinical status ranges from well to acutely ill, requiring visits that may be brief or may last the entire day⁽¹⁰⁾. Specific characteristics of the outpatient setting may theoretically place patients at increased risk of droplet-borne or airborne diseases⁽⁵⁸⁾:

- Patients are clustered in common waiting areas, often for extended periods of time.
- Many infectious patients come to outpatient facilities for evaluation and treatment, particularly during periods endemic for viral infections.
- Patients frequently move between waiting areas, examination rooms, and diagnostic areas.
- Children frequently share toys in waiting rooms.
- Patients may be inadequately screened for infectious agents, particularly for those that are spread through the air by droplets.
- Outpatient facilities frequently have inadequate triage systems.
- The number of air exchanges in the building is often lower than recommended, and the air is often recirculated without filtration.
- Airborne infection isolation rooms may not be available.

There are limited data on the transmission of infection between patients in ambulatory care^(58;683;684). Most infections resulting from ambulatory care have been related to surgery or other invasive procedures performed in these settings, problems with aseptic practices, or inadequate cleaning and disinfection of equipment and supplies between patients^(18;684). Outbreaks have illustrated that bacterial and viral pathogens such as *M. tuberculosis*, measles, rubella, *B. pertussis*, and *Legionella* can be transmitted within ambulatory care by airborne or droplet spread^(486;685-690). Although influenza virus has been transmitted in the inpatient setting, published descriptions of outbreaks in the ambulatory care setting are not available. O'Mahoney and co-workers described an outbreak of Legionnaires' disease in an

outpatient department resulting in the death of 22 patients⁽⁶⁹⁰⁾. Transmission of infection was attributed to design flaws in the ventilation system, which allowed *L. pneumophilla* in the chiller unit to be aerosolized.

In the ambulatory care setting, patients with CF present a unique infection control challenge. Respiratory tract colonization with *B. cepacia* can cause an accelerated decline in pulmonary function, and 20% of CF patients colonized with this organism develop fatal fulminant pneumonia⁽⁵⁶⁰⁾. Patient-to-patient transmission of *B. cepacia* within CF clinics likely contributes to pulmonary colonization of some patients^(134;691).

The transmission of *B. cepacia* among patients with CF depends on many factors. Different strains may vary in transmissibility and virulence⁽⁶⁹²⁾. Govan et al. documented spread of an epidemic strain of *B. cepacia* within and between patients attending regional clinics in Edinburgh and Manchester and identified social contact as a significant risk factor associated with direct transmission of *B. cepacia* from CF patient to CF patient⁽¹³⁴⁾. Indirect spread of *B. cepacia* between patients with CF and patients without CF through contaminated fomites and respiratory equipment, facilitated by poor compliance with hand hygiene, has also been reported^(11;130;693;694). Drabick et al. demonstrated that *B. cepacia* in sputum from patients with CF can survive for long periods of time on the environmental surfaces typically found in CF clinics⁽⁶⁹²⁾. Ensor and co-workers examined droplet transmission of *B. cepacia* from eight adult patients⁽⁵⁶⁹⁾. Before physiotherapy, 16% of air samples were positive for *B. cepacia*. However, during physiotherapy as coughing was induced, and after physiotherapy, 47% and 44% of air samples were positive respectively.

Construction, renovation, repair, and remediation projects (e.g., removing old sinks, installing wiring for new information systems) are common in ambulatory care areas within and separate from the hospital. Environmental disturbances associated with construction, renovation, and repair projects pose airborne and waterborne risks for the large number of patients who are at risk of healthcare-associated opportunistic infections. Such high-risk individuals may receive care in facilities across the continuum of care, e.g., oncology patients in ambulatory units, HSCT patients in clinics, and dialysis patients in freestanding satellite units.

3. Home Care

Home care organizations now provide support to more acutely ill individuals who often have a number of underlying medical conditions, such as chronic obstructive pulmonary disease, cancer, AIDS, diabetes, and renal failure. These, together with the use of invasive devices for home health treatment, significantly increase the client's risk of infection^(10;695;696). A survey of home health care clients revealed that these predominantly elderly individuals had an average of 3.6 comorbid conditions, and 12% had invasive devices⁽⁵⁷⁾.

Although there are no studies of the risk of infection in the home environment, many home care clients have the same risk factors for respiratory tract and other types of infection as patients in the hospital. These include intrinsic factors, such as older age, underlying diseases, compromised immune status, and poor nutritional status, as well as extrinsic factors, such as devices that bypass upper airway defences (e.g., tracheostomy tube, nasogastric tube), surgery, burns, radiation, chemotherapy, and trauma^(57;544;697).

Environmental factors in the home may also increase a patient's susceptibility to infection. Sanitation in the home and/or the client's personal hygiene may be poor, supplies and equipment may be contaminated, and clients may be exposed to communicable diseases in other family members. In addition, inadequate knowledge may contribute to a lack of appropriate infection control and prevention measures by the client or responsible care giver between visits by home care providers⁽⁵⁴⁴⁾.

Increasingly sophisticated respiratory care equipment and devices, including ventilators, are used in the home and require meticulous maintenance in order to prevent bacterial contamination and respiratory tract infection. Infection prevention and control issues related to equipment and devices used in home respiratory care are reviewed in the Respiratory Equipment and Devices section of this guideline.

V. Summary of Risk Factors and Prevention Measures for Healthcare-Associated Pneumonia

1. Patient-Related Risk Factors

Specific patient-related risk factors are discussed within each clinical setting where pneumonia occurs. In general, risk factors reflect pre-existing conditions that impair host defences and increase colonization of the upper airway with Gram-negative bacilli. These include extremes of age, the severity of underlying illness, immune suppression, malnutrition, coma or other causes of impaired consciousness, prolonged hospitalization,

and the presence of certain comorbid conditions^(38;68;75;575). These risk factors generally cannot be altered. Nevertheless, efforts should be made to recognize the potential for nosocomial pneumonia and the need to minimize exposure to additional risk factors.

Vaccination programs have been successful in reducing the incidence of infection caused by specific pathogens, including *S. pneumoniae*, *H. influenzae*, *B. pertussis*, and the influenza virus⁽⁶⁹⁸⁻⁷⁰⁷⁾. A study of elderly patients with chronic lung disease showed that those who received influenza vaccine had significantly fewer hospitalizations ($p = 0.0008$) and outpatient visits ($p = 0.002$) for pneumonia and influenza and lower mortality ($p = 0.001$) than those who were unvaccinated⁽⁷⁰⁸⁾. In multivariate analysis, Loeb and co-workers found that receipt of influenza vaccine was protective against the development of pneumonia in elderly residents of long-term care facilities (OR, 0.4; 95% CI: 0.3 to 0.5; $p = 0.01$)⁽⁵³⁾. The effectiveness of influenza vaccination in this study was similar to that determined in a meta-analysis, in which pooled estimates of vaccine efficacy ranged from 53% to 56%⁽⁶⁹⁸⁾, confirming the importance of annual influenza vaccination.

Outbreaks of both antibiotic-susceptible and antibiotic-resistant *S. pneumoniae* have occurred in nursing homes where fewer than 5% of residents received pneumococcal vaccine⁽⁷⁰³⁾. Nichol et al. found that pneumococcal vaccination resulted in lower risk of pneumonia hospitalization and death in the institutionalized elderly with chronic lung disease. During influenza season, the benefits of both pneumococcal and influenza vaccinations were additive in reducing pneumonia hospitalizations and both influenza and death among vaccine recipients⁽⁷⁰⁸⁾. The evidence supports universal routine pneumococcal immunizations in long-term care facilities^(52;704). The pneumococcal conjugate vaccine is highly efficacious in children^(709;710). Administration of anti-RSV immunoglobulin or monoclonal antibody against RSV reduces the risk of severe infection with RSV in high-risk children⁽⁷¹¹⁾.

Antiviral agents are effective in the prevention of influenza. Amantadine is 70%-90% effective in preventing illness due to influenza A if taken after exposure and has been effective in controlling some outbreaks^(700;712). The newer neuraminidase inhibitors zanamivir and oseltamivir have also been effective in controlling outbreaks in nursing homes⁽⁷¹³⁻⁷¹⁷⁾.

Aspiration and gastric reflux are common in hospitalized patients^(601;611-613;718). The supine position increases the risk of aspiration, especially during feeding, irrespective of whether by mouth or gastroenteric feeding tube. Ibanez and coworkers reported gastroesophageal reflux in 70% of patients receiving tube feedings; 40% had evidence of pulmonary aspiration⁽⁷¹⁸⁾. Positioning of patients in the semirecumbent position (30°-45°) has been shown to reduce the occurrence of reflux, aspiration, and subsequent pneumonia^(583;601), probably by preventing aspiration⁽⁷¹⁹⁾. In a cohort study of ICU patients, supine head position during the first 24 hours of mechanical ventilation was independently associated with an increased risk of VAP and death⁽⁶⁵⁾. Semirecumbent positioning may be a cost-effective approach for the prevention of NP.

There is an increased frequency of pulmonary and non-pulmonary complications among patients confined to bed. Immobilized trauma patients are at high risk of nosocomial pneumonia⁽⁷²⁰⁾. Kinetic or lateral rotational beds, by intermittent or continuous rotation on the longitudinal axis, theoretically prevent pneumonia by increasing tidal volume and improving the drainage of secretions in the lungs. Although five clinical trials of continuous rotation or oscillation in critically ill adults have demonstrated lower rates of NP and other pulmonary complications⁽⁷²¹⁻⁷²⁵⁾, only one study demonstrated a statistically significant reduction in the incidence of pneumonia in patients given continuous lateral rotation therapy compared with those in standard beds (14% compared with 40%, RR = 0.35, 95% CI: 0.16 to 0.75)⁽⁷²²⁾. High costs and patient discomfort are associated with this mode of preventive therapy. Clinical trials that examine efficacy and cost-effectiveness should be conducted to evaluate the role of this technology.

Other preventive measures to reduce the risk of nosocomial pneumonia in the surgical patient include early ambulation to prevent atelectasis and retained secretions^(601;726).

2. Device-Related Risk Factors

Devices that bypass the upper respiratory tract defence mechanisms have been identified as risk factors for NP^(23;38;727). Devices include those used for both diagnostic (e.g., bronchoscopy) and therapeutic (e.g., endotracheal tubes, respiratory therapy equipment) purposes.

2.1. Endotracheal tube

Tracheal intubation for mechanical ventilation is the most significant risk factor for the development of nosocomial pneumonia^(31;36;38;39;728;729). An endotracheal tube facilitates the entry of bacteria into the trachea, decreases clearance of bacteria and secretions from the lower airway, and acts as a surface on which bacteria may collect and form a protective

biofilm^(38;599;600;604;730). Investigators have suggested that leakage of contaminated secretions that pool above inflated endotracheal tube cuffs may be a source of tracheal colonization and aspiration, which increases the risk of VAP^(451;598;731). Endotracheal tubes furnished with a separate lumen open to the subglottic area above the endotracheal cuff, allow continuous aspiration of subglottic secretions. In two randomized clinical trials there was a significant reduction in the incidence of VAP with the use of these devices^(599;600). Maintaining appropriate cuff pressures may decrease leakage of pooled secretions into the trachea and prevent VAP. Rello and coworkers demonstrated that there was a trend toward a higher risk of VAP for patients with persistent intra-cuff pressure below 20 cm H₂O⁽⁵⁹⁸⁾. These data highlight the importance of maintaining adequate cuff pressure to reduce aspiration around the endotracheal tube.

Biofilm formation, demonstrated within the lumens of endotracheal tubes using scanning electron microscopy, may be an important risk factor for VAP^(604;730). Biofilms develop on foreign bodies and allow the proliferation of microorganisms within a protected environment. Antimicrobial penetration into biofilms is limited, diminishing the killing capacity of these drugs for bacteria within the biofilm. Some investigators believe that bacterial aggregates may become dislodged by ventilation flow, tube manipulation, or suctioning and subsequently embolize into the lower respiratory tract and cause focal pneumonia^(603;605;606). Research continues with the aim of developing medical devices with specially bonded surfaces to prevent the formation of biofilms, but no clinical trials of such devices have yet been performed.

Endotracheal reintubation may be an important risk factor in the development of NP⁽⁷³²⁾. Care should therefore be taken before deciding on endotracheal extubation to avoid the possible need for re-intubation.

Nasal intubation and sinusitis: Nasal endotracheal intubation and placement of a nasogastric tube may increase the risk of both nosocomial sinusitis and VAP. Clinical trials have found an association between the occurrence of sinusitis and VAP, suggesting that aspiration of infected secretions originating from the nasal sinuses into the lower airway may result in VAP^(727;733;734). These investigations also suggest that the preferred route of intubation is via the oropharynx and not the nasopharynx.

Non-invasive positive pressure ventilation (NIPPV): Some of the infection risk associated with intubation of the trachea can be avoided in selected groups of patients by delivering ventilation through a full face mask or a nasal mask⁽⁷³⁵⁻⁷³⁷⁾. Lower rates of nosocomial pneumonia among patients receiving NIPPV have been suggested in several studies^(592;736;738). One randomized controlled study of severely hypoxemic patients showed that more patients in the conventional ventilation group developed pneumonia (diagnosed by BAL) and sinusitis than those who received positive pressure ventilation through a mask (31% vs. 3%, $p = 0.003$)⁽⁵⁹⁴⁾. A matched case-control study by Girou and colleagues found that the rates of NP were significantly lower among critically ill patients who received NIPPV than those treated with mechanical ventilation (8% vs. 22%; $p = 0.04$) and that the use of NIPPV was associated with a shortened stay in the ICU and reduced mortality⁽⁵⁹³⁾.

2.2. Nasogastric/orogastric tube and enteral feeding

Most critically ill patients have a gastric tube to manage gastric secretions, prevent gastric distension, or provide nutritional support. Placement of a nasogastric tube may increase nasopharyngeal colonization, contribute to reflux of gastric contents, and provide a pathway for bacteria to migrate to the oropharynx and hence be a risk factor for the development of pneumonia^(739;740). Some investigators have proposed using a small-bore rather than a large-bore nasogastric tube, and others have suggested bypassing the stomach by using a jejunal tube instead of a gastric tube to reduce the risk of reflux of gastric contents into the oropharynx^(741;742). These issues require further study before definite recommendations on a preferred route of enteral feeding can be made.

By impairing host defences, malnutrition has been shown to be a contributing factor to the development of pneumonia and has led to the current trend of early nutritional support for critically ill patients^(729;743). Enteral nutrition, particularly given early, is generally preferred to parenteral feeding and is associated with fewer septic complications⁽⁷⁴⁴⁾. However, some investigators have suggested that administering enteral feedings with high pH through the oral gastric tube may raise the pH in the stomach, thus increasing bacterial colonization, volume, pressure, reflux, aspiration, and the risk of pneumonia^(576;618). Feedings can become contaminated during preparation, which may lead to gastric colonization with Gram-negative bacilli. An investigation implicated contaminated food coloring dye in an outbreak of respiratory infections with *P. aeruginosa*⁽⁶²⁰⁾.

Tap water may be a potential source of nosocomial Gram-negative bacilli, *Legionella*, and *Mycobacterium avium-intracellulare* complex organisms. Sterile water for the preparation of both feeds and nasogastric tube flushes has been advocated^(147;620). In continuing care and home settings, tap water may be used to rinse feeding bags and tubing. Sterile or boiled water has been suggested to rinse feeding systems of immunocompromised individuals in these settings.

The role of intermittent vs. continuous administration of enteral feeding in decreasing gastric colonization and pneumonia has been the subject of several studies⁽⁷⁴⁵⁻⁷⁴⁸⁾, but findings are inconclusive. There are several other unresolved issues:

- whether acidified enteral feedings decrease infection
- whether metoclopramide should be used to increase gastric emptying
- whether the stomach contents should be monitored for the presence of feeding solutions and the gastric residual removed if the volume is large or bowel sounds are not auscultated
- optional feeding tube size
- location of optimal tube placement in the gastrointestinal tract

2.3. Endotracheal suction catheters

Tracheal suction catheters used on mechanically ventilated patients may carry bacteria directly into the lung, increasing the risk of tracheal colonization. To avoid hypoxia, hypotension, and contamination of suction catheters entering the endotracheal tube, investigators have examined closed suctioning systems. Several studies report that there is no difference in the risk of healthcare-acquired pneumonia in patients managed with either a closed or open suction system^(451;470;472), but one randomized trial concluded that the incidence of VAP was reduced with the use of a closed suctioning system⁽⁴⁷³⁾. The main advantages attributed to the closed, multi-use catheters are lower costs and decreased environmental cross-contamination^(749;750). One randomized, controlled trial found that elimination of routine in-line suction catheter changes was safe and cost-effective, compared with daily changes⁽⁴⁷¹⁾.

2.4. Other respiratory equipment and devices

Respiratory therapy and resuscitation equipment (e.g., ventilation, medication delivery) used for treatment or diagnosis can become colonized with microorganisms and potentially deliver contaminated fluids or aerosols to respiratory mucous membranes and the lower respiratory tract. A comprehensive discussion of risk and recommendations for prevention of pneumonia associated with healthcare equipment, both in healthcare facilities and in the home, may be found in the Respiratory Equipment and Devices section of this guideline.

3. Treatment-related Risk Factors

3.1. Sedatives and neuromuscular blockers

An altered level of consciousness has been identified as a risk factor for VAP⁽⁶²³⁾. Sedatives or narcotics can suppress central nervous system function, particularly among the elderly and patients with swallowing impairment, increasing the risk of aspiration while decreasing cough and the ability to clear secretions⁽⁵¹⁾. Sedating medications and neuromuscular blockade have been identified as independent risk factors for VAP in separate studies^(50;751).

3.2. Antimicrobial administration

The relation between exposure to antimicrobials and occurrence of nosocomial pneumonia is complex, and studies have produced contradictory findings. Prolonged or repeated administration of antimicrobials for any reason may eliminate or alter the normal respiratory tract flora and favour selection and subsequent colonization with resistant pathogens⁽¹¹⁰⁾. In observational studies, previous antibiotic exposure is identified as a risk factor for the development of NP and for VAP due to resistant pathogens such as *P. aeruginosa* and MRSA^(65;83;110;752). On the other hand, antibiotics are associated with a reduced risk of early onset VAP^(101;598). In the prospective cohort study of 1014 mechanically ventilated patients in 16 intensive care units in Canada, exposure to antibiotics conferred protection against VAP (RR = 0.37 [95% CI: 0.27 to 0.51])⁽⁵⁰⁾. A controlled trial by Sirvent and colleagues reported that two doses of cefuroxime after intubation decreased the risk of early onset pneumonia⁽⁷⁵³⁾. The evidence suggests that the risk of early onset pneumonia, caused predominantly by antimicrobial-sensitive endogenous colonizers, is decreased by the use of antimicrobials. Weighed against this is the increased risk of late onset pneumonia caused by more resistant pathogens and an associated increased risk of death with antimicrobial use. In a before-after study of the effects of antibiotic rotation and restriction in a medical ICU, rates of VAP and antimicrobial-resistant organisms were decreased by a program that included restriction of ceftazidime and ciprofloxacin with concurrent review of all antimicrobial use⁽⁷⁵⁴⁾ suggesting that judicious antibiotic use that is reviewed on an ongoing basis may be an appropriate means of limiting rates of VAP as well as antimicrobial-resistant organisms.

3.3. Prophylactic antimicrobial therapy

Selective decontamination of the digestive tract:

The role of topical and/or systemic antimicrobials in the prevention of ICU-acquired pneumonia has been repeatedly evaluated. The strategy is known as selective decontamination of the digestive tract (SDD). The intent of the antimicrobial therapy is to eliminate colonizing organisms from the oropharynx and gut that may cause pneumonia following aspiration into the trachea. Systemic antibiotics theoretically prevent early

infections caused by organisms colonizing patients on admission, until the topical therapy is effective. Topical regimens usually consist of polymixin (colistin), amphotericin B, and an aminoglycoside (less commonly a quinolone) applied to the oral cavity and administered through a nasogastric tube (or orally in non-intubated patients). The topical agents have poor oral absorption and no anaerobic activity, and allow natural colonization resistance. The systemic agent has usually been cefotaxime or ceftriaxone for three days or more.

Results have been inconsistent and difficult to compare in more than 40 trials or meta-analyses⁽⁷⁵⁵⁻⁷⁸⁵⁾. Studies use different regimens (different drugs, oral therapy only, oral and systemic therapy, different durations of prophylaxis), patient populations, study methodologies, and sample size. Despite these discrepancies, two findings have been consistent. Oropharyngeal and upper gastrointestinal tract colonization with Gram-negative bacilli is less frequently seen in treated patients than in controls. Also, topical therapy with or without systemic agents lowers the risk of ICU-acquired pneumonia. The impact on mortality is less certain, most studies demonstrating no survivor benefit in treated patients. However, two meta-analyses have identified a protective effect of combined topical and systemic antimicrobials, one in surgical patients and the other in a mix of critically ill medical and surgical patients. The protective effect conferred was modest and suggests that 23 patients need to be treated to prevent one death. Selective decontamination of the digestive tract has not gained widespread use in North America because of concern with the development of antimicrobial resistance in units where this strategy would be used. While most of the trials have not found increased antimicrobial resistance, few studies have reported on the ecologic effects of the long term use of SDD. Infection or colonization with Gram-positive organisms tends to be more common in those receiving SDD, which has little impact on these bacteria. Finally, no study has determined whether SDD represents a cost-effective treatment.

Chlorhexidine oral rinse:

In one randomized clinical trial, patients undergoing heart surgery who received chlorhexidine oral rinses to decontaminate the oropharynx had a decreased rate of lower respiratory tract infection compared with patients receiving a placebo⁽⁷⁸⁶⁾. The mortality rate and use of intravenous antibiotics were also decreased among those receiving the chlorhexidine rinse without any change in antimicrobial resistance patterns. Although these data are promising, additional studies are required before chlorhexidine oral rinses can be recommended for nosocomial pneumonia prophylaxis⁽⁷⁸⁶⁾.

3.4. Oral hygiene

Implementation of comprehensive oral hygiene programs has been associated with a decrease in rates of pneumonia, including VAP, in two clinical studies, one in an ICU⁽⁷⁸⁷⁾ and another in a nursing home setting⁽⁷⁸⁸⁾. Oral hygiene programs consisted of frequent tooth brushing and mouth swabbing with an antiseptic agent; and in the ICU, frequent suctioning of the mouth and subglottic area of patients receiving mechanically assisted ventilation. On the basis of these studies, healthcare facilities should consider implementing such programs.

3.5. Stress bleeding prophylaxis

Bacterial colonization of the stomach in the pathogenesis of pneumonia is debated and may be less important than once thought^(116;614;621). Histamine-2 (H₂) blockers and antacids are frequently used in ICU patients to prevent the development of stress ulcers and bleeding. However, by raising intragastric pH these agents enhance colonization of the stomach by Gram-negative bacteria and may increase the risk of pneumonia^(616;789). The cytoprotective agent sucralfate, on the other hand, prevents stress ulcer bleeding without elevating gastric pH⁽⁷⁹⁰⁾. Evidence of the impact of antacids, H₂-blockers, and sucralfate on the development of pneumonia is conflicting. In an early trial comparing sucralfate with antacids and/or an H₂ blocker there was a trend towards fewer VAPs and lower mortality in the sucralfate group⁽⁶¹³⁾. In a randomized controlled study involving mechanically ventilated patients, sucralfate use was associated with a significant reduction in late onset pneumonia compared with ranitidine and antacids, but the incidence of early onset pneumonia was not different among the three regimens⁽⁷⁹¹⁾. Both the rate of VAP and mortality were lower in patients receiving sucralfate compared with antacids in another report⁽⁷⁹⁰⁾. Other studies, however, have found no difference between these agents or suggested that sucralfate was associated with an increased risk of VAP⁽⁷⁹²⁻⁷⁹⁴⁾. Additionally, a greater risk of gastrointestinal bleeding was reported in the sucralfate-treated patients in one study⁽⁷⁹³⁾. The balance of evidence suggests that the differences in risk of VAP may be small among the three classes of agents with no compelling evidence to use one over the other to reduce VAP.

4. Environment-related Risk Factors

4.1. Personnel

The hands of HCWs are continuously in contact with patients and their environments and are most at risk of contamination during patient care, with subsequent transfer of organisms between patients, to the HCW, and to environmental surfaces⁽¹⁸⁾. Gram-negative bacilli and *S. aureus* commonly colonize the hands of HCWs, although usually transiently⁽¹⁸⁾. On the basis of chronological evaluation and the similarity of strains assessed by molecular

type, Bergmans et al. reported that two of eight cases (25%) of VAP due to *P. aeruginosa* were likely the result of cross-colonization^(115;123). Frequent manipulation of respiratory therapy equipment and handling of contaminated ventilator condensate increase the likelihood of cross-colonization by means of the hands of HCWs⁽¹¹³⁾.

Hand hygiene before and after each patient contact is effective in removing transient bacteria and limiting transmission of microorganisms from HCWs to patients^(18;795). However, numerous observational studies conducted in a variety of healthcare settings have repeatedly reported poor compliance with recommended hand hygiene practice⁽¹⁸⁾. Impediments to hand washing include skin damage from frequent washing and inadequate access to sinks⁽⁷⁹⁶⁾. Compared with hand washing, alcohol-based hand rubs are less damaging to the skin, require less time for hand hygiene, and are effective at reducing microbial hand contamination unless hands are visibly soiled⁽⁷⁹⁷⁻⁷⁹⁹⁾. Feedback to HCWs about hand hygiene compliance can also improve hand hygiene practices and reduce infections^(800;801). Although not a substitute for hand hygiene, the appropriate use of gloves as recommended in current infection prevention and control guidelines may also reduce cross-contamination between patients⁽¹⁸⁾.

Immunization of healthcare personnel against influenza reduces the risk of infection in high-risk patients and outbreaks in healthcare facilities⁽⁸⁰²⁾. Acceptance of vaccine by personnel is often poor. Misinformation, fear of adverse reactions, and lack of motivation have been noted. Compliance is better when personnel are educated about the vaccine and when there is improved access to vaccination^(239;803;804).

4.2. Patients

The hospital environment includes patients with respiratory viral infections. Prevention of nosocomial viral infections requires additional precautions against contact and droplet transmission.

A variety of strategies have been used to decrease transmission of RSV, with variable success. Use of gowns and masks have been found to be ineffective in preventing RSV transmission to patients and personnel^(805;806), probably because these measures do not prevent hand contamination and eye inoculation. Infection rates among patients and personnel were decreased when personnel wore masks and goggles or face shields that covered the eyes and nose^(231;232). Since compliance with hand hygiene is frequently poor, use of gloves has been advocated. Use of gloves may also deter personnel from touching their eyes or nose during patient care. Such use has resulted in a decrease in RSV infection

when good compliance was achieved, through educational activities, active monitoring of compliance and feedback about RSV infection rates⁽²³⁰⁾. On the other hand, another study showed no decrease in infection rate with the use of gowns and gloves alone or with rapid screening for RSV and cohorting; however, infections were significantly reduced by a combination of screening and cohorting and use of gloves and gowns with the infected cohort⁽⁸⁰⁷⁾. An earlier study showed cohorting of infected patients was of some success in reducing infections in patients but not in personnel⁽⁸⁰⁸⁾. Cohorting of infected patients, along with use of gowns, gloves, and masks, and restriction of visitors, controlled the transmission of RSV in an NICU⁽⁸⁰⁹⁾. Admission screening of all children less than three years of age and others at risk of severe RSV disease with cohorting based on RSV result reduced the RSV infection rate considerably⁽³⁵³⁾. In another study, rapid screening of patients with respiratory symptoms and cohorting of RSV-infected patients, combined with education of personnel and parents, emphasis on hand hygiene, availability of alcohol-based hand rubs, and, where possible, assignment of personnel with respiratory symptoms to the infected cohort, resulted in a 66% decrease in nosocomial RSV infections⁽⁸¹⁰⁾.

An outbreak of parainfluenza infection in an NICU was controlled by cohorting and the use of gloves and gowns⁽²⁴⁴⁾. Cohorting, use of gloves, gowns, and masks or goggles, and exclusion of symptomatic staff have been used to control outbreaks of adenovirus infection^(250;252). Rapid diagnosis and cohorting with use of masks, gloves, and gowns limited the spread of an outbreak of influenza in an NICU⁽⁸¹¹⁾.

4.3. Physical environment

The hospital environment itself may increase the risk of nosocomial infection, particularly for the severely immunocompromised patient. This includes patients who have undergone HSCT or solid organ transplantation, oncology patients who are receiving chemotherapy, patients receiving dialysis, and patients taking immunosuppressive medication, including steroids. Healthcare facilities are undergoing construction and renovation to address restructuring in the healthcare system, the changing distribution of patient populations, and the aging of hospitals and other healthcare facilities⁽¹⁵⁶⁾. Environmental disturbances associated with construction projects pose airborne and waterborne risks for the large number of patients who are at risk of healthcare-associated opportunistic infections.

Several reports describe outbreaks of Legionnaires' disease related to inhalation of contaminated aerosols from respiratory equipment, room air humidifiers, showers, cooling towers, and aspiration of contaminated potable water^(145;147-150;154;158;171;174). Because *Legionella* is not spread from person to person, any institutionally acquired case indicates a probable environmental source and should prompt further investigation.

Two different approaches to the prevention of healthcare-associated Legionnaires' disease in healthcare facilities have been proposed. Some investigators have suggested routine environmental cultures of the water distribution system (hot- water tanks, and selected shower heads and faucets) to increase the index of suspicion for Legionnaires' disease in patients with healthcare-associated pneumonia^(148;160): if $\geq 30\%$ of environmental cultures are positive for *Legionella* spp., the facility's potable water system is decontaminated, but if the prevalence of contaminated sites is lower, disinfection of the water supply is not necessarily required. If *Legionella* is isolated, prospective surveillance for nosocomial Legionnaires' disease is undertaken. On the other hand, because of the high prevalence of *Legionella* in water distribution systems in healthcare facilities and the high costs of environmental surveillance and eradication of *Legionella* from environmental sources, the CDC and others have advocated investigation for a facility source of *Legionella* spp., only upon identification of nosocomial cases⁽³⁰⁾.

Aspergillus spores are found universally in unfiltered air and survive well in air, dust, and moisture^(156;204). The presence of *Aspergillus* spp. in the healthcare environment is the most important extrinsic risk factor for invasive aspergillosis⁽²⁰⁴⁾. Construction, renovation, and repair projects disturb dust particles contaminated with bacteria and fungi, and produce bursts of airborne fungal spores. Increased levels of dust and fungal spores have been associated with clusters of nosocomial cases of invasive aspergillosis in immunocompromised patients, particularly those who are granulocytopenic^(205;211;652). Outbreaks, clusters, and case series of nosocomial aspergillosis have also been associated with environmental sources that include wet fire-proofing material, contaminated bird droppings in air ducts, contaminated air-conditioning and air handling units, and the soil of indoor plants⁽²⁰³⁾. Hospital water has also been suggested as a possible reservoir for potential transmission of an *Aspergillus*⁽²⁰⁶⁾. Sherertz and colleagues found that the risk of nosocomial *Aspergillus* infection in HSCT recipients could be eliminated by using high-efficiency particulate air (HEPA) filters with horizontal laminar flow⁽²¹²⁾. Prevention measures during periods of hospital construction, renovation, and repair should be aimed at minimizing fungal spore counts by using HEPA filtration with > 12 air changes per hour and taking optimal precautions, as outlined in published guidelines^(156;204).

A.6. Surveillance for Healthcare-Associated Pneumonia

I. Introduction

Surveillance is defined as “the ongoing, systematic collection, analysis, and interpretation of health data essential to the planning, implementation, and evaluation of public health practice, closely integrated with the timely dissemination of these data to those who need to know”⁽⁸¹²⁾. The most important purpose of infection surveillance is to prevent healthcare-associated infections. Surveillance of healthcare-associated infections provides useful data for identifying infected patients and factors that predispose to such infections. Surveillance data also allow the evaluation of the efficacy of interventions. In addition, surveillance permits early detection of clusters or trends of infection⁽⁸¹³⁾. For more than 30 years, nosocomial infection surveillance has been the foundation on which performance improvement and infection prevention and control strategies have been built^(814;815).

The components of surveillance for healthcare-associated pneumonia in any healthcare setting are to systematically collect relevant data for a specified purpose during a defined time period, manage and organize the data, analyze and interpret the data, and communicate the results to those empowered to make beneficial changes⁽⁸¹⁶⁾. Surveillance should enable infection prevention and control personnel to identify new problems quickly and to intervene immediately after they determine the probable causes.

Each healthcare organization serves different types of patients with varied risks for healthcare-associated pneumonia. The type, method, and specific goals of surveillance should be tailored to the care setting (e.g., acute care, long-term care, ambulatory or home care) and based on the types of infections most common to the care or services provided and the population served⁽¹⁰⁾. To determine whether infection surveillance is indicated, the target population should be assessed for risk of infection. A patient’s predisposition to infection is strongly influenced by personal characteristics and exposures. These risk factors are broadly divided into two categories: intrinsic (e.g., severity of illness) and extrinsic (e.g., degree of exposure to devices)⁽⁸¹⁷⁾.

Changes in healthcare systems have affected the collection of surveillance data. Finding infections has become even more challenging because of shortened hospital stays and increased care delivery in the outpatient setting. Innovative approaches to surveillance are needed to meet these challenges.

II. Efficacy and Cost-Benefit

Evidence that surveillance improves patient outcomes was demonstrated in the landmark SENIC project⁽⁸¹⁸⁾. SENIC found that hospitals with the lowest nosocomial infection rates had strong surveillance and prevention programs. In 2000, the NNIS system reported findings that support the benefits of surveillance: during the period 1990-1999, risk-adjusted infection rates decreased for all three body sites (i.e., respiratory tract, urinary tract, and bloodstream) monitored in ICUs in selected hospitals⁽⁸¹⁹⁾.

With a focus on improving quality and reducing costs, today's healthcare systems have increased their attention to activities that accurately measure and report outcomes. An epidemiologically sound surveillance program can be cost-effective by reducing the level of acute disease⁽⁸¹⁵⁾. An active surveillance program for influenza or RSV-like illness can help identify healthcare-associated infections early in their course and prevent spread to other patients and healthcare personnel. Studies have demonstrated the cost-benefit of surveillance programs to prevent the nosocomial transmission of RSV⁽³⁵²⁾ and to reduce VAP⁽⁸²⁰⁾. Kelleghan and colleagues evaluated the ability of a surveillance program to reduce VAP in an ICU. After measuring the existing infection rate, several simple interventions were implemented, including increased surveillance with periodic feedback of infection rates to HCWs. The ICU's policies to prevent NP were reviewed, staff hand hygiene practices and compliance were evaluated, and an educational program was developed and presented for ICU personnel. As a result of these efforts, the rate of VAP declined by 57% with an estimated annual cost saving of \$105,000.00 US to the facility.

III. Surveillance in Acute Care Facilities

1. Surveillance Methods

Infection prevention and control practitioners should choose highly sensitive methods for case-finding, so that they will miss few important cases. However, they also should refine surveillance to increase specificity and thereby reduce time wasted collecting irrelevant data. A surveillance project's sensitivity and specificity can be determined by examining a random subset of medical records for a defined period and comparing the number of events identified by this review with those identified by the usual surveillance system⁽⁸¹⁶⁾.

Surveillance or "case-finding" for infection may be accomplished by passive or active means. In passive surveillance, persons who do not have a primary surveillance role, that is, persons other than infection prevention and control practitioners (ICPs), are relied on for identification and reporting of infections.

For example, forms might be completed by physicians or nurses when a nosocomial infection is detected. Problems associated with passive surveillance include misclassification, under-reporting, and lack of timeliness of data. Active surveillance is the process of vigorously looking for nosocomial infections using trained personnel, nearly always ICPs, to seek out nosocomial infections by using various data sources (e.g., patient's chart, laboratory culture reports, Kardexes, antibiotic administration sheets, conversations with patient care staff, etc.). ICPs who regularly visit clinical wards can gain excellent information about patients, infections, and other adverse events. This method allows the ICP to be highly visible in patient care areas, to observe infection prevention and control practices directly, and to talk with HCWs caring for patients⁽⁸¹⁶⁾.

Hospital-wide surveillance provides a global view of what is happening in the hospital, so that potential clusters of infection or antimicrobial resistance can be detected anywhere. It does, however, require considerable time and personnel resources, and may not be driven by clear objectives for prevention. Furthermore, denominators that adjust for case mix are not available for calculating risk-adjusted infection rates for different units⁽⁸²¹⁾. There are two types of hospital-wide surveillance: incidence and prevalence. Incidence surveillance is continual monitoring of all patients for new nosocomial infections of all kinds on the wards. Prevalence surveillance is surveillance for all active (existing and new) nosocomial infections in the hospital on a single day (point prevalence) or over several days (period prevalence). The advantage of prevalence surveillance is that it is a rapid, inexpensive way to estimate the magnitude of nosocomial infection problems in the hospital⁽⁸¹³⁾.

Targeted surveillance focuses on detecting nosocomial infections occurring in one area of the hospital. Of all the surveillance strategies, targeted surveillance is the most commonly used⁽⁸¹⁵⁾. This ensures that surveillance resources are allocated to monitoring outcomes that have a recognized impact on morbidity, mortality, length of stay, and cost of care^(821;822). The widespread use of tracheal intubation and mechanical ventilation to support the critically ill has defined an expanding group of patients who are at particularly high risk of healthcare-associated pneumonia^(38;39). Therefore, intubated adult and pediatric patients in intensive care should be a focus of surveillance for nosocomial pneumonia^(816;817). Other high-risk populations and/or areas that may be targeted for surveillance include immunosuppressed patients, select postoperative patients (e.g., thoracoabdominal surgery), and those on neurology/neurosurgery units and trauma units.

Targeted surveillance may also focus on a specific disease, organism, or outbreak. Examples include programs attempting to reduce the transmission of specific organisms such as influenza⁽⁸²³⁾ and RSV^(352;824). On general pediatric wards, surveillance for viral respiratory infections may be performed during seasons of high prevalence in the community⁽⁸²⁵⁾. Organism-specific surveillance is indicated for certain rare, but serious, nosocomial infections (e.g., *Legionella*) and for AROs.

Because of growing support for the evaluation of processes of care in a rational and organized manner, infection prevention and control programs that have largely been based on outcome measurement are being challenged to begin incorporating process surveillance into the overall monitoring system. A process is the series of steps taken to achieve an outcome. Process surveillance is the consistent and quantitative monitoring of practices that directly or indirectly contribute to a health outcome and the use of those data to improve outcomes⁽⁸²⁶⁾. Processes included in a surveillance plan should always be outcome driven and should be those that have the most important impact on the population served⁽⁸²⁷⁾. Monitoring of the annual influenza vaccination participation rate of HCWs is one example of process surveillance. The rationale to monitor this process is that vaccination for influenza is recognized as the single most effective way of preventing or attenuating influenza for those at high risk of serious illness or death from influenza infection or related complications^(700;802).

2. Definition of Nosocomial Pneumonia

For any surveillance, all data elements should be clearly defined. Valid definitions will enhance consistency, accuracy, and the reproducibility of surveillance information⁽⁸²⁷⁾. For calculating incidence rates, one should use a definition applicable to all patients over prolonged periods. Infection prevention and control personnel should be able to make the diagnosis according to commonly available clinical and laboratory findings⁽²⁹⁸⁾. Population-based surveillance for healthcare-associated pneumonia requires both a numerator (the infection) and denominator (number of patients or days of exposure to the risk)⁽⁸²¹⁾.

For the numerator, accurate and consistent case finding of NP in the population under study is needed. Accurate, validated, and easily applied definitions for case finding are important. Use of uniform written definitions is critical if data from one hospital are to be compared with those of another hospital or with an aggregated database (such as the NNIS system)^(298;821).

Nosocomial pneumonia must not be present or incubating at the time of admission to the hospital. Thus, most surveillance criteria include pneumonia developing 48-72 hours or more after admission. NP may also develop after discharge from the hospital.

Nosocomial pneumonia, particularly VAP, is difficult to define. Many of the clinical findings observed in VAP are also found in the non-infectious pulmonary complications seen in critically ill patients. In this guideline, VAP is defined as pneumonia in persons who had a device to assist or control respiration continuously through a tracheostomy or by endotracheal intubation within the 48 hour period before the onset of infection⁽²⁹⁸⁾. The CDC definitions of NP have been widely used for surveillance. These rely predominantly on clinical and radiographic criteria, although the results of other diagnostic tests may also be used. They have not been rigorously evaluated for their validity. To improve specificity, CDC definitions for nosocomial pneumonia were revised in 2004⁽²⁹⁸⁾. For consistency, physician diagnosis *alone* is no longer an acceptable criterion for NP. When assessing a patient for the presence of pneumonia, it is important to distinguish pneumonia from other disease entities or changes in clinical status, such as myocardial infarction, congestive heart failure, acute respiratory distress syndrome, pulmonary embolism, atelectasis, malignancy, or hyaline membrane disease in neonates. The clinical criteria for nosocomial pneumonia include fever, cough, and development of purulent sputum, in combination with radiologic evidence of a new or progressive pulmonary infiltrate, a suggestive Gram's stain, and positive cultures of sputum, tracheal aspirate, pleural fluid, or blood. Although clinical criteria together with cultures of tracheal specimens are sensitive for bacterial pathogens, they are not specific, especially in patients with mechanically assisted ventilation⁽⁸¹⁷⁾.

3. Data Collection

Three categories of data make up the usual information collected on a patient with NP: demographic, clinical, and laboratory. Information describing important risk factors for pneumonia (e.g., ventilation) should also be collected. Additional risk factors for infection may be collected, but only if they will be analyzed and used. Laboratory data include the pathogens isolated.

The denominator data represent the patients at risk of acquiring infection. For comparative purposes the traditional denominators of numbers of patients admitted to or discharged from the hospital, ward, or service have largely been replaced by those that better account for differences in the risks, such as number of days of device exposure (e.g., ventilator-associated pneumonia rates per 1000 ventilator-days in a specific type of ICU)⁽⁸²¹⁾.

4. Defining and Calculating Nosocomial Pneumonia Infection Rates

A rate is an expression of the occurrence of an event. The time period must be specified and be identical for the numerator and denominator. The period chosen for surveillance of nosocomial pneumonia needs to be large enough for an adequate estimation of a hospital's infection rate and usually varies depending on the number of occupied beds in a hospital. Three kinds of rates are used in surveillance: incidence, prevalence, and incidence density.

Incidence is the number of new cases of disease that occur in a defined population during a specified period. The incidence of NP is the number of new nosocomial infections in a given period divided by the number of patients at risk during that period.

Prevalence is the total number of active (existing and new) cases of the disease in a defined population, either during a specified period (period prevalence) or at a specified point in time (point prevalence). The prevalence rate is calculated by dividing the number of active nosocomial infections by the number of patients surveyed.

Incidence density (or incidence rate) is measured in units of the number of cases of disease per unit of time. An example of an incidence density that is commonly used in hospitals is the number of NPs per 1000 ventilator-days. Incidence density is useful when the infection rate varies in a linear fashion with the length of time a patient is exposed to a risk factor (i.e., the longer a patient is exposed, the greater the chance of acquiring an infection). For example:

$$\frac{\# \text{ ventilator-associated pneumonia} \quad \times 1000}{\# \text{ ventilator-days}}$$

To compare an infection rate among patient groups within a hospital, over time, or across hospitals the rate should be adjusted for the variations in the major risk factors that lead to the infection^(821;828). Therefore, it is important to adjust nosocomial pneumonia risk for the use of a ventilator, the major risk factor for NP^(38;39). In addition, in NICU patients it is important to stratify the nosocomial pneumonia infection rate by categories of birth weight (i.e., $\leq 1,000$ g, 1001-1500 g, 1501-2500 g, > 2500 g) to control for the differential risk of infection in infants of different birth weights.

Surveillance of homogenous populations, controlling for the most important confounding variables, results in calculation of infection rates that are more valid for comparison⁽⁸²¹⁾. Studies of nosocomial infection rates in NICUs and PICUs have shown that the rates are different between these units^(40;591) and different from those of adult medical or surgical ICUs^(37;591), and thus should be reported individually and not be combined with other units.

Infection rates may be useful in assessing trends over time in a specific institution if the patient population under surveillance has not changed significantly over time. Otherwise, inter and intrahospital comparison of infection rates should be made cautiously and with an understanding of the limitations of these rates⁽⁸²¹⁾. Factors that can account for differences in NP rates include different surveillance definitions or techniques, inaccurate or insufficient information about clinical or laboratory evidence of infections in the patient's medical record, and lack of adjustment for the patient's intrinsic risks of infection (e.g., a hospital with a large proportion of immunocompromised patients would be expected to have a population at higher intrinsic risk of infection than a hospital without such a population of patients).

IV. Surveillance in Long-Term Care Facilities

The feasibility of routine surveillance in LTCFs has been demonstrated, and data have been used to provide a basis for continuing education⁽⁸²⁹⁾. Surveillance data are used primarily to plan control activities and educational programs and to prevent epidemics, but surveillance may also detect infections that require therapeutic action. In LTCFs, active surveillance for influenza can help identify facility-acquired cases of influenza. Before the influenza season, HCWs should be trained to recognize influenza illness and made aware of the available mechanisms for reporting patients with suspected influenza to those in charge of infection prevention and control⁽³⁰⁾. More data on rates, risk factors, and management of infections in residents of such facilities are needed for optimal quality of resident care and cost-effectiveness of infection prevention and control programs⁽⁸³⁰⁾. Surveillance needs to be simple and pragmatic, particularly because infection prevention and control personnel may be able to spend only a few hours per week on these activities^(10;831). Focused or high-risk resident surveillance (e.g., aspiration pneumonia in residents receiving tube feedings) may permit conservation of resources⁽⁸³¹⁾.

1. Definition of Healthcare-Associated Pneumonia in Long-Term Care

There are no standard surveillance definitions for respiratory infection in long-term care. Standard definitions for use in acute care hospitals are very dependent on laboratory and radiologic data, as well as recorded clinical observations. In the LTCF, radiology and microbiology data are less available, and written physician notes and nursing assessments in the medical record are usually brief. Compounding the difficulty in diagnosing pneumonia is the fact that pneumonia in the elderly often presents with atypical symptoms. Most LTCF residents with bacterial pneumonia do not have fever, a productive cough, or signs of consolidation on physical examination⁽⁹⁰⁾.

LTCF-specific definitions for surveillance, including criteria for healthcare-associated respiratory tract infection, have been developed for use and may be modified for the facility⁽⁸³⁰⁾. These definitions have been adapted to address some of the unique limitations of nursing home surveillance previously mentioned. The diagnosis of pneumonia requires chest radiographic findings of pneumonia with at least two of the following signs and symptoms of lower respiratory tract infection: cough, sputum production, fever (temperature of $\geq 37.8^{\circ}\text{C}$ or temperature $> 1.5^{\circ}\text{C}$ higher than baseline), pleuritic chest pain, physical findings on chest examination, worsening mental or functional status, increased shortness of breath, and a respiratory rate of ≥ 25 per minute. In addition, three important conditions should apply:

- All symptoms must be new or acutely worse.
- Non-infectious causes should always be considered before a diagnosis of infection is made.
- Identification of infection should not be based on a single piece of evidence.

Microbiologic and radiologic findings should be used only to confirm clinical evidence of infection. Similarly, physician diagnosis should be accompanied by compatible signs and symptoms of infection.

2. Data Collection

For the typical LTCF, prospective data collection for healthcare-associated pneumonia would appear to be ideal to provide more timely data for detection of epidemics and to maximize opportunities for informal education during surveillance⁽⁸³²⁾. One recommended method is “walking rounds” on at least a weekly basis⁽⁸³³⁾. During rounds, staff responsible for infection prevention and control may use house reports from nursing staff, chart review, laboratory or radiology reports, treatment review, and clinical observations as sources of information⁽⁸³¹⁾.

3. Calculation of Infection Rates

Calculation of site-specific (e.g., healthcare-associated pneumonia) infection rates provides the most accurate information to establish baseline infection rates, track progress, determine trends, and detect outbreaks⁽⁸³¹⁾. Data presented in terms of incidence rates (e.g., the number of infections per 1000 resident care days) are preferred⁽⁸³¹⁾. Rates may be calculated by using resident days or average resident census for the surveillance period (such as month, quarter, or year) as the denominator:

$$\frac{\text{\# new healthcare-associated pneumonia cases} \quad \times 1000}{\text{\# resident days in the month (e.g., days in the month} \times \text{average census for the month)}}$$

The average daily census is not an accurate denominator for hospitals; however, it can be used by LTCFs, because the facility is usually full, and resident turnover is less than in acute care facilities.

To compare rates within a facility or between facilities, the method of calculating rates must be identical (including the denominator). Even when calculation methods are consistent, infection rates may vary between facilities because of differences in resident risk factors and disease severity, and comparisons may not be valid⁽⁸²¹⁾.

To date, published studies of LTCF pneumonia rates have not adequately accounted for specific risk factors (e.g., device use) that would permit appropriate risk stratification of infection rates.

V. Surveillance in Home Care

There is a need for surveillance and reporting of infections associated with delivery of health care in the home, because patients may develop infections in these settings and there are no comprehensive data on risks associated with care in the home^(10;834). The purpose of surveillance in home health is to^(835;836)

- establish a baseline rate of infection
- monitor trends over time to improve infection control practices
- evaluate specific control measures
- tailor staff and patient/caregiver education related to prevention of infection
- identify possible outbreaks.

Targeted surveillance of high-risk procedures or devices (e.g., studies of pneumonia in ventilated patients) can be performed to focus prevention and control efforts^(544;836). Without surveillance, it would be very difficult for home care providers to know whether problems are occurring and whether high-quality care is being provided.

1. Definition of Home Healthcare-Associated Pneumonia

Home healthcare-associated infections refer to infections that develop in patients that were neither present nor incubating at the time the patient began receiving home health care (generally, 48-72 hours after the start of care, but this may vary according to the incubation of the infecting pathogen). An infection that develops in a patient who has been receiving home health care and is subsequently admitted to a healthcare facility may be considered a home healthcare-associated infection if the infection was incubating at the time of discharge from home health care⁽⁸³⁵⁾.

No standardized definitions exist for monitoring infections in the home care setting. Definitions of healthcare-associated infections widely accepted as standard definitions in the hospital⁽²⁹⁸⁾ and in long-term care facilities⁽⁸³⁰⁾ have been used as a reference to develop draft definitions that are relevant in home care^(835;837). These definitions take into account the information routinely available in this setting. The criteria for home healthcare-associated lower respiratory tract infections and/or pneumonia include combinations of clinical findings and the results of laboratory and other diagnostic tests. Because laboratory testing and radiologic procedures are performed less frequently in home health care, clinical observations by home healthcare providers are often relied on to assess changes in the patient's status⁽⁸³⁵⁾.

The evaluation of a suspected infection should include consideration of whether the symptoms are new or acutely worse than the established baseline. Non-infectious causes should also be considered.

Physician diagnosis should be accompanied by compatible signs and symptoms of infection. Laboratory reports alone are not used to define infection but may be used adjunctively as supportive evidence to confirm infection⁽⁸³⁵⁾.

2. Data Collection

Home care surveillance poses several unique challenges, including lack of standard surveillance methods, loss of patient follow-up, lack of trained infection prevention and control personnel in home care settings, difficulty in capturing clinical and laboratory data, and difficulty in obtaining numerator and denominator data⁽⁸³⁴⁾. Despite these limitations, strategies for developing and implementing effective surveillance systems, including methods for collection, analysis, and interpretation of data, have been published^(10;544;696;836-840).

3. Calculation of Infection Rates

Simply reporting the number of cases of pneumonia is not useful, as this number does not take into consideration the population at risk. Therefore, incidence rates for healthcare-associated pneumonia related to home care should be calculated⁽⁸³⁶⁾. Incidence rates are developed by using both the numerator (number of infections) as well as a denominator (number of patients at risk or number of days of exposure). For example, to calculate the cumulative incidence rate for postoperative pneumonia, the numerator would be the number of cases of pneumonia; the denominator would be the number of postoperative patients cared for during the surveillance period.

$$\frac{\text{\# new cases during surveillance period}}{\text{total population at risk}} \times 100$$

In calculating the incidence density of ventilator-related pneumonia, the numerator is also the number of cases. However the denominator is the number of days at risk for all patients receiving ventilator care.

$$\frac{\text{\# new cases during surveillance period}}{\text{total days at risk}} \times 1000$$

VI. Surveillance in Ambulatory Care

Given the nature of the procedures and the limitations of surveillance systems, healthcare-associated pneumonia associated with endoscopy and other procedures in the ambulatory care setting are difficult to identify unless they occur in clusters⁽⁵⁸⁾. Implementation of a surveillance system for infection is recommended for this care setting⁽¹⁰⁾. To date,

surveillance efforts in ambulatory care have focused primarily on detection of surgical site and bloodstream infections following high-volume, high-risk procedures, such as surgery and infusion therapy^(10;684).

VII. Surveillance and Quality Improvement

Although many terms have been used to describe quality initiatives in the past decade (quality assurance, quality monitoring, continuous quality improvement), the equivalent term used in hospital epidemiology has remained unchanged – *surveillance*. Effective infection surveillance and quality improvement programs are those that use data for evaluating and improving clinical processes and outcomes⁽⁸⁴¹⁾.

Several studies describe successful efforts to prevent VAP^(820;842-847). In every report, surveillance is used to measure performance, and other important quality improvement concepts are implemented. While specific interventions varied, the process was similar:

- VAP rates were reviewed and compared with external benchmarks. Prospective surveillance was continued after interventions had been introduced, and post-intervention data were compared with baseline infection data^(820;842;843;846).
- Multidisciplinary teams with diverse representation (e.g., hospital epidemiologist, surgical and medical intensivists, respirologist, infection prevention and control practitioner, ICU nursing and respiratory therapy staff, nursing education, pharmacist) were formed to identify best care practices supported by research and published guidelines and to evaluate current practices^(820;842-846). Teams also helped formulate interventions and discussed these with their respective disciplines.
- Educational activities were used to introduce and provide training on the interventions that were identified. These activities included training for nurses and other ICU staff, multidisciplinary ICU rounds, self-education study packets, nursing and physician grand rounds, and teaching lectures^(820;842;845).
- After the interventions had been introduced, hospitals disseminated data to their staff describing the impact of the interventions on nosocomial infection rates. Data included comparison of hospital infection rates with national and international benchmarks, intrahospital rates over time, and rates of compliance with interventions^(820;842;846).

These reports effectively demonstrate that infection prevention and control programs can significantly reduce endemic rates of nosocomial VAP through surveillance, quality improvement methods, and multidisciplinary interventions, with standard infection control procedures used for improvement. Collaboration among physicians, nurses, infection prevention and control personnel, and other professionals was the driving force for these improvement efforts.

In any healthcare setting, demonstrating the value of surveillance data to both the organization's patient care personnel and administration is essential. However, it is most important that patient care personnel perceive value in the data; if they do, they will rely on the data for decisions and alter their behaviour in ways that should reduce the incidence of healthcare-associated infections. By changing the behavior of caregivers, surveillance of healthcare-associated infections can improve the quality of patient care⁽⁸²⁸⁾.

Part B Recommendations for the Prevention of Healthcare-Associated Pneumonia

B.1. Administrative Recommendations for All Healthcare Settings

- a. Healthcare facilities and organizations providing patient/resident/client care should have policies and procedures for the prevention of healthcare-associated pneumonia⁽⁸⁴⁷⁻⁸⁴⁹⁾.
AII

- b. Healthcare facilities should have an infection prevention and control program^(70;818;819;850).
AII

- c. Healthcare facilities should have sufficient numbers of qualified infection control (IC) personnel to support the infection prevention and control program^(55;818;851).
AII

- d. Healthcare facilities should have a sufficient number of qualified personnel to provide patient care in a manner that prevents cross-transmission of infection^(19-21;852).
AII

- e. Healthcare organizations should have access to qualified infection prevention and control physician/doctoral consultants^(55;818).
BIII

- f. Healthcare facilities and organizations should have formal quality assurance processes to evaluate the effectiveness of their policies and procedures in preventing healthcare-associated pneumonia^(843;846).
BII

- g. Healthcare facilities should have rapid access to the laboratory services necessary for diagnosis of pneumonia^(824;853).
AII

- h. Healthcare workers and healthcare providers who have direct patient / resident / client contact should receive annual influenza immunization^(700;802).
AI-AIII

i. Healthcare workers with acute respiratory infections should have minimal contact with patients^(199;241).

AI I

j. Individuals with acute respiratory infections should not visit healthcare facilities unless the visit is essential^(18;700).

AI I I

B.2. Recommendations to Prevent Cross-Transmission

I. General Recommendations for All Healthcare Settings

1. Education

The increasing complexity of patient, client, and resident care and the increasing severity of illness of patients and clients in all healthcare settings necessitate increasing awareness of the appropriate infection prevention and control measures and how to apply them.

1.1. HCWs and home care providers (HCPs)

a. Continuing education should be provided to all HCWs and HCPs consistent with their work environment (e.g., patient care, administration, engineering services, housekeeping) and responsibility level within the facility and/or organization regarding the following^(10;18;543;555;800;801;848;854;855):

- routine practices and additional precautions for preventing the transmission of infections in health care
- epidemiology of healthcare-associated pneumonia, specific to the work setting
- modes of transmission of specific microbial agents responsible for healthcare-associated pneumonia
- specific measures and procedures to prevent and control healthcare-associated pneumonia
- the importance of compliance with infection control practices and procedures to prevent and control healthcare-associated pneumonia.

AI I

b. Education and training programs for different learner groups should be evaluated to ensure that workers have the appropriate knowledge and skill to implement and comply with the recommended measures and procedures to prevent healthcare-associated pneumonia^(555;854).

AI I

- c. Healthcare workers and home care providers should regularly undergo assessment of their competency in the skills required to prevent the transmission of infections in health care⁽⁵⁵⁵⁾.

BIII

1.2. Patient, resident, client, and informal caregiver teaching

- a. Patients, clients, residents, and their families should understand the nature of any infectious diseases they may have, the precautions being used, and how to prevent the transmission of infection to family and friends. Patients, residents, and clients should also understand the importance of compliance with infection prevention and control procedures for self-care, along with the cleaning and disinfection of personal equipment, when responsible for these activities in the home or in the facility.

BIII

2. Healthcare Worker Practices

2.1. Routine practices

Hand hygiene

- a. Hand hygiene should be performed according to the *Infection Control Guideline: Hand Washing, Cleaning, Disinfection and Sterilization in Health Care*⁽¹⁸⁾ and *Infection Control Guidelines: Routine Practices and Additional Precautions for Preventing the Transmission of Infection in Health Care*⁽¹⁸⁾
- after any direct contact with a patient/resident/client and before contact with the next patient/resident/client
 - before performing invasive procedures
 - before caring for patients in ICUs and for immunocompromised patients
 - after contact with blood, body fluids, secretions, excretions, and exudates from wounds
 - after contact with items known or likely to be contaminated with blood, body fluids, secretions, or excretions (e.g., suction catheters, mechanical ventilator circuit or any of its components, or condensate)
 - immediately after removing gloves
 - between certain procedures on the same patient, resident, or client when soiling of hands is likely, to avoid cross-contamination of body sites
 - before preparing, handling, serving or eating food, and before feeding a patient
 - when hands are visibly soiled
 - after personal use of toilet or wiping nose.

AI I

b. Patients/residents/clients and family members should be instructed in proper hand hygiene⁽⁸¹⁰⁾.

BIII

c. In settings where patient hygiene is poor, patients/residents/clients should have their hands washed. Patients/residents/clients should be helped to wash their hands before eating, after toileting, and when soiled.

BIII

d. Plain soap may be used for routine hand washing⁽¹⁸⁾.

BII

e. Hand antiseptics with an antiseptic soap or hand rinse is indicated:

- before performing invasive procedures
- before contact with immunocompromised patients and patients with extensive skin damage
- before contact with percutaneously implanted devices.

BIII

f. Waterless, antiseptic hand rinses are superior to soap and water in reducing hand contamination and should be made available as an alternative to hand washing.

AI

When there is visible soiling, hands should be washed with soap and water before using waterless antiseptic hand rinses. If soap and water are unavailable, cleanse hands first with detergent-containing towelettes⁽¹⁸⁾.

BIII

For further information and recommendations on hand hygiene refer to *Infection Control Guidelines: Routine Practices and Additional Precautions for Preventing the Transmission of Infection in Health Care* and *Infection Control Guideline: Hand Washing, Cleaning, Disinfection and Sterilization in Health Care*⁽¹⁸⁾.

Gloves⁽¹⁸⁾

a. Gloves should be used as an additional protective measure, not as a substitute for hand hygiene⁽⁸⁵⁶⁾.

BII

b. Gloves are not required for routine patient care activities in which contact is limited to a patient's intact skin.

BIII

c. Clean, non-sterile gloves should be worn as follows:

- for contact with blood, body fluids, secretions and excretions, mucous membranes, draining wounds, or non-intact skin (open skin lesions or exudative rash)
- for handling items visibly soiled with blood, body fluids, secretions or excretions
- when the HCW has open skin lesions on the hands.

AII

d. When indicated, gloves should be put on directly before contact with the patient/resident/client or just before the task or procedure requiring gloves⁽⁸⁵⁷⁾.

AII

e. Gloves should be changed between care activities or procedures with the same patient/resident/client and after contact with materials that may contain high concentrations of microorganisms, e.g., suctioning an endotracheal tube⁽⁸⁵⁷⁾.

BIII

f. Gloves should be removed immediately after completion of care or a specific task, at point of use, and before touching clean environmental surfaces⁽⁸⁵⁷⁾.

AIII

g. Hand hygiene should be performed immediately after removing gloves^(856;857).

AII

h. Single-use disposable gloves should not be reused or washed⁽⁸⁵⁶⁾.

AII

Gowns⁽¹⁸⁾

a. The routine use of gowns is not recommended.

AI

b. Gowns should be used to protect uncovered skin and prevent soiling of clothing during procedures and care activities likely to generate splashes or sprays of blood, body fluids, secretions, or excretions.

BIII

Mask, eye protection, face shield⁽¹⁸⁾

a. Masks and eye protection or face shields should be worn where appropriate to protect the mucous membranes of the eyes, nose, and mouth during procedures and patient care activities likely to generate splashes or sprays of blood, body fluids, secretions, or excretions, or when there is the potential for exposure to respiratory secretions from the coughing patient/resident/client.

BIII

2.2. Additional precautions

In certain circumstances, additional precautions as well as routine practices are necessary for the prevention of transmission of certain pathogens or clinical presentations. These additional precautions are determined by the specific mode(s) of transmission. Microbial agents causing healthcare-associated respiratory tract infections may be transmitted by droplets (e.g., pertussis) and/or by direct or indirect contact (e.g., RSV and SARS-coronavirus). Additional precautions may also be necessary for patients, residents, or clients with epidemiologically important microorganisms, e.g., MRSA, transmitted by direct or indirect contact. The degree of risk of infection varies in each healthcare setting. Practices are tailored to the level of care being provided and the inherent risk to the individual and the population if transmission occurs. Additional precautions should be taken on the basis of clinical presentation. To prevent the transmission of all respiratory infections in healthcare settings, respiratory hygiene/cough etiquette procedures should be implemented at the first point of contact with a potentially infected person⁽²⁶³⁾.

For further information and recommendations on routine practices and additional precautions; hand hygiene; the use of gloves, gowns, masks, and eye protection in specific healthcare settings; respiratory hygiene/cough etiquette in healthcare settings; and prevention of occupationally transmitted infections in the HCW, refer to *Infection Control Guidelines: Routine Practices and Additional Precautions for Preventing the Transmission of Infection in Health Care*, *Infection Control Guidelines: Hand Washing, Cleaning, Disinfection and Sterilization in Health Care*⁽¹⁸⁾, *Infection Control Guidelines: Preventing the Transmission of Blood borne Pathogens in Health Care and Public Services Settings*⁽⁸⁵⁸⁾, *Guidelines for Preventing the Transmission of Tuberculosis in Canadian Health Care Facilities and Other Institutional Settings*⁽⁴⁸⁸⁾, *Febrile Respiratory Illness (Ministry of Health and Long Term Care of Ontario)*, *Respiratory Hygiene/Cough Etiquette in Healthcare Settings*⁽²⁶³⁾, and *Infection Control Guidelines: Prevention and Control of Occupational Infections in Health Care*⁽²⁰¹⁾.

II. Specific Recommendations for Acute Care Facilities

1. *Bordetella pertussis*

1.1. Management of the patient with confirmed or suspected pertussis

a. In addition to routine practices, patients with laboratory-confirmed or suspected pertussis should be managed with droplet precautions, as detailed in *Infection Control Guidelines: Routine Practices and Additional Precautions for Preventing the Transmission of Infection in Health Care*^(18;196-198).

AII

b. In an outbreak, a patient with a laboratory-confirmed pertussis infection who is known not to have any other respiratory infection may be cohorted in a room with other patients with laboratory-confirmed pertussis until after completion of the first five days of a full course of antimicrobial treatment or, if untreated, until the end of the period of communicability (21 days after the onset of cough)⁽¹⁸⁾.

AIII

c. Diagnostic laboratory tests for confirmation or exclusion of pertussis should be immediately performed on patients who are admitted with, or develop symptoms of, pertussis to facilitate timely, appropriate infection control precautions. Rapid screening tests should be used when available^(196;197;202).

BIII

1.2. Contact follow-up

- a. If exposure of an individual to a confirmed case of pertussis occurs in the healthcare setting, IC in collaboration with occupational health (OH) should assess the communicability of the source and evaluate the extent of the exposure. Those exposed should be monitored for symptoms of pertussis and referred for clinical management, which should include laboratory investigation and chemoprophylaxis^(18;193;198;201;202). For further details, refer to *Infection Control Guidelines: Routine Practices and Additional Precautions for Preventing the Transmission of Infection in Health Care*⁽¹⁸⁾ and *Infection Control Guidelines: Prevention and Control of Occupational Infections in Health Care*⁽²⁰¹⁾.

AIII

- b. Surveillance for secondary cases should be performed⁽¹⁹³⁾.

AIII

1.3. Vaccination of HCWs for primary prevention of pertussis

- a. For adults who have not previously received a dose of acellular vaccine, it is recommended that a single diphtheria-tetanus booster dose be replaced by the combined diphtheria-tetanus-acellular pertussis vaccine⁽⁷⁰¹⁾.

AIII

1.4. Vaccination for secondary prevention during an outbreak of pertussis

- a. Although efficacy data are lacking on its role in preventing hospital outbreaks, pertussis vaccine (both whole-cell and acellular) has been used for vaccinating adults, including HCWs, during an institutional outbreak of pertussis^(193;704;859;860).

C

- b. In children, if immunization status is incomplete and there are no contraindications, any necessary doses should be given as recommended by the latest National Advisory Committee on Immunization (NACI) *Statement on Pertussis Vaccine*^(701;704).

AI

1.5. Chemoprophylaxis

- a. Chemoprophylaxis with an appropriate antimicrobial may be administered to anyone who has had close contact with persons with pertussis⁽⁸⁶¹⁾. Refer to the latest edition of Compendium of Pharmaceuticals and Specialties (CPS) for proper regiment⁽⁸⁶²⁾.

BI

- b. Symptomatic HCWs who have a diagnosis of or are exposed to *B. pertussis* should be excluded from work until after five days of effective therapy or, if untreated, from the beginning of the catarrhal stage through the third week after the onset of paroxysms^(198;201;863).

AIII

- c. Asymptomatic HCWs not receiving prophylaxis should be excluded from work until 20 days after their last exposure⁽²⁰¹⁾.

AIII

For more information and recommendations on the management of HCWs, immunization, and chemoprophylaxis, refer to *Infection Control Guidelines: Prevention and Control of Occupational Infections in Health Care*⁽²⁰¹⁾, *CCDR Statement on Management of Persons Exposed to Pertussis and Pertussis Outbreak Control*⁽¹⁹³⁾, *Canadian Immunization Guide 2006*⁽⁷⁰⁴⁾, and the National Advisory Committee on Immunization (NACI) *Statement on Prevention of Pertussis in Adolescents and Adults*⁽⁷⁰¹⁾ or the latest edition of those documents.

2. Influenza

2.1. Surveillance for infection

- a. Active surveillance for nosocomial influenza should be implemented during the influenza season (usually November-April).

AII

- b. Mechanisms should be established so that facility personnel are promptly alerted to influenza activity in the community.

BIII

2.2. Vaccination of staff and physicians

- a. HCWs and other staff who are potentially capable of transmitting influenza should receive annual influenza immunization⁽⁷⁰⁰⁾.

AIII

2.3. Management of patient with confirmed or suspected influenza

- a. A diagnosis of influenza should be made promptly and reported to IC immediately.

AIII

- b. Rapid tests for the diagnosis of influenza should be used when clinically indicated, particularly during the influenza season^(811;853;864). Test results can be used to initiate cohorting of patients and downgrade infection prevention and control precautions to the minimum required for the patient's infection.

BII

- c. In addition to routine practices, children and adult patients with confirmed or suspected influenza should be managed with droplet and contact precautions as described in *Infection Control Guidelines: Routine Practices and Additional Precautions for Preventing the Transmission of Infection in Health Care*⁽¹⁸⁾. (Note: This recommendation represents a change. In the past, it was unclear as to whether or not additional precautions were necessarily indicated for adults with influenza. Given the potential for cross-transmission of respiratory viruses, droplet and contact precautions are now recommended. Personal communication, Consensus Meeting for infection control measures with patients presenting with acute, respiratory illness, Gatineau, Quebec, November 24, 2003.)

AII

- d. The movement/transport of patients with a diagnosis of or suspected to be infected with influenza should be restricted to essential diagnostic and therapeutic tests.

AIII

- e. The use of airborne infection isolation rooms should be considered for patients with suspected influenza who are to be accommodated in oncology or bone marrow transplant units^(663;865).

C

- f. To reduce the potential for transmission of antiviral-resistant influenza strains, persons at high risk of complications from pneumonia should not have contact with patients or personnel who are taking an antiviral agent for the treatment of confirmed or suspected influenza during and until two days after treatment has been discontinued⁽⁷⁰⁰⁾.

AII

2.4. Management of visitors

- a. Individuals who have symptoms of influenza should not visit patients. Individuals who do visit, should be instructed on how to prevent transmission of influenza^(663;866;867).

AIII

2.5. Influenza outbreak control

- a. Consider deferring admissions to an affected unit/ward. **C**

- b. Limit individuals visiting the affected unit/ward. **C**

- c. During a facility influenza outbreak, in addition to routine precautions, adult and pediatric patients with influenza should be managed with droplet and contact precautions⁽¹⁸⁾ (personal communication, Consensus Meeting for infection control measures with patients presenting with acute, respiratory illness, Gatineau, Quebec, November 24, 2003). **BIII**

- d. If a private room is not available, consider cohorting patients with confirmed influenza (identified by culture or rapid antigen test) in a single geographic area of the unit/ward or hospital⁽¹⁸⁾. **BIII**

- e. Antiviral chemoprophylaxis should be given to all patients in the involved outbreak unit, whether previously vaccinated or not, who are not already ill with influenza. Prophylaxis should be given until eight days after the onset of the last case and for a minimum of two weeks^(700;868). **BIII**

- f. Antiviral prophylaxis should be administered to all unvaccinated HCWs on the involved outbreak unit unless contraindications exist^(201;700). **AIII**

- g. Unvaccinated HCWs who receive antiviral prophylaxis should also be immediately vaccinated against influenza unless contraindications exist^(201;700). **AIII**

- h. HCWs who are symptomatic or infected with influenza should be excluded from direct patient care⁽⁷⁰⁰⁾. **AIII**

- i. In an outbreak unit, unvaccinated HCWs who are not taking antiviral prophylaxis should be excluded from direct patient care. Unexposed, unvaccinated HCWs may be deployed elsewhere^(201;700).

AI I

For further information and recommendations on the management of HCWs, immunization, and chemoprophylaxis, refer to *Infection Control Guidelines: Prevention and Control of Occupational Infections in Health Care*⁽²⁰¹⁾, The latest *Statement on Influenza Vaccine*⁽⁷⁰⁰⁾, and the latest *Canadian Immunization Guide*⁽⁷⁰⁴⁾.

3. RSV, Parainfluenza Virus, and Adenovirus

3.1. Surveillance for viral respiratory tract infection (RTI)

- a. Surveillance for nosocomial viral RTI should be implemented, especially in pediatric facilities and hematopoietic stem cell transplant units, during the viral respiratory season (usually November to April)^(353;809).

AI II

- b. Mechanisms should be established to alert healthcare personnel, including infection control practitioners, to an increase in the activity of RSV, parainfluenza virus, adenovirus, or other respiratory viruses in the community. These may include laboratory-based alerts or alerts from public health reports.

BI II

3.2. Management of the patient with viral RTI

- a. Rapid tests for the diagnosis of viral RTI should be used when clinically indicated, particularly during seasons (usually winter and spring) when the prevalence of viral respiratory illnesses in the community or healthcare facility is increased, to facilitate using the appropriate level of infection control precautions to the minimum required for each patient's specific viral infection^(352;353;807;853;864).

AI I

- b. Elective admission of adults and children with viral RTIs should be postponed.

C

- c. Patients with viral RTIs should not share a room with patients who are immunocompromised^(247;656).

AI I

d. In addition to routine practices, children and adult patients with laboratory-confirmed or suspected RSV, parainfluenza virus, or adenovirus should be managed with droplet plus contact precautions, as detailed in *Infection Control Guidelines: Routine Practices and Additional Precautions for Preventing the Transmission of Infection in Health Care*. For care of children with symptoms of acute respiratory viral infection, masks are generally only required by HCWs if they are within two metres of a patient who is coughing or if performing procedures that may result in coughing^(18;869). (Note: This recommendation represents a change. In the past, it was unclear as to whether or not additional precautions were necessarily indicated for adults with seasonal influenza. Given the potential for cross-transmission of respiratory viruses, droplet and contact precautions are now recommended. (Personal communication, Consensus Meeting for infection control measures with patients presenting with acute, respiratory illness, Gatineau, Quebec, November 24, 2003).

AI I

e. Patients known to be infected with the same organism (identified by culture or rapid antigen test) may be cohorted^(18;353;807;809).

AI I

f. The movement/transport of patients with a diagnosis of or suspected to be infected with a respiratory virus should be restricted to essential diagnostic and therapeutic tests.

AI I I

g. Eye protection (glasses, goggles, face shields) should be considered for the care of children and adults with symptoms of acute respiratory infection. The primary purpose of eye protection in this situation is to keep the HCW from self-inoculation via the eyes^(18;231;232).

BI I

h. Gloves should be worn for direct contact with patients with symptoms of acute respiratory infection and fomites potentially contaminated with respiratory secretions^(230;249;807;809).

AI I

i. Gloves should be changed and hands washed between patients or after handling secretions or potentially contaminated fomites⁽²³⁰⁾.

AII

j. HCWs should take extreme care not to inoculate themselves with the virus by touching the nose or eye during patient care.

BIII

k. If possible, HCWs should be cohorted to infected or noninfected patients⁽⁸⁰⁷⁻⁸⁰⁹⁾.

BII

3.3. Management of visitors

a. Individuals who have symptoms of a respiratory viral infection should not visit patients unless it is essential. Individuals who do visit, should be instructed on how to prevent transmission of viral RTI^(663;809).

AIII

3.4. Viral RTI outbreak control

a. Deferral of elective admissions of high-risk patients during a hospital outbreak should be considered^(213;215).

C

b. In addition to routine precautions, children and adult patients with symptoms of viral RTI should be managed with contact and droplet precautions⁽¹⁸⁾.

AII

c. As soon as screening test results are available, patients known to have the same virus may be cohorted^(353;807-809).

AII

d. Equipment for patient care, toys, and other personal objects should be restricted to use by a single individual⁽²⁴⁹⁾.

BII

e. Reusable non-critical equipment should not be used for another patient until it has been properly cleaned and disinfected^(18;870).

AII

- f. HCWs with symptoms of an acute viral respiratory infection should be assessed for fitness to work by occupational health⁽²⁰¹⁾.

BIII

- g. Occupational health should minimize contact of HCWs who have acute respiratory infections with high-risk patients, i.e., children with chronic cardiac or pulmonary disease, neonates, and immunocompromised patients^(201;218).

BIII

For further details, refer to occupational health Work Practices to Manage HCWs Exposed to or Infected with Respiratory Infections, in: *Infection Control Guidelines: Prevention and Control of Occupational Infections in Health Care*⁽²⁰¹⁾.

4. SARS

4.1. Screening and triage

Signage

- a. Post signs at the entrance instructing patients and persons who accompany them (e.g., friends, family) to inform healthcare staff of symptoms of a respiratory infection (screening questions #1 and #2, see Screening Questions) when they first register for care⁽²⁶³⁾.

BIII

Screening

- a. In the presence of SARS in Canada, a nurse should administer an FRI (febrile respiratory infection) screening questionnaire to all patients at their first encounter with a healthcare setting (e.g., emergency departments/EMS (Emergency Medical Services), outpatient clinics, physicians' offices)^(267;271;272).

BIII

- b. During a SARS outbreak, all entrances to healthcare facilities should be restricted to allow screening of all persons entering the facility^(267;271;272).

BIII

c. Active screening should be conducted in addition to self-screening in outbreaks. It is recommended that 14 days be used as the observation period for the purposes of screening^(267;271;272).

BIII

d. If SARS is present in Canada, the screening should be done outside the entrance if possible. Hand hygiene supplies, surgical masks, tissues, and waste receptacles should be placed at the entrances to emergency and outpatient departments for patient use. Staff should be assigned to monitor the performance of hand hygiene and ensure that the box of masks does not become contaminated^(267;271;272).

BIII

e. If SARS is present elsewhere in the world but not in Canada, the screening can be done at reception.

BIII

f. The HCW should maintain a distance of at least two metres from the patient while asking the screening questions. If within two metres of the patient, the HCW should wear personal protective equipment (PPE). Alternatively, the HCW may be positioned behind a transparent barrier (e.g., Plexiglas)^(263;267;869).

BIII

g. Triage staff should have hand hygiene supplies and the recommended PPE (i.e., mask, eye protection, and gloves) readily available to use if the patient responds yes to screening questions 1 and 2⁽²⁶³⁾.

BIII

Screening questions

1. Do you have new or worsening cough or shortness of breath?
2. Have you had fever or chills?

IF “yes” to BOTH, put surgical/procedure mask on the patient and accompanying family/friends and continue questionnaire:

3. Have you been in an area identified as a SARS area (country or facility as identified on the Public Health Agency of Canada Web site) within the last 14 days?
4. Have you had contact with a sick person who has been to a SARS area (country or facility as identified on the Public Health Agency of Canada Web site) within the last 14 days?
5. Are you a laboratory or research worker who has been in contact with SARS coronavirus within the last 14 days?
6. Are you a healthcare worker?

If the patient is a HCW, ask the following additional questions:

- 6.a Have you been in a healthcare facility that is caring for a patient with SARS within the last 14 days?
- 6.b Have you had contact with a person with SARS within the last 14 days?

If answers to questions 1 and 2 are YES but to questions 3 to 6 are NO, follow the procedures outlined in the healthcare institutions policy and procedure: Infection Prevention and Control Precautions for Preventing the Transmission of Febrile Respiratory Illness (FRI) in Healthcare Settings.

Notification

- a. Notify infection control and local public health authorities if the response to any one of questions 3 to 6 is “yes”. Notify occupational health if the patient is a HCW.

Other considerations for screening and triage

- a. If the provisional diagnosis is confirmed or suspected SARS, the patient should be placed in a single room⁽²⁶⁷⁾.

B II

- b. Long-term care facilities should ask screening questions and document the responses with transfer information when transferring a resident to another facility/agency^(263;267;271;272).

B III

- c. Ambulance dispatch should ask the caller the screening questions and notify EMS. EMS should ask the patient the screening questions and, if indicated, take a temperature reading prior to transporting patients^(267;271;272).

B III

4.2. Management of the patient with confirmed or suspected SARS

- a. The following recommendations are in addition to routine practices and additional precautions, as detailed in the *Infection Control Guideline: Routine Practices and Additional Precautions for Preventing the Transmission of Infection in Health Care*⁽¹⁸⁾.

- b. HCWs should not wash their hands in patient washrooms. If a patient washroom is used for hand washing, care should be taken to avoid hand contamination from the environment after hand hygiene^(18;267;271;272).

A II

- c. Medical-quality gloves of adequate size for the wearer should be worn. Hand hygiene should be performed immediately before and after removing gloves. When a gown is worn, the gloves should cover the sleeve cuffs^(18;267;271;272).

A II

- d. Impervious gowns are not essential. Long-sleeved gowns are recommended. The gown should be worn to fully cover the front torso and arms and should be tied at the back^(267;271;272).

B III

e. Available evidence suggests that SARS transmission in healthcare settings occurs mainly via the droplet and contact routes. The use of mask is adequate for routine care⁽⁸⁷¹⁾.

BII

f. The mask should be removed carefully using the straps to prevent self-contamination^(18;267;271;272).

AI

g. There is no evidence to support the need for enhanced respiratory PPE, such as powered air-purified respirators (PAPR), during the care of patients with SARS. These devices are not recommended.

AIII

h. Eye protection (safety glasses, goggles, or face shields) should be worn to protect the mucous membranes of the eyes, nose, and mouth. Prescription eyeglasses do not provide adequate protection against splashes and sprays. HCWs should choose a type of eye protection that does not impair their vision and thereby interfere with patient care^(18;267;271;272).

BIII

i. Safety glasses, goggles, and face shields should be removed carefully to prevent self-contamination. HCWs should avoid touching their eyes during care of a patient with SARS^(267;271;272).

BIII

j. Disposable eye protection is recommended. If the eye protection is to be reused, it should be cleaned in a manner that will not contaminate the HCW. The safety glasses, goggles, or face shields should be cleaned between uses according to the manufacturer's recommendations using low-level disinfection at a minimum^(267;271;272).

BIII

k. HCWs should perform hand hygiene after removing eye protection^(18;272).

AI

l. HCWs should follow these precautions as long as the patient is considered infectious^(267;272).

BIII

m. A hierarchy of preferred accommodations should be established for patients with SARS that is operational in any facility as the SARS outbreak evolves^(267;271;272).

B III

n. Available epidemiologic evidence does not indicate that a airborne infection isolation room is required to prevent SARS transmission. Airborne infection isolation rooms may be considered for aerosol-generating procedures.

B III

o. A single room is recommended for cases of confirmed or suspected SARS. If the recommended accommodation is not available, consider cohorting confirmed SARS cases or designating a SARS unit/ward^(266;271;272).

B III

p. The entry to the SARS room/unit should have signage to inform all HCWs and any visitors of the precautions and other infection control measures that should be followed. These signs should be easy to read, and the information should provide systematic instructions.

B III

q. For the transport of SARS patients, personnel should wear a mask, eye protection, gown, and gloves. PPE should be carefully removed immediately on completion of patient transport⁽²⁶⁷⁾.

B III

r. Patients should be out of their rooms for essential procedures only. Patients should wear a surgical mask during transport.

B III

s. The transport route should be expedient and should avoid well-populated areas if possible.

B III

t. If unable to keep the mask on a child, use tissues to cover the child's nose and mouth. An incubator can be used for infant transport.

B III

u. Transport personnel should take precautions to minimize direct contact between the patient and other patients and environmental surfaces and objects^(266;271;272).

BIII

v. The medical needs of all patients with SARS should be critically evaluated before any transfer to another institution. Transfers to another institution should be avoided whenever possible^(267;272).

BIII

w. When a patient is transferred, the transferring institution should advise the personnel transporting the patient of infection control precautions required during transport.

BIII

x. The receiving agency should be notified and be aware of the infection control precautions to be followed, including recommended PPE. Patients transferred from a SARS-affected hospital should be monitored for signs and symptoms of SARS for 14 days.

BIII

4.3. Patient care equipment

a. Ensure that staff members receive proper training and are following the recommendations for cleaning, disinfecting, and sterilizing patient care equipment in accordance with the *Infection Control Guideline: Hand Washing, Cleaning, Disinfection and Sterilization in Health Care*⁽¹⁸⁾.

BIII

b. Disposable equipment should be used whenever possible^(267;271).

c. Patient care equipment (e.g., thermometer, blood pressure cuff, pulse oximeter) should be dedicated to the use of that patient and should be cleaned and disinfected before reuse with another patient^(267;271).

BIII

d. The reprocessing method required for a specific item depends on the reprocessing instructions provided by the manufacturer, the item's intended use, the risk of infection to the patient, and the amount of soiling⁽¹⁸⁾.

BIII

e. Equipment that is visibly soiled should be cleaned promptly with soap and water, detergents, or enzymatic agents before disinfection.

BIII

4.4. Environmental control

a. Refer to the *Infection Control Guideline: Hand Washing, Cleaning, Disinfection and Sterilization in Health Care*⁽¹⁸⁾.

BIII

b. Procedures should be established for assigning responsibility and accountability for routine cleaning of all environmental surfaces, including furniture (e.g., bed rails and over bed table) and non-critical patient care items (e.g., call-bell)^(18;271;273;275).

BIII

c. Personnel who are assigned this responsibility should be trained and supervised in cleaning and disinfection methods^(267;271;272).

BIII

d. Personnel involved in cleaning and disinfection of a SARS patient's room should wear recommended PPE: mask, eye protection, gown, and gloves^(267;271;272).

BIII

e. Environmental surfaces and non-critical patient care items should be cleaned frequently (at least daily and more often when soiled) using a hospital-grade-disinfectant.

BIII

f. Routine practices should be applied in the handling of soiled linen and clinical waste⁽¹⁸⁾.

BIII

- g. Since SARS patients have prolonged fecal excretion for many weeks, care should be taken when disposing of fecal material or handling fecally contaminated surfaces and equipment⁽²⁷³⁾.

BIII

4.5. Visitors

- a. Routine visiting should not be permitted. Limited visiting, on a case-by-case basis, may be allowed after careful review for compassionate reasons and careful instruction about the precautions to follow^(267;272).

C

- b. Visitors should talk with a nurse before entering the room and should be instructed in the appropriate use of PPE (mask, eye protection, gown, gloves) and hand hygiene. Ensure that visitors are following the same infection control precautions as the HCWs.

BIII

- c. All visitors' names and information should be entered into a log book for contact tracing purposes (name, address, telephone number, date of visit) and instructed to report to public health any new cough and fever within 14 days of the last visit.

BIII

4.6. Education

- a. Family and patients should be educated in respiratory etiquette to limit transmission of respiratory illness. Hand hygiene supplies, signage, surgical masks, tissues, and waste receptacles should be readily available^(263;268).

BIII

- b. HCWs should be able to demonstrate the proper method and sequence to don and remove PPE and perform hand hygiene^(268;271;275).

BII

- c. HCWs should have a working knowledge of the epidemiology and symptoms of SARS. HCWs should self-screen for febrile respiratory illness, report such illness immediately to the occupational health service (or designated alternative service if occupational health is closed), and not come to work if symptomatic^(268;271).

BII

d. HCWs should report possible SARS exposures to the occupational health Department⁽²⁷¹⁾.

BII

4.7. Postmortem care

a. Routine practices should be followed⁽¹⁸⁾.

BIII

4.8. Home care services

a. Home care services should do careful pre-screening for confirmed and suspected SARS before entering homes. Temporary suspension of home care visits may need to be considered in consultation with the local Medical Officer of Health (MOH), attending physician, and agency administration. A hierarchy of priorities should be established in order to maximize home and acute care resources.

BIII

5. Pulmonary Aspergillosis

5.1. Case finding, identification, and follow-up of healthcare-associated infections

a. Ongoing surveillance for cases of invasive pulmonary aspergillosis should be performed in high-risk immunocompromised patient populations, particularly during facility construction, renovation, remediation, repair, and demolition⁽¹⁵⁶⁾. High-risk patients include the following:

- patients with severe and prolonged neutropenia; HSCT patients are at the highest risk^(211;638;648;649;652)
- patients undergoing chemotherapy for hematologic malignancy when they are severely neutropenic⁽²¹¹⁾
- patients undergoing solid organ transplantation^(208;646)
- patients with advanced AIDS⁽⁶⁴⁷⁾
- persons receiving high-dose corticosteroids⁽²¹¹⁾

Surveillance sources should include autopsy or pathology reports of *Aspergillus* infection in inpatients.

AIII

b. Routine microbiologic surveillance cultures of the nasopharynx of asymptomatic high-risk patients for *Aspergillus* spp. are not indicated⁽⁶⁶³⁾.

BII

- c. If a case of invasive pulmonary aspergillosis is identified in an immunocompromised patient (see a. above), infection control should assess whether the infection is healthcare-associated or community-acquired on the basis of the following⁽²⁰⁵⁾:
- background rates of disease at the facility
 - presence of concurrent or recent cases
 - length of patient's stay in the facility before the onset of infection; patient's visits to ambulatory care settings within the facility or other facilities
 - patient's transfer from another healthcare facility

AII

- d. If a confirmed case of healthcare-associated infection with *Aspergillus* spp. is identified, an epidemiologic and an environmental investigation should be performed to identify and eliminate the source^(25;872).

AIII

6. *Legionella* (Legionnaires' Disease)

6.1. Case finding, identification, and follow-up of healthcare-associated infections

- a. Surveillance for healthcare-associated pneumonia should incorporate a high index of clinical suspicion for the diagnosis of legionellosis in patients who are at high risk of acquiring the disease^(149-153;171;173;174;655;873):
- immunosuppressed adults, children, and neonates, especially solid organ transplant recipients
 - patients receiving immunosuppressive doses of corticosteroids
 - patients with chronic underlying diseases e.g., diabetes mellitus, chronic obstructive pulmonary disease

AII

- b. Physicians should be educated to maintain a high suspicion for healthcare-associated Legionnaires' disease, and laboratory diagnostic tests for legionellosis should be readily available^(355;874).

BIII

- c. Isolates of *Legionella* sp. obtained from patient(s) with nosocomial Legionnaires' disease and the environment should be saved and subtyped.

BIII

- d. When one inpatient has laboratory-confirmed, definite (i.e., after ≥ 10 days of continuous inpatient stay) or possible (i.e., two to nine days of in-patient stay) healthcare-associated Legionnaires' disease, or when two or more patients acquire laboratory-confirmed Legionnaires' disease within six months of each other after having visited the same outpatient unit in the two to ten day period before illness onset:
- i. infection control should conduct an epidemiologic investigation, including retrospective review of microbiologic, serologic, and postmortem data to identify previous cases, and should conduct intensive prospective surveillance for additional cases of Legionnaires' disease⁽²⁰⁴⁾;

AII
 - ii. infection control, in collaboration with appropriate healthcare facility personnel, i.e., engineering services and microbiology laboratory staff, should conduct an environmental investigation to determine the source(s) of *Legionella* spp. See Section B.5 *Recommendations for Environmental Controls*^(167;168;170;408;655;875;876);

AII
 - iii. if an environmental source is identified, it should immediately be removed or decontaminated if possible⁽²⁰⁴⁾, see Section B.5 *Recommendations for Environmental Controls*;

AII
 - iv. if the potable water is found to be the environmental source of *Legionella* spp., the following measures should be implemented until *Legionella* are no longer detected by culture^(204;663):
 - a. the water distribution system should be decontaminated as outlined in Section B.5 *Recommendations for Environmental Control*;

AII
 - b. immunosuppressed patients should be restricted from taking showers or washing hair under taps;

BII
 - c. water free of *Legionella* spp. should be used for sponge baths for HSCT recipients⁽⁶⁶³⁾;

BII

d. water free of *Legionella* spp. should be provided for tooth brushing, drinking, and for flushing nasogastric tubes for immunosuppressed patients⁽¹⁴⁵⁾;

BII

e. aerators should be removed from faucets.

BII

v. if an environmental source is not identified, surveillance for new cases should be continued for at least two months after the initiation of surveillance;

BIII

vi. if there is evidence of ongoing transmission and no source is identified, according to the number of cases and the scope of the outbreak, infection control should decide on either deferring decontamination pending identification of the source(s) of *Legionella* spp. or proceeding with decontamination of the hospital's water system, with specific attention to those areas involved in the outbreak. See Section B.5 *Recommendations for Environmental Control*.

C

7. *Pseudomonas* spp., *Acinetobacter* spp., *Stenotrophomonas maltophilia*, and *Burkholderia cepacia*

7.1. Surveillance for infection

a. Surveillance should be conducted to detect an increased incidence of sporadic cases or the occurrence of clusters of infection and/or colonization.

BII

b. Case clusters should be investigated to identify potentially preventable causes, such as patient-to-patient transmission or transmission from environmental sources^(126;136;425).

AII

c. In an outbreak, possible contamination from water sources should be assessed if waterborne organisms are isolated from clinical specimens, or if colonization or infection occurs following patient care procedures that use water sources^(142;143;204).

AII

- d. Consideration should be given to typing of isolates to investigate an outbreak^(142;143;415;422;519).

AII

7.2. Prevention measures

- a. Strict adherence to routine practices should be emphasized to reduce the potential for patient-to-patient transmission of waterborne pathogens via the hands of healthcare workers^(122;123).

AII

- b. Nonsterile (tap) water (e.g., water baths and water with cut flowers) should not be allowed to stand in critical care and immunocompromised patient care areas or areas where medical equipment or supplies are prepared or stored^(136;877).

AIII

- c. Water-retaining bath toys should not be used by immunocompromised HSCT recipients and candidates⁽⁶⁶³⁾.

AIII

7.3. Additional measures to control transmission of *Burkholderia cepacia*, with particular reference to cystic fibrosis (CF) patients

- a. CF patients (both *B. cepacia* colonized and non-colonized) should not share hospital rooms with each other^(11;129;134;569;571;691;878-881).

AII

- b. CF patients should not share a hospital room with other patients. If sharing a room cannot be avoided, they should share a room with a patient not at high risk of colonization or complications from *B. cepacia*^(694;882).

BIII

- c. All respiratory interventions (e.g., sputum collection, aerosol therapy) should be performed in the patient's room⁽⁵⁶⁹⁾.

AIII

- d. CF patients with *B. cepacia* and other multiresistant organisms should be discouraged from visiting one another in hospital^(11;134;881).

BII

- e. Persons with CF who visit or provide care and are not infected or colonized with *B. cepacia* may elect to wear a mask when within two metres of a colonized or infected patient who is coughing or undergoing chest physiotherapy^(11;869).

C

III. Specific Recommendations for Long-Term Care Facilities (LTCF)

See General Recommendations.

This section recommends practices and procedures to prevent transmission of specific microbial agents within LTCFs when the recommendations differ from those for acute care facilities. For organisms not detailed in this section of the guideline, recommendations provided for acute care facilities are applicable to LTCFs. For further information and recommendations on routine practices and additional precautions, and infection prevention and control in LTCF, refer to *Infection Control Guidelines: Routine Practices and Additional Precautions for Preventing the Transmission of Infection in Health Care*⁽¹⁸⁾, *Infection Prevention and Control in the Long Term Care Facility*⁽⁸³¹⁾ and *Infection Control Guidelines for Long Term Care Facilities*⁽⁸⁸³⁾.

1. Influenza

1.1. Surveillance for infection

- a. Prospective surveillance for respiratory and influenza-like illnesses should be established in every LTCF^(235;868;884).

BIII
- b. Provisions for influenza diagnostic testing should be in place before the onset of influenza season each year.

BIII
- c. Diagnostic testing should be done in symptomatic residents as soon as influenza is recognized in the community⁽⁸⁸⁵⁾.

BII
- d. Rapid diagnostic tests should be available to facilitate the earlier detection of influenza in LTCFs, with earlier initiation of infection control measures, and reduction in transmission⁽⁸⁸⁵⁾.

BII

- e. A protocol for testing residents with influenza-like illness to confirm the presence of influenza by rapid testing, viral culture, or serology should be established for each LTCF.

B III

1.2. Vaccination of residents

Refer to B.3 Recommendations for Modifying Host Risk Factors.

1.3. Vaccination of staff and physicians

HCWs, HCPs, and other personnel who have direct contact with residents should receive annual influenza immunization as a standard of care for influenza prevention^(700;802;886).

A II

1.4. Management of the resident with confirmed or suspected influenza

- a. A resident with symptoms of an acute viral respiratory tract infection should be managed with droplet and contact precautions⁽¹⁸⁾.

B III

- Consideration should be given to maintaining two metres spatial separation from other residents and from visitors⁽⁸⁶⁹⁾.

B III

- Participation in group activities may need to be adjusted or restricted while the resident is symptomatic.

B III

- Room-mates and visitors should be aware of precautions to follow.

B III

For further information and recommendations for the management of HCWs exposed to, or symptomatic/infected with, influenza, refer to *Infection Control Guidelines: Prevention and Control of Occupational Infections in Health Care*⁽²⁰¹⁾.

1.5. Influenza outbreak control^(18;235;700;884)

- a. All LTCFs should have a written plan for managing an influenza outbreak.

B III

- b. Residents with influenza should be confined to their rooms if possible. Restrict cases (ill residents) to their room until five days after the onset of acute illness or until symptoms have completely resolved (whichever is shorter)⁽⁸⁸⁷⁾.
C
- c. Consider restricting social activities to wards when there is an influenza outbreak in the LTCF.
C
- d. Individuals who have symptoms consistent with influenza should not visit.
C
- e. In addition to routine precautions, contact and droplet precautions should be applied during an outbreak of influenza, as detailed in the Long-Term Care section of *Infection Control Guidelines: Routine Practices and Additional Precautions for Preventing the Transmission of Infection in Health Care*⁽¹⁸⁾.
BIII
- f. Consideration should be given to maintaining two metres spatial separation from other residents and from visitors⁽⁸⁶⁹⁾.
BIII
- g. All unvaccinated residents should be given influenza vaccination immediately when an outbreak occurs, unless contraindications exist.
C
- h. If an influenza outbreak is identified in the LTCF, prophylactic influenza antiviral therapy should be given to all residents not already ill with influenza, whether previously vaccinated or not. Prophylaxis should be given until eight days after the onset of the last case and for a minimum of two weeks^(700;714;716;868).
AII
- i. Antiviral prophylaxis should be considered for all unvaccinated HCWs without contraindications⁽⁷⁰⁰⁾.
C

j. In an outbreak, unvaccinated HCWs who are not taking antiviral prophylaxis should be excluded from direct resident care^(700;886).

C

k. Unvaccinated HCWs who receive prophylaxis should also be immediately vaccinated for influenza unless contraindications exist and may continue work without restrictions.

C

For more information on prevention of influenza in LTCFs, influenza vaccination, and management of HCWs refer to the current National Advisory Committee on Immunization: *Statement on Influenza Vaccination*⁽⁷⁰⁰⁾; the SHEA (Society for Healthcare Epidemiology of America) Position Paper: *Prevention of Influenza in Long Term Care Facilities*⁽⁸⁸³⁾; *Infection Control Guidelines: Prevention and Control of Occupational Infections in Health Care*⁽²⁰¹⁾; and *Infection Control Guidelines: Routine Practices and Additional Precautions for Preventing the Transmission of Infection in Health Care*⁽¹⁸⁾.

2. RSV, Parainfluenza Virus and Adenovirus Infections

2.1. Management of resident with a confirmed or suspected viral RTI

a. When a resident has symptoms of an acute viral RTI, he/she should be managed with droplet and contact precautions⁽¹⁸⁾:

- Consideration should be given to maintaining two metres spatial separation from other residents and from visitors⁽⁸⁶⁹⁾.

C

- Participation in group activities may need to be adjusted or restricted while the resident is symptomatic.

C

- Room-mates and visitors should be aware of precautions to follow.

C

For further information and recommendations for the management of HCWs exposed to, or symptomatic/infected with, respiratory viruses, refer to *Infection Control Guidelines: Prevention and Control of Occupational Infections in Health Care*⁽²⁰¹⁾.

2.2. Viral RTI outbreak control^(18;235;700;884)

- a. All LTCFs should have a written plan for managing an outbreak due to viral RTI.
C
- b. Residents with a viral RTI should be confined to their rooms if possible. Restrict cases (ill residents) to their room until five days after the onset of acute illness or until symptoms have completely resolved (whichever is shorter)⁽⁸⁸⁷⁾.
C
- c. Consider restricting social activities to wards when there is a viral RTI outbreak in the LTCF.
C
- d. Restrictions in the number of visitors may be advisable to prevent continued introduction of the virus into the facility.
C
- e. Contact and droplet precautions should be applied during an outbreak of viral RTI, as detailed in the Long-Term Care section of *Infection Control Guidelines: Routine Practices and Additional Precautions for Preventing the Transmission of Infection in Health Care*⁽¹⁸⁾.
C

3. Legionella (Legionnaires' disease)

3.1. Surveillance for infection

- a. Surveillance for healthcare-associated pneumonia should incorporate a high index of clinical suspicion for the diagnosis of legionellosis in long-term care residents who are at high risk of acquiring the disease, particularly during outbreaks of undiagnosed respiratory infections in nursing homes^(93;94;173;536):
 - the elderly
 - those with chronic underlying diseases
 - those with swallowing difficulties**AIII**
- b. Access to specialized laboratory diagnostic tests for *L. pneumophilla* should be made available to physicians when Legionnaires' disease is suspected^(93;94).
AIII

c. When one case of laboratory-confirmed Legionnaires' disease is identified in a resident and appears to have been acquired in the LTCF (e.g., the resident is debilitated and/or never leaves the nursing home), personnel responsible for infection control should begin intensive prospective surveillance for additional cases of Legionnaires' disease.

AI I

d. When two cases of laboratory-confirmed Legionnaires' disease are identified, personnel responsible for infection control should:

- conduct a full-scale epidemiologic investigation, including a retrospective review of microbiologic, serologic, and postmortem data, when available, to identify previous cases and carry out intensive surveillance for additional cases;

AI I

- in collaboration with public health authorities and appropriate healthcare facility personnel, conduct an environmental investigation to determine the source(s) of *Legionella* spp. See B.5 *Recommendations for Environmental Controls*^(93;94;166;167;170);

AI I

- if an environmental source is not identified, intensive surveillance for new cases should be continued for at least two months;

BI I I

- if there is evidence of ongoing transmission and no source has been identified, on the basis of the number of cases and the scope of the outbreak, personnel responsible for infection control should decide on either deferring decontamination pending identification of the source(s) of *Legionella* spp. or proceeding with decontamination of the facility's water system, with specific attention to those areas involved in the outbreak. See B.5 *Recommendations for Environmental Controls*;

C

- if an environmental source is identified, it should immediately be removed or decontaminated. See B.5 *Recommendations for Environmental Controls*;

AI I

- if the potable water is found to be the environmental source of *Legionella* spp., the water distribution system should be decontaminated, as outlined in B.5 *Recommendations for Environmental Controls*^(204;663).

AII

IV. Specific Recommendations for Ambulatory Care

See **General Recommendations**. This section recommends specific practices and procedures for preventing cross-transmission of infection in the ambulatory care setting. Although the basic principles for infection transmission and prevention are the same in ambulatory care as in hospital settings, prevention strategies may vary with the patient population and the specific setting. Additional precautions should be based on clinical presentation, and infection prevention and control measures should be implemented at the first point of contact with a potentially infectious person⁽²⁶³⁾.

1. Waiting Areas

- a. Triage procedures should be as expedient as possible^(267;684).

BIII

- b. Waiting areas in ambulatory care centres should have appropriate space, traffic flow, and ventilation^(555;683).

AII

- c. If possible, separate waiting rooms or areas for well-child visits and for children with acute respiratory symptoms should be considered, especially during community outbreaks^(18;684).

BIII

- d. Immunocompromised clients who may be at increased risk of droplet-spread viral RTIs should be identified and contact with other clients/patients in the waiting room minimized⁽⁸⁸⁸⁾.

BIII

2. Management of Patients with Suspected or Confirmed Acute Respiratory Infection

- a. Patients with signs and symptoms of respiratory infection should be placed in a separate examination room as soon as possible. Symptoms should be evaluated and, if required, additional precautions should be applied prior to full diagnostic work-up^(271;272;555;889).

BIII

3. Special Considerations for CF patients^(11;130;134;571;692;693;881)

- a. CF patients who are not colonized with *B. cepacia* should be segregated from those who are colonized with *B. cepacia*. **AII**

- b. CF patients colonized with *B. cepacia* should be segregated from each other. **AII**

- c. Waiting rooms should have no communal items, such as toys. **C**

- d. Frequently touched surfaces in examination rooms should be cleaned between patients as well as when contaminated with respiratory secretions or visibly soiled, according to hospital policy. **C**

V. Specific Recommendations for Home Care

See General Recommendations. This section recommends practices to prevent cross-transmission in the home setting.

- a. Clients with symptoms of potentially transmissible respiratory infections should be managed according to *Infection Control Guidelines: Routine Practices and Additional Precautions for Preventing the Transmission of Infection in Health Care*⁽¹⁸⁾. **BIII**

- b. HCWs, volunteers, and family members in home care should receive appropriate vaccinations, as recommended by the latest NACI statement^(700;704). **AIII**

- c. Home care services should conduct careful pre-screening for confirmed and suspected SARS before entering homes. Temporary suspension of home care visits may need to be considered in consultation with the local MOH, attending physician, and agency administration. A hierarchy of priorities should be established in order to maximize home and acute care resources. **BIII**

1. Special Considerations for CF patients

- a. Clients should not share items that come into contact with mucous membranes (e.g., toothbrush, utensils, respiratory therapy equipment) with other household members^(550;552;571).

AI I

- b. Home physiotherapy should be performed in a separate room with only one client in the room at the time of treatment^(569;571).

AI I

For further information and recommendations for the management of home care providers who are symptomatic with or have a respiratory infection, refer to *Infection Control Guideline: Prevention and Control of Occupational Infections in Health Care*⁽²⁰¹⁾.

B.3. Recommendations For Modifying Host Risk Factors

I. General Recommendations for All Healthcare Settings

This section recommends measures to modify host risk factors that may be applied in any healthcare setting. Although measures to prevent host aspiration and colonization are focused on the acute care setting, in specific circumstances their use may be warranted in the ambulatory, long-term, or home care settings.

1. Immunization

1.1. Childhood immunization

Children should receive all routine vaccines as appropriate for their age, especially those developed against respiratory pathogens with the potential to cause pneumonia (pneumococcal disease, influenza, pertussis, RSV, *Hemophilus influenzae* type b, measles)^(704;890).

AI I

1.2. Pneumococcal vaccine

- a. Pneumococcal vaccine should be provided according to the national guidelines^(52;704;891). For detailed information on individuals for whom pneumococcal vaccination is recommended, refer to the latest *Canadian Immunization Guide*⁽⁷⁰⁴⁾, and the NACI statement on recommended use of pneumococcal conjugate vaccine.

AI I

- b. Pediatric patients should receive conjugate pneumococcal vaccine if ≤ 23 months. Those aged 24 to 59 months of age should receive conjugate vaccine if at high risk of invasive pneumococcal infection. For detailed information on individuals considered to be at high risk, refer to the latest *Canadian Immunization Guide*^(704;886).

AI

- c. Acute and long-term care facilities should develop strategies to immunize patients/residents at risk of pneumococcal infection.

AIII

1.3. Influenza vaccine

- a. All healthcare facilities and home care organizations should ensure that vaccine programs are in place to provide annual influenza vaccination to patients, residents, and clients, as indicated.

BIII

- b. In LTCFs, influenza vaccine should be provided annually in the fall to residents of any age^(53;698;700).

AI

- c. In LTCFs, strategies to improve coverage should include the following⁽⁸⁹²⁾:
- standing order policies allowing nurses to administer vaccine
 - simultaneous immunization of staff and residents
 - written policy for the influenza program
 - a policy of obtaining consent for annual influenza vaccination upon admission, which is durable for future years
 - automatic administration of vaccine to residents whose guardians cannot be contacted for consent

BII

- d. Immunization against influenza should be given annually in the fall to individuals at high risk of influenza-related complications. Decisions regarding the exact timing of vaccination are to be made on the basis of local epidemiology and should acknowledge the opportunity of patient contact with HCWs and HCPs for immunization.

For further information and recommendations refer to the latest NACI Statement on Influenza Vaccination⁽⁷⁰⁰⁾.

AI

- e. In the acute, ambulatory, and home care settings, HCWs, HCPs, and their employers should actively promote, implement, and comply with influenza immunization recommendations in order to decrease the risk of infection and complications in the vulnerable population they care for. Strategies to improve coverage should include the following⁽⁷⁰⁰⁾:
- standing order policies in institutions allowing nurses to administer vaccine
 - vaccinating people at high risk who are being discharged from hospital or visiting the emergency room in the autumn
 - promoting influenza vaccination in clinics that see high-risk groups (e.g., cancer clinics, cardiac clinics, and pulmonary clinics)

AI I

1.4. Pertussis vaccine

- a. Children two months of age and older should receive acellular pertussis vaccine unless there are contraindications. In children seven years of age and older who have not had primary pertussis immunization or for whom the immunization status is unknown, adolescent/adult diphtheria-tetanus-acellular pertussis (dTdap) should be given. For further information and recommendations refer to the latest NACI *Statement on Pertussis Vaccine*⁽⁸⁹³⁾ and the latest *Canadian Immunization Guide*^(701;704).

AI

- b. For adults who have not previously received a dose of acellular vaccine, it is recommended that a single diphtheria-tetanus booster dose be replaced by the combined diphtheria-tetanus-acellular pertussis vaccine⁽⁷⁰¹⁾.

AI I I

1.5. RSV immunoprophylaxis

- a. Acute care facilities should develop policies for administration of RSV immunoprophylaxis to high-risk infants in accordance with current guidelines⁽⁸⁹⁴⁾.

BI

- b. The use of RSV immunoprophylaxis for preventing the spread of RSV among otherwise healthy patients is not recommended⁽⁸⁹⁴⁾.

C

2. Measures to Prevent Aspiration

2.1. Device-related measures

General: Devices that are in contact with the respiratory tract (e.g., endotracheal, tracheostomy, and oro/nasogastric tubes) should be removed as soon as they are no longer necessary for clinical care^(38;575;576;604;618;669;727;730;741).

AII

Endotracheal tube

a. Non-invasive positive pressure ventilation delivered continuously through a full face or nasal mask should be used whenever possible in patients who are in respiratory failure and not requiring immediate intubation rather than conventional mechanical ventilation delivered through an endotracheal tube^(593;594;736;738).

AI

b. The decision for extubation of the patient should be carefully considered, to limit the need for re-intubation^(68;732).

BII

c. Endotracheal tubes with a separate lumen open to the subglottic area above the endotracheal cuff should be used to allow continuous aspiration of subglottic secretions in patients ventilated for >72 hours^(451;598;599;895;896).

BI

d. Intubation should be performed via the oropharynx, rather than the nasopharynx, if the patient's condition allows^(727;734).

AII

e. An adequate intracuff pressure (below 20 cm H₂O) should be maintained during mechanical ventilation to decrease the leakage of pooled secretions into the patient's trachea⁽⁵⁹⁸⁾.

BII

f. Before the cuff of an endotracheal tube is deflated, the secretions above the cuff should have been suctioned.

BIII

Nasogastric/orogastric tube and enteral feeding

a. In the critically ill patient, enteral nutrition may be preferred to parenteral feeding and should begin as early as possible in the course of the patient's illness⁽⁷⁴⁴⁾.

C

b. Enteral feeds should be administered in a manner that minimizes colonization of the gastrointestinal tract and aspiration of gastric contents^(63;68;583;897). The following measures have been suggested:

- routinely verifying appropriate placement of the feeding tube

AIII

- monitoring gastric residual volume and removal if volume is large or bowel sounds are not heard

C

- using agents that increase gastrointestinal motility (e.g., metoclopramide)⁽⁸⁹⁸⁾

C

- administering enteral feeds continuously rather than intermittently^(745;746;748;899)

C

- using sterile water to provide nasogastric feeds to high-risk patients⁽¹⁴⁵⁾

C

- using acidified enteral feedings⁽⁹⁰⁰⁾

C

- supplying enteral nutrition with smaller-bore feeding tubes⁽⁹⁰¹⁾

C

- administering feeding solutions directly into the small bowel instead of the stomach, i.e., jejunal tube feeding^(742;902)

C

2.2. Treatment-related

Sedatives and neuromuscular blockers: should be used judiciously to minimize the risk of aspiration in the mechanically ventilated patient. One strategy to achieve this might be sedation vacations for the patient^(50;903).

BII

2.3. Patient positioning

Patients receiving mechanical ventilation should be maintained in a semi-upright body position with the head of the bed elevated at an angle of 30°-45° if there are no contraindications^(583;601;719;903).

AI

3. Measures to Prevent Host Colonization

3.1. Oropharyngeal colonization

Chlorhexidine oral rinse: There is insufficient evidence to support the routine use of chlorhexidine gluconate as an oral rinse for pneumonia prophylaxis⁽⁷⁸⁶⁾.

C

Oral hygiene: A comprehensive oral-hygiene program (that might include the use of an antiseptic agent) should be developed and implemented for patients in acute care settings or residents in LTCFs who are at high risk of healthcare-associated pneumonia^(787;788;904).

AI

3.2. Gastric colonization

Selective decontamination of the digestive tract (SDD): SDD alone should not be used routinely to prevent pneumonia in mechanically ventilated or ICU patients⁽⁷⁵⁵⁻⁷⁸⁵⁾.

AI

Stress bleeding prophylaxis: Sucralfate, H₂-blockers, and/or antacids have similar risks for pneumonia when used for stress bleeding prophylaxis in patients receiving mechanically assisted ventilation. If SDD is indicated, the choice of agent should depend on factors relating to the patient (e.g., the presence or absence of a nasogastric tube, the potential for unwanted drug interactions) and the local costs associated with providing the various forms of therapy^(613;790-794;905;906).

AI

4. Other Measures To Prevent Pneumonia

4.1. Antimicrobial administration

a. Routine use of systemic prophylactic antimicrobial agents in critically ill patients is not recommended^(65;83;110;907;908).

AI

- b. There is insufficient evidence to support the use of inhaled, oral, or intravenous antifungal agents as prophylaxis for pulmonary aspergillosis in patients at high risk of this infection⁽⁹⁰⁹⁻⁹¹³⁾.

C

4.2. Rotation and/or restricted use of antimicrobials

There is insufficient evidence to support rotation and/or restricted use of antimicrobials to prevent VAP^(754;914).

C

4.3. Kinetic or lateral rotational beds

There is insufficient evidence to recommend the routine use of kinetic or lateral rotational beds to prevent healthcare-associated pneumonia in critically ill or immobilized patients⁽⁷²¹⁻⁷²⁵⁾.

C

5. Prevention of Postoperative Pneumonia

- a. Patients who have underlying chronic obstructive pulmonary disease, particularly those who will undergo thoracic, abdominal, head, or emergency surgery, or who smoke, should be instructed on deep breathing exercises and the benefit of early ambulation after surgery. All patients should be encouraged to perform these activities as soon as medically indicated following surgery^(584;915-917).

BI

- b. Incentive spirometry should be considered for patients after abdominal or thoracic surgery⁽⁹¹⁶⁾.

BI

- c. Chest physiotherapy has not been shown to reduce the occurrence of VAP or nosocomial pneumonia among hospitalized patients and should not routinely be performed^(915;917-919).

AI

- d. Patients should stop smoking at least two months preoperatively for elective surgical procedures^(920;921).

BII

II. Modifications for Long-Term Care and Home Care

See General Recommendations. This section recommends additional and/or modified measures that may be taken to prevent aspiration in residents of LTCFs or clients receiving home care. Since prevention of pulmonary aspiration in this population has not been well studied, evidence to support recommendations is lacking.

1. *Measures to Minimize Aspiration and Colonization of the Oropharynx*^(51-54;667;668;670;831)

- a. Swallowing should be assessed in residents/clients who are at risk of aspiration. A modified barium swallow should be used for this assessment if indicated. C

- b. HCWs should be educated to identify residents/clients who may be at risk of, or who have dysphagia. C

- c. An appropriate diet and liquid consistency should be provided to residents/clients with swallowing disorders. C

- d. Positioning issues, i.e., hyperextended neck, that prevent spontaneous clearing of secretions and increase the risk of aspiration, should be addressed, if possible. C

- e. The resident/client should be in an upright position (elevate the head of the bed to 30°-45° degrees) during meals or tube feeds and for at least one hour after eating. BIII

- f. The use of anti-cholinergic and/or sedative-hypnotic medications should be minimized. Drug use should be monitored to ensure that it is consistent with standards, and residents/clients should be routinely evaluated for tardive dyskinesia and other movement disorders. C

g. Attention should be given to oral hygiene and dental care, especially in residents/clients with oral dryness (xerostomia). Residents/clients should have routine dental evaluations, and staff should be aware of dental hygienic techniques.

C

h. Residents/clients with xerostomia should be treated as follows: medication modification, optimized hydration status, artificial saliva or water as oral lubricants, mechanical stimulants (e.g., sugarless gum), gustatory stimulants (e.g., sugarless lemon drops), systemic salivary stimulants (pilocarpine), close dental monitoring, and fluoride treatment for decay.

C

i. Residents/clients who are at risk of salivary gland dysfunction (i.e., medications causing xerostomia, Sjogren's syndrome, radiation-induced dysfunction, dehydration, infection, gland occlusion) should be identified.

C

j. Feeding, gastrostomy, and jejunostomy tubes have not been shown to prevent pneumonia in residents/clients at risk of aspiration.

C

B.4. Recommendations For Respiratory Equipment, Devices and Procedures

I. General Recommendations for All Healthcare Settings

This section recommends routine practices and procedures for the care and use of respiratory equipment and devices in acute, long-term, ambulatory, and home care. When available, the manufacturer's recommendations on the proper use and care of equipment should be followed.

1. General Measures for Sterilization, Disinfection, and Maintenance

a. The basic principles of cleaning, disinfection, and sterilization should be the same in all settings where health care is delivered. The agent and process used are based on the type and use of the equipment rather than the patient's condition^(434;537).

All

- b. Every healthcare facility and home care organization should have written protocols for the appropriate cleaning and disinfection or sterilization of equipment and devices used to examine and/or treat the respiratory tract^(434;537).
AII
- c. All equipment items and devices that are reused must be meticulously cleaned and adequately rinsed before being subjected to disinfection or sterilization procedures^(432;434;922).
AII
- d. Devices that come into direct or indirect contact with mucous membranes are considered semi-critical and require, at a minimum, high-level disinfection. Preferred methods to achieve sterilization include steam sterilization or low-temperature sterilization methods. Methods to achieve high-level disinfection are wet heat pasteurization (75° C for 30 minutes), and liquid chemical disinfectants for items that are heat or moisture sensitive^(390;403;404;409;414;424;433;434;922).
AII
- e. Only disinfectants with a drug identification number (DIN) (i.e., disinfectants approved for sale in Canada) should be used⁽⁴³⁴⁾.
AIII
- f. Disinfectants should be used according to the manufacturer's guidelines and at the concentration required by the manufacturer's instructions. Agents should be active against waterborne pathogens⁽¹²¹⁾.
AII
- g. Items that have been disinfected or sterilized should be dried and stored in a manner preventing re-contamination^(428;922).
AII
- h. Antiseptics should be stored and used as recommended by the manufacturer⁽¹²¹⁾.
AII
- i. When rinsing is required after disinfection of reusable semi-critical equipment and devices, sterile water should be used^(161;168;399;408;515;517).
AII

j. Equipment exteriors should be cleaned with an appropriate detergent or disinfectant between patients and when visibly soiled. Particular attention should be paid to knobs, buttons, and other frequently handled and/or difficult to clean components^(434;922).

BIII

k. Adequate workflow space, traffic flow, ventilation, temperature, and humidity for reprocessing activities should be provided^(434;922).

AIII

l. If adequate facilities for equipment reprocessing activities are not available on site, the use of disposables and/or outsourcing to a facility with appropriate resources should be considered. After reprocessing, sterility should be maintained until point of use^(434;922).

AIII

2. Components of Mechanical Ventilation

2.1. Mechanical ventilators

a. The internal components of the mechanical ventilator do not normally require sterilization or disinfection^(396;491).

AII

b. In-line monitoring devices (e.g., temperature probes) should receive high-level disinfection or sterilization between patients^(136;415;417;425).

AII

2.2. Ventilator circuits and humidification systems

a. Reusable ventilator circuits and bubbling or wick humidifiers must undergo sterilization or high-level disinfection between use on different patients^(18;414;428;433;922).

AII

b. The ventilator circuit used on an individual patient should not be routinely changed on the basis of duration of use. The circuit should be changed when it is visibly soiled or mechanically defective, whether used with heat-moisture exchanger or heated humidifier^(441;446;448;449;451).

AI

c. Sterile water should be used to fill bubble-type humidifiers^(168;399;478).

AII

d. Fluids used to fill aerosol-producing devices should be handled aseptically⁽³⁹⁹⁾.

AIII

e. Sterile water or boiled tap water should be used with passover or wick-type humidifiers that do not generate aerosols⁽⁴⁴⁰⁾.

C

2.3. Condensate

a. The condensate that collects in the tubing or the water trap of a mechanical ventilator should be periodically drained and discarded, and not allowed to drain toward the patient^(444;452;584).

AIII

b. Condensate should be considered contaminated waste and therefore minimally handled and disposed of through the standard hospital waste stream. Gloves should be worn while handling condensate and hand hygiene performed after disposal of the condensate and removal of the gloves^(113;452).

AII

2.4. Ventilator circuits with heat-moisture exchangers

a. Either a heated humidifier, a heat-moisture exchanger (HME), or an HME filter (HMEF) may be used if cost-effective. There is no evidence that one is better than another^(441;451;453-458;923).

AI

b. An HME or HMEF that is in use on a patient should be changed when it becomes visibly soiled or it mechanically malfunctions but otherwise may be used for up to 120 hours^(459-461;923;924).

BI

2.5. Medication delivery devices

a. Between single inhaled medication treatments on the same patient, nebulizers should be cleaned, disinfected, rinsed with sterile water, and air-dried^(135;168;390;398;407;408).

AII

b. The time interval between nebulizer changes on the same person is unknown. Factors to consider include 1) the ability to disinfect, rinse, or air dry the nebulizer; 2) the presence of visible soiling; 3) evidence of cross-contamination on a patient care unit.

C

c. Between patients, nebulizers should be subjected at a minimum to high-level disinfection or discarded^(396;397).

AI I

d. Only sterile fluids for nebulisation^(150;168;388;399;408;435).

AI I

e. Medications for use in nebulizers should be aseptically prepared and dispensed^(135;388;405).

AI I

f. Single-dose vials or delivery systems are preferred^(135;393;405).

AI I

g. If multidose vials are used, they should be handled, dispensed, and stored according to the manufacturer's instructions^(135;388;405).

AI I

2.6. Manual ventilation bags

a. Manual ventilation bags (MVB) should undergo, at a minimum, high-level disinfection between patients^(404;424;464;466;467).

AI I

b. The required time interval between manual ventilation bag changes for the same patient is undetermined.

C

c. While an MVB is being used on the same patient, the exterior surface and the exhalation (connector) port of the MVB should be cleaned of visible secretions daily and then disinfected with a low-level disinfectant. If the MVB remains visibly soiled after attempts to clean and disinfect, it should be disassembled, cleaned, and, at a minimum, it should undergo high-level disinfection^(467;925).

AI I

3. Other Respiratory Care Equipment and Procedures

3.1. Spirometers

a. The internal machinery of PFT equipment does not ordinarily require sterilization or disinfection between patients⁽⁵⁶¹⁾.

AIII

b. For spirometers using the closed-circuit technique (dry rolling seal), reusable mouthpieces and breathing tubes should be cleaned and then subjected to high-level disinfection or sterilization between patients. With the open-circuit technique (pneumotach), it is not necessary to change breathing tube or hose between patients unless water condensation occurs, provided inspiration is avoided^(559;561;567;926).

AII

c. Nose clips, mouthpieces, and any other reusable equipment coming into direct contact with mucosal surfaces should be cleaned, at a minimum, high-level disinfected, and dried between patients^(434;567;922).

AII

d. There is no evidence to recommend the routine use of filters to prevent healthcare-associated pneumonia associated with spirometry^(563;566;567).

BIII

e. Portable respirometers and peak flow meters that are used on multiple patients should be subjected to, at a minimum, high-level disinfection between patients^(124;394;925).

AII

3.2. Large-volume nebulizers (including room humidifiers) and mist tents

a. Between use on different patients, large-volume nebulizers, mist tents, and hoods should undergo, at a minimum, high-level disinfection or be discarded^(387;396;397).

BIII

b. Large-volume nebulizers and mist tent reservoirs should be filled with sterile water^(399;413).

AII

- c. If the nebulizer requires filling while in use on the same patient, any remaining water should be discarded, and the nebulizer or mist tent should be refilled with sterile water^(406;412;927). **AI I**
- d. Mist tent nebulizers, reservoirs, and tubings used on the same patient should undergo daily low-level disinfection or pasteurization followed by air-drying. **BI I I**
- e. The required time interval between equipment changes on the same person is unknown. **C**
- f. Room humidifiers that create aerosols (e.g., vaporizers, spinning disks, and ultrasonic nebulizers) should not be used in patient care areas^(412;413;928). **AI I**

3.3. Suction catheters and suctioning of the respiratory tract

- a. Suctioning should be performed using “no touch” technique or gloves on both hands. Although new gloves should be used for each suctioning, sterile gloves are not needed. **AI I**
- b. Either the multi-use closed system suction catheter or the single-use open system catheter may be used to suction respiratory tract secretions. With the open system suction catheter, appropriate barrier precautions should be used^(451;470;472;473;929). **AI**
- c. A sterile single-use catheter should be used when suctioning respiratory tract secretions with the open suction system^(421;930). **AI I**
- d. Extended use of in-line suction catheters has not been associated with an increased risk of VAP^(471;931). **BI**
- e. Only sterile fluid should be used if flushing of the catheter is required^(421;465). **AI I**

- f. To prevent eye infections, care should be taken during suctioning not to contaminate the patient's face and/or environment with secretions from the catheter^(419;427;932).

AII

3.4. Suction collection tubing and canisters

- a. Suction collection tubing (up to the canister) should be changed between patients^(465;930).

AII

- b. With the exception of short-term care units (post-anaesthetic care unit or emergency departments), a suction canister should routinely be changed between use on different patients⁽⁴⁷⁵⁾.

C

- c. In short-term care units, canisters may be changed less frequently. The required time interval between equipment changes in short-term care units is unknown.

C

3.5. Tracheostomy care

- a. Tracheostomy care should be performed using aseptic technique.

BIII

- b. When changing a tracheostomy tube, aseptic technique should be used. The new tube should have undergone sterilization or high-level disinfection.

AIII

3.6. Oxygen delivery equipment and humidification

- a. Reusable oxygen humidifier units should be refilled aseptically with sterile water^(399;536;927).

AII

- b. For use on the same patient, units should be emptied, dried, and refilled with sterile water^(399;927).

AII

- c. The required time interval between equipment changes for prefilled disposable oxygen humidifier units on the same person is unknown.

C

- d. When used for multiple patients in short-term care areas (e.g., post-anaesthetic care unit and emergency), prefilled units may be used until empty or, at a maximum, for 30 days^(481;482).

AI I

- e. Small-bore tubing used to deliver oxygen from a wall outlet should be discarded after each patient and/or when it malfunctions or is visibly soiled.

AI I I

- f. Cannulas and masks should, at a minimum, undergo high-level disinfection between patients, or be discarded.

AI I I

3.7. Sputum induction

- a. Between use on different patients, nebulizers should receive high-level disinfection or sterilization^(396;397).

AI I

- b. Before the procedure, patients undergoing sputum induction should receive education regarding proper covering of the mouth during coughing.

BI I I

3.7.1 Sputum Induction when Tuberculosis is or may be present

- a. Assess the patient for the possibility of pulmonary or laryngeal Tuberculosis

AI I

- b. Sputum induction should be performed in a Airborne Infection Isolation Room or an isolation booth. The door should remain closed during the procedure^(487;488).

AI I

- c. During sputum induction, all persons in the room should wear respiratory protection⁽⁴⁸⁸⁾.

AI I

3.8. Anaesthesia equipment

- a. The internal components of the anaesthesia machine (gas sources, outlets, gas valves, flow meters and vaporizers) do not ordinarily require sterilization or disinfection⁽⁴⁹¹⁾.

AIII

- b. Between use on different patients, all reusable components of the breathing system or patient circuit (tracheal tube or face mask, inspiratory and expiratory breathing circuits, connectors and valves, reservoir bag, humidifier, and tubing) should be subjected to sterilization or high-level disinfection^(433;434;491;496;922).

AII

- c. The frequency of cleaning and disinfecting unidirectional valves and carbon dioxide absorber chambers is undetermined. Consideration should be given to the degree of contamination and to following the manufacturer's recommendations for reprocessing.

C

- d. The use of filters in the patient circuit or breathing system does not reduce the risk of healthcare-associated pneumonia related to anaesthesia^(32;443;499).

AII

- e. Although filters can prevent transfer of bacteria from the patient to the anaesthetic machine and from the machine to the patient, there are insufficient clinical data to support their use as a substitute for circuit changes between patients⁽⁵⁰⁶⁾.

C

3.9. Bronchoscopes

- a. Written procedures for cleaning and disinfection of bronchoscopes should be readily available and meticulously followed⁽⁵³⁰⁾.

AII

- b. Between patients, bronchoscopes should be subjected, at a minimum, to high-level disinfection^(120;434;520;523;525;530;533).

AII

- c. Products and methods for cleaning and disinfection/sterilization should be compatible with the bronchoscope and its design, as confirmed by the manufacturer of the bronchoscope^(507;513;533). **AII**
- d. Immediately after use on a patient and prior to disinfection or sterilization, the bronchoscope should be meticulously cleaned with an enzymatic detergent, taking care to irrigate all channels to remove particulate matter^(526;528;530). **AII**
- e. If disposable cleaning brushes are used, they should be discarded after each procedure. If cleaning brushes are reusable, they should be thoroughly cleaned and high-level disinfected or sterilized after each use⁽⁵¹⁴⁾. **AII**
- f. After chemical disinfection, the bronchoscope should be rinsed with sterile or bacteria-free water^(515;533;933). **AII**
- g. For automated washers, if unfiltered tap water is used, it should be followed by a 70% ethyl or isopropyl alcohol flush^(517;934). **AII**
- h. The bronchoscope and its channels should be thoroughly dried before use on another patient^(512;521;934). **AII**
- i. All reusable accessories that penetrate mucosal barriers (e.g., biopsy forceps, cytology brushes) should be mechanically cleaned (e.g., using an ultrasonic bath) and sterilized between patients or discarded after use^(433;434;533). **AII**
- j. Bronchoscopes should be inspected and leak tests performed to identify any damage to the equipment after each use before being reprocessed^(520;530;533;933). **AII**

- k. If an automated reprocessor is used, the manufacturer’s device-specific instructions should be followed to ensure adequate function of the reprocessing equipment^(520;521).

AII

- l. If bronchoscopes are reprocessed off-site at another facility, they should be rinsed immediately after use and prior to transport.

AIII

II. Modifications for Long-Term Care

See General Recommendations. This section recommends additional or modified practices and procedures to be applied in the long-term care sector. LTCFs are not all the same (see definition in Glossary), therefore practices should be tailored to the level of care that is provided in each facility and the inherent risk to the resident and the population. Studies to support evidence-based recommendations in this population are lacking. Recommendations are extrapolated and modified from a combination of acute care and home care recommendations.

1. General

If there is any risk that equipment may be shared by another resident (e.g., equipment is reprocessed in a central area), it must be subjected to high-level disinfection at a minimum^(434;922).

AII

2. Tracheostomy Care

2.1. Site care

- a. Aseptic technique should be used for a tracheostomy less than one month old⁽⁵⁴⁴⁾.

C

- b. A clean technique rather than aseptic technique may be used if the tracheostomy is more than one month old^(538;543;544).

C

- c. The healed tracheostomy site should be cleansed as needed but at least twice daily with equal parts 3% hydrogen peroxide and water^(538;543), or according to the resident’s established routine.

C

d. Clean gloves should be worn for contact with the tracheostomy tube⁽⁵⁴³⁾. C

e. Tracheostomy ties and dressings should be changed when they are soiled⁽⁵⁴³⁾. C

2.2. Suctioning

a. A clean technique may be used for suctioning the trachea^(538;543;544). Suctioning should be performed using “no touch” technique or while wearing gloves on both hands. Although fresh gloves should be used for each suctioning, sterile gloves are not needed. C

b. Sterile water should be used for suctioning and clearing the catheter during and after suctioning⁽⁵⁴⁵⁾. C

c. In the long-term care setting, suction catheters may be cleaned, reprocessed, and reused on the same resident as long as the structural integrity or function of the catheters is not changed in the process and they are stored in a manner to keep them dry and free from contamination^(538;543;935). C

d. If the suction catheter is reused without reprocessing, it should be replaced with a new, sterile catheter every 8-24 hours⁽⁹³⁵⁾. C

e. Between uses, suction catheters and cannulas should be mechanically cleaned to remove secretions⁽⁵⁴⁴⁾. AII

f. Before reuse, the catheter should be flushed with sterile water⁽⁵⁴³⁾. AII

g. Suction collection canisters that are reused should be emptied when full or at least daily and cleaned with soap and water. The system with tubing should be disinfected at least weekly with a 1:10 bleach solution⁽⁵⁴⁴⁾. C

2.3. Tracheostomy cannula care

a. Tracheostomy inner cannulas should be cleaned as necessary with soap and water using a clean pipe cleaner or small bottle brushes to clear the inner lumens of cannulas^(543;544).

C

b. If dedicated for sole use by a resident, inner cannulas should be disinfected as necessary by one of the following methods: 1) soak in 3% hydrogen peroxide (30 minutes), wash in hot soapy water, rinse, and air dry; 2) soak in 70% isopropyl alcohol (five minutes) and rinse thoroughly with tap water; or 3) boil metal cannula for 15 minutes and dry thoroughly^(543;544).

C

3. Ventilator and Equipment Care

3.1. Ventilator circuits

a. When changed, circuits should be taken apart, washed with soap and water, and scrubbed with a brush if necessary to remove secretions or other foreign material⁽⁵⁴⁷⁾.

AII

b. All parts of the circuit , including tubing, connectors, nebulizer or humidifier, and exhalation valve, should undergo high-level disinfection at a minimum and be thoroughly dried before reuse^(414;547;922).

AII

3.2. Large volume nebulizers and medication delivery devices

a. Nebulizers and the circuits used to deliver mist to the patient should be taken apart, cleaned, and disinfected every 24 hours^(138;547;550;551;936).

AII

b. Sterile solutions should be used with aerosol delivery devices^(168;399).

AII

c. Fresh, previously unopened sterile solutions must be used for the preparation of medication⁽¹⁶⁸⁾.

AII

d. After each treatment, nebulizers should be rinsed and dried^(138;539;552;936).

AII

168

3.3. Oxygen delivery equipment and humidification

a. If a pre-filled humidifier is used, it may be used down to the minimum effective fluid level and then discarded⁽⁵⁴⁷⁾.

C

b. If the humidifier is reusable, it should be emptied and rinsed well and the water replaced daily. Sterile water is not required. Humidifiers should not be “topped up” with water⁽⁹³⁷⁾.

AI I

c. The humidifier should be cleaned and disinfected after 72 hours (three days) of use⁽⁵⁴⁷⁾.

C

d. Oxygen therapy tubing and cannulas may be cleaned with a white vinegar solution of one teaspoon per quart of water or saline solution⁽⁵⁴⁴⁾.

C

3.4. Room humidifiers

a. Aerosol-producing humidifiers should not be used^(412;469;928).

AI I

b. Wick-type humidifiers can be used if humidity is desired.

C

3.5. Nasal and mask CPAP devices

a. As devices are for single patient use, they should be cleaned as necessary according to the manufacturer’s recommendations⁽⁵⁴⁷⁾.

C

III. Modifications for Ambulatory Care

See General Recommendations. This section recommends additional or modified practices and procedures to be applied in the ambulatory care setting.

1. Cystic Fibrosis Clinics

a. Between treatments on the same CF patient, in-line and hand held nebulizers should receive high-level disinfection, be rinsed with sterile water, and air-dried^(130;550;552;553;571).

AI I

b. A disposable in-line bacterial filter may be used for each patient when performing a pulmonary function test⁽⁵⁷¹⁾.

C

c. Disposable mouthpieces are preferred^(571;938).

C

IV. Modifications for Home Care

See General Recommendations. This section recommends additional or modified practices and procedures to be applied in home care. Since the risk of cross-transmission of organisms from one individual to another is lower in the home environment, measures for infection prevention in this setting may be less rigorous than those in the hospital setting. Recommendations are derived primarily from knowledge of infection control principles combined with experience in providing care in the home.

1. Tracheostomy Care

1.1. Site care

a. Aseptic technique should be used for a tracheostomy that is less than one month old⁽⁵⁴⁴⁾.

C

b. A clean technique rather than aseptic technique may be used if the tracheostomy is more than one month old^(538;543;544).

C

c. The healed tracheostomy site should be cleansed as needed but at least twice daily with 3% hydrogen peroxide^(538;543).

C

d. Clean gloves should be worn for contact with the tracheostomy tube⁽⁵⁴³⁾.

C

e. Tracheostomy ties and dressings should be changed when they are soiled⁽⁵⁴³⁾.

C

1.2. Suctioning

a. A clean technique may be used for suctioning the trachea^(538;543;544). Suctioning should be performed using “no touch” technique or while wearing gloves on both hands. Although new gloves should be used for each suctioning, sterile gloves are not needed.

C

b. Recently boiled or sterile distilled water should be used for clearing the catheter during and after suctioning, followed by suctioning of air through the device to dry the internal surface. The outer surface may be wiped with alcohol or hydrogen peroxide. The catheter should be allowed to air dry and then stored in a clean dry area⁽⁵⁴⁵⁾.

C

c. In the home care setting, suction catheters may be cleaned, reprocessed, and reused as long as the structural integrity or function of the catheters is not changed in the process and they are stored in a manner to keep them dry and free from contamination^(538;543;935).

C

d. If the suction catheter is reused without reprocessing, it should be replaced with a new, sterile catheter every 8-24 hours^(538;543;935).

C

e. Between uses, suction catheters and cannulas should be mechanically cleaned to remove secretions before disinfection^(544;546).

AI I

f. Before reuse, the catheter should be flushed with sterile water⁽⁵⁴³⁾.

AI I

g. Suction catheters may be processed for reuse according to one of the following methods: 1) clean with soapy water, rinse, and boil catheters for 20 min; 2) flush with sterile water and place in 3% hydrogen peroxide; flush with sterile water before use; 3) flush with 3% hydrogen peroxide, place in boiling, soapy water and let sit overnight; rinse with hot tap water; suction boiling water through catheter; air dry; wipe outside of catheter with alcohol and store in plastic bag^(543;544;546).

C

h. After processing for reuse, suction catheters should be stored in a manner to keep them dry and to avoid contamination^(546;935).

C

i. Suction collection canisters should be emptied when full or at least daily and cleaned with soap and water. The system with tubing should be disinfected at least weekly with a 1:3 vinegar solution, a 1:10 bleach solution, or a phenolic solution⁽⁵⁴⁴⁾.

C

1.3. Tracheostomy cannula care

a. Tracheostomy inner cannulas should be cleaned as necessary with soap and water using a clean pipe cleaner or small bottle brush to clean the inner lumen^(543;544).

C

b. Inner cannulas should be disinfected as necessary by one of the following methods: 1) soak in 3% hydrogen peroxide (30 min) and wash in hot soapy water; rinse; and air dry; 2) soak in 70% isopropyl alcohol (five minutes) and rinse thoroughly with tap water; or 3) boil metal cannula in water for 15minutes and dry thoroughly^(543;544).

C

2. Ventilator and Equipment Care

2.1. Ventilator circuits

a. When changed, circuits should be taken apart, washed with soap and water, and scrubbed with a brush, if necessary, to remove secretions or other foreign material, then rinsed until all soap is gone⁽⁵⁴⁷⁾.

AII

b. All parts of the circuit, including tubing, connectors, nebulizer, or humidifier and exhalation valve, should be soaked in a disinfectant solution recommended for home use (e.g., bleach, 70% alcohol, 3% hydrogen peroxide) according to the manufacturer's instructions and thoroughly rinsed and dried before they are reused^(538;543;544;547).

AII

c. Drain off as much water as possible and hang tubing to dry⁽⁵⁴⁷⁾.

AII

2.2. Large volume nebulizers and medication delivery devices

a. Nebulizers and the circuits used to deliver mist to the patient should be taken apart, cleaned, and disinfected every 24 hours^(138;547;550;551;936).

AII

b. Sterile solutions should be used with aerosol delivery devices⁽³⁹⁹⁾.

AII

c. Fresh, previously unopened sterile solutions should be used for the preparation of medications⁽¹⁶⁸⁾.

AII

d. After each treatment, nebulizers should be cleaned with soap and water, and disinfected by one of the following methods: 1) boil in water for five minutes; or 2) immerse in one of the following: 1:50 dilution of 5.25% to 6.15% sodium hypochlorite (household bleach) for three minutes, 70% to 90% ethyl or isopropyl alcohol for five minutes or 3% hydrogen peroxide for 30 minutes; rinse with sterile water (or, as an alternative, 70% to 90% ethyl or isopropyl alcohol); air dry all equipment. A standard cycle dishwasher may also be used if the water temperature is 70° or higher^(138;539;552;571;936).

AIII

2.3. Oxygen delivery equipment and humidification

a. If a pre-filled humidifier is used, it may be used down to the minimum effective level and then discarded⁽⁵⁴⁷⁾.

C

b. If the humidifier is reusable, it should be emptied, rinsed well, and the water replaced daily. Sterile water is not necessary. Humidifiers should never be "topped up" with water⁽⁴⁷⁹⁾.

C

c. The humidifier should be cleaned and disinfected after 72 hours (three days) of use⁽⁵⁴⁷⁾.

C

d. Oxygen therapy tubing and cannulas may be cleaned with a white vinegar solution of one teaspoon per quart of water or saline solution⁽⁵⁴⁴⁾.

C

2.4. Room humidifiers

a. Aerosol-producing humidifiers should not be used^(412;469).

AII

b. Wick-type humidifiers can be used if humidity is desired.

C

2.5. Nasal and mask CPAP devices

a. As devices are for single patient use, CPAP masks, devices, and circuits should be cleaned as necessary following the manufacturer's recommendations⁽⁵⁴⁷⁾.

C

B.5. Recommendations For Environmental Controls

I. Recommendations for Healthcare Facilities

1. Ventilation

1.1. Air handling systems

a. Heating, ventilation, and air conditioning (HVAC) systems, including installation, cleaning and maintenance, should conform to Canadian standards for health care⁽⁹³⁹⁾.

AIII

b. All HVAC systems (e.g., HVAC filters, humidity controls, placement and cleaning of air intakes and exhaust outlets) should be designed, installed, operated, and maintained with consideration for infection control^(204;939). For details, refer to CSA Standard Z317.2-01: *Special Requirements For Heating Ventilation and Air Conditioning (HVAC) Systems in Health Care Facilities: a National Standard of Canada*⁽⁹³⁹⁾, and the CDC *Guideline for Environmental Infection Control in Health care Facilities*⁽²⁰⁴⁾.

AII

c. Monitor ventilation systems in accordance with engineers' and manufacturers' recommendations. Plan for preventive maintenance and monitoring of function with specific frequencies, according to the degree of risk of patients in the area^(204;939).

AIII

1.2. Special ventilation systems

Protective environments (PE)

- a. Care areas for HSCT recipients should be designed to minimize fungal spore counts in air by maintaining 1) filtration of incoming air by means of central or point-of-use HEPA filters; 2) directed room air flow; 3) positive room air pressure relative to the corridor (pressure differential ≥ 2.5); 4) well-sealed rooms; and 5) ≥ 12 air changes per hour (ACH)^(204;663).

A II

- b. HSCT centres should provide back-up emergency power and redundant air-handling and pressurization systems to maintain a constant number of air exchanges and room pressurization when the central ventilation system is off^(204;663).

B III

- c. Infection control and maintenance personnel should together develop protocols to protect PE from bursts of mold spores that might occur when air-handling systems are restarted after shut-down⁽⁶⁶³⁾.

B III

- d. False ceilings should be avoided whenever possible⁽⁶⁶³⁾.

B II

- e. Where false ceilings cannot be avoided, the area above them should be vacuumed routinely to minimize dust⁽⁶⁶³⁾.

B II

- f. Surveillance of the ventilation status of PE should be performed⁽³⁰⁾.

A III

For specific dust-control and ventilation engineering specifications for planning and construction of new PE units, refer to *Infection Control Guidelines for Construction-Related Nosocomial Infections in Patients in Health Care Facilities: Decreasing the Risk of Aspergillus, Legionella and Other Infections*⁽¹⁵⁶⁾ and the CDC *Guideline for Environmental Infection Control in Health Care Facilities 2003*⁽²⁰⁴⁾.

g. Allogeneic HSCT recipients should be placed in PE rooms as described in point "a." of this section⁽⁶⁶³⁾.

AII

h. HEPA-filtered rooms should be considered for autologous recipients if they experience prolonged neutropenia⁽⁶⁶³⁾.

C

i. Laminar air flow rooms are not required for the care of HSCT patients^(204;212;663).

AII

j. The length of time that immunocompromised patients in PE are outside their room should be minimized⁽⁶⁶³⁾.

C

Airborne Infection Isolation Room and high-risk procedure rooms

a. Airborne infection isolation rooms should be used for patients with or suspected of having an infection transmitted by the airborne route. Newly constructed isolation rooms or areas should have a minimum of nine ACH, and those in existing facilities should have at least six ACH. All isolation rooms should have inward directional air flow (pressure differential ≥ 2.5), and air should be exhausted directly to the outside or through a HEPA filter if recycled^(18;204;488;939).

BII

b. Airborne infection isolation rooms should be used for bronchoscopy or cough induction procedures (e.g., sputum induction). High-risk procedure rooms in new facilities should have a minimum of 12 ACH, and rooms in existing facilities should have a minimum of six ACH. Rooms should have inward directional air flow (pressure differential ≥ 2.5) and air should be exhausted to the outside or through a HEPA filter if recycled^(204;488).

AII

For detailed information on ventilation requirements, specifications, and infection control measures for healthcare facilities refer to *Guidelines for Preventing the Transmission of Tuberculosis in Canadian Health Care Facilities*⁽⁴⁸⁸⁾; CSA Standard. *Special Requirements for Heating, Ventilation, and Air Conditioning (HVAC) Systems in Health Care Facilities: a National Standard of Canada*⁽⁹³⁹⁾; *Infection Control Guidelines: Routine Practices and Additional Precautions for Preventing the Transmission of Infection in Health Care*⁽¹⁸⁾; the CDC *Guideline for Environmental Infection Control in Health care Facilities*⁽²⁰⁴⁾; and *Guidelines for Preventing Opportunistic Infections among Hematopoietic Stem Cell Transplant Recipients*⁽⁶⁶³⁾.

2. Construction, Renovation, Remediation and Repair

a. At the initial stage of construction and renovation projects, a multidisciplinary team of infection control professionals, architects, engineers, representatives from environmental services, administration, medicine, and nursing should be established to plan, coordinate, and implement infection control prevention measures throughout such projects^(156;204).

BIII

b. The construction team and HCWs should be educated about immunocompromised patient care areas regarding infection risks associated with construction/renovation and control measures^(156;204).

BIII

c. When planning hospital construction, renovation, repairs, or demolition or when other dust-generating activities are anticipated, infection prevention and control personnel in collaboration with nursing should identify patient population(s) that may be at risk and the appropriate preventive measures to ensure their safety^(156;204).

AII

d. Surveillance for airborne environmental infection (e.g., invasive pulmonary aspergillosis) should be conducted as appropriate during construction/renovation projects^(156;204).

AIII

e. Environmental controls should be routinely implemented to minimize fungal spore contamination during periods of construction, renovation, and repair in areas where high-risk patients are cared for^(156;204;663).

AII

f. Preventive measures are not limited to but should include the following : 1) rigid, dust-proof barriers with airtight seals (i.e., sealed drywall) should be constructed between patient care and construction or renovation areas; 2) patients who are immunosuppressed should be moved to an area away from the construction/renovation zone if air quality cannot be guaranteed during construction; 3) pedestrian traffic should be directed away from the construction/renovation zone; 4) air pressure within the construction/renovation zone should be negative compared with adjacent areas, with air exhausted to the outside or, if recirculated, HEPA-filtered; and 5) construction workers should avoid contact with patients, patient care areas, and non-construction areas. For detailed infection control preventive measures refer to the *Infection Control Guidelines for Construction -Related Nosocomial Infections in Patients in Health Care Facilities: Decreasing the Risk of Aspergillus, Legionella and Other Infections*⁽¹⁵⁶⁾ and the CDC *Guideline for Environmental Infection Control in Health care Facilities*⁽²⁰⁴⁾.

BIII

g. Immunocompromised patients should avoid hospital construction or renovation areas^(156;652;663;940).

AIII

h. Patients should wear a high-efficiency mask if it is necessary to transport them through the construction area^(156;663).

BIII

i. Standard surgical masks are not recommended to prevent invasive aspergillosis in immunocompromised patients^(156;663).

BIII

j. Patient care areas should be thoroughly cleaned (see below) during and after construction activity, including minor renovations. Patients should not be readmitted to these areas until cleaning has been completed and the area inspected^(156;663).

BIII

- k. If a case of healthcare-acquired opportunistic environmental airborne fungal disease occurs during or immediately after construction/renovation, follow-up and control measures should be implemented^(156;204).

AIII

For detailed guidelines and recommendations regarding environmental controls during construction, renovation, remediation and repair, refer to *Infection Control Guidelines for Construction-Related Nosocomial Infections in Patients in Health Care Facilities: Decreasing the Risk of Aspergillus, Legionella and Other Infections*⁽¹⁵⁶⁾, the *CDC Guideline for Environmental Infection Control in Health Care Facilities*⁽²⁰⁴⁾, and *Guidelines for Preventing Opportunistic Infections Among Hematopoietic Stem Cell Transplant Recipients*⁽⁶⁶³⁾.

3. Cleaning the Environment

- a. Methods to control dust should be used routinely, particularly in areas designated for immunocompromised (e.g., HSCT and solid organ transplant) patients^(156;204;663):

- Exhaust vents, window sills, and all horizontal surfaces should be damp dusted with an approved hospital disinfectant.

BIII

- Immunocompromised patients should not be exposed to activities such as floor or carpet vacuuming. Doors to patient rooms should be kept closed when vacuuming central corridors.

AIII

- Vacuum cleaners used in PEs should be fitted with HEPA filters.

BIII

- Materials for furnishings, flooring, and finishes (i.e., wall coverings, window shades) should collect minimal dust and be easily cleaned.

BIII

- b. Water leaks should be cleaned up and repaired as soon as possible but within 72 hours to prevent mold proliferation in floor and wall coverings, ceiling tiles, and cabinetry in and around all HSCT patient care areas. If clean-up and repair are delayed ≥ 72 hours after the water leak, the involved materials should be assumed to contain fungi and handled accordingly^(204;663).

B III

- c. Play areas and toys for pediatric patients should be cleaned and disinfected according to published guidelines. Toys that cannot be washed, disinfected, or dry cleaned after use should be avoided^(434;663).

B III

For detailed information, refer to *Guidelines for Preventing Opportunistic Infections Among Hematopoietic Stem Cell Transplant Recipients*⁽⁶⁶³⁾, the *CDC Guideline for Environmental Infection Control in Health Care Facilities*⁽²⁰⁴⁾, and Health Canada's *Hand Washing, Cleaning, Disinfection and Sterilization in Health Care Guideline*⁽⁴³⁴⁾.

4. Flowers and Plants

- a. Flowers (fresh or dried) and potted plants should not be permitted in areas where immunocompromised and critical care patients receive care^(204;651;663).

B III

5. Plumbing

5.1. General recommendations

Water distribution systems

- a. Plumbing materials selected for use in healthcare facilities should be durable and resistant to corrosion and bacterial growth^(156;941).
- A III**
- b. A regular program of preventive maintenance should be in place for the healthcare facility water system^(156;204).
- A III**
- c. Faucet aerators and other obstructing and stagnating features (e.g., long pipes and plumbing dead-ends) should be removed if possible^(156;941).

B III

d. The facility's water temperature at the tap should be maintained at $\geq 51^{\circ}\text{C}$ for hot water and $< 20^{\circ}\text{C}$ for cold water, as allowable by regulations or codes^(156;204).

B III

e. When the potable water supply will be disrupted (e.g., during construction), alternative water sources for patient use should be provided. Discoloured potable water should be reported to maintenance personnel and the infection control department^(156;204).

A III

f. Water lines should be flushed before use if they were disrupted (e.g., during maintenance, construction)^(156;204).

B III

Cooling towers

a. When planning construction of a new facility, cooling towers should be designed to minimize the volume of aerosol drift and located so that drift is directed away from the facility's air-intake system^(204;942).

B II

b. Cooling towers should have drift eliminators installed, be routinely disinfected with effective biocides, and be maintained according to the manufacturer's recommendations⁽⁹⁴²⁾.

B II

5.2. Environmental investigation and control measures for *Legionella* infection

a. When an environmental investigation is required as part of an investigation of a *Legionella* outbreak, water samples and swabs of point-of-use devices or system surfaces that may contain biofilms should be collected and cultured for *Legionella* spp.⁽²⁰⁴⁾. Possible sampling sites are outlined in Appendix C.

A II

b. Isolates of *Legionella* spp. obtained from patients or residents and the environment should be saved and subtyped.

A II

c. If an environmental source is identified it should be immediately removed or decontaminated.

AI I

d. If the heated water system has been identified as the source of *Legionellae*, decontamination of the hot-water system should occur using one of the following approaches⁽²⁰⁴⁾:

AI I

- Pulse (one time) thermal decontamination (superheat and flush): raise the hot water temperature to 71° -77°C and maintain at that level while progressively flushing each outlet (faucets and showerheads) around the system for five minutes, or more at a minimum.
- Hyperchlorination: hyperchlorinate the system by flushing all outlets for five minutes with water containing ≥ 2 mg/L (≥ 2 ppm) free residual chlorine at the tap.

e. After either of the above treatments, water temperatures in the hot water tank and at distal outlets should be maintained as per 5.1 d, or heated water should be chlorinated to achieve 1-2 mg/L (1-2 ppm) free residual chlorine at the tap on a continuous basis to prevent recolonization of the system.

f. Hot water storage tanks and water heaters should be cleaned to remove accumulated scale and sediment. Aerators and shower heads may also require cleaning and decontamination⁽²⁰⁴⁾.

AI I

g. If the cooling towers or evaporative condensers are identified as a source of *Legionella*, the cooling tower system should be cleaned and decontaminated according to the manufacturer's recommendations and published guidelines. For detailed procedures refer to the CDC *Guideline for Environmental Infection Control in Health Care Facilities*^(204;942).

AI I

h. Control measures to reduce or eliminate *Legionella* spp. from environmental sources should be evaluated by collecting specimens for culture at two week intervals for three months. If results are negative, continue to culture monthly for another three months. If results are positive in one or more cultures, repeat initial decontamination procedures or consider a combination of superheating and hyperchlorination of the water system⁽²⁰⁴⁾.

AII

i. Records should be kept of all infection control measures and environmental test results for potable water systems.

AIII

j. Routine culturing of potable water in facilities that do not have patient care areas for persons at high risk of *Legionella* infection is not recommended.

BIII

k. Facilities with organ transplant units can consider conducting periodic culture of potable water for *Legionella* spp. in an effort to maintain water systems with no detectable organisms. The optimal frequency or number of sites for surveillance cultures has not been determined^(204;356;663;875).

BIII

For detailed infection prevention measures for water distribution systems in healthcare facilities, refer to Canadian Standards Association *Special Requirements for Plumbing Installations in Health Care Facilities; Infection Control Guidelines for Construction-Related Nosocomial Infections in Patients in Health Care Facilities*⁽⁹⁴¹⁾; *Decreasing the Risk of Aspergillus, Legionella and Other Infections*⁽¹⁵⁶⁾; the CDC *Guideline for Environmental Infection Control in Health Care Facilities, 2003*⁽²⁰⁴⁾; *Guidelines for Preventing Opportunistic Infections Among Hematopoietic Stem Cell Transplant Recipients*⁽⁶⁶³⁾; American Society of Heating Refrigeration and Air-Conditioning Engineers. *ASHRAE Guideline 12-2000: Minimizing the risk of Legionellosis associated with Building Water Systems*⁽⁹⁴²⁾.

B.6. Recommendations For Surveillance

I. General Recommendations for all Healthcare Settings

a. Hospitals should perform surveillance for healthcare-associated pneumonia^(818;828).

AII

b. Patients at high risk of healthcare-associated pneumonia should be identified for targeted surveillance (e.g., patients in ICUs undergoing mechanically assisted ventilation, selected postoperative patients, patients at risk of nosocomial viral pneumonia)^(818;827;943).

AIII

c. LTCFs should conduct surveillance for influenza and other healthcare-associated lower respiratory tract infections⁽⁹⁴⁴⁾.

BII

d. Other out-of-hospital settings (e.g., home and ambulatory care) should conduct surveillance for healthcare-associated pneumonia as part of an established infection surveillance plan, based on the type of care provided and an evaluation of the population at risk, e.g., ventilated patients, relative frequency of the event, potential for surveillance information to contribute to prevention activities^(10;827).

C

e. A written plan should outline objectives and elements of the surveillance process so that resources can be targeted appropriately^(10;827;945).

BIII

f. A documented surveillance procedure should be used, including written definitions of healthcare-associated pneumonia appropriate to the healthcare setting where surveillance will be performed^(10;55;298;544;696;818;830;835-840;945-947).

AIII

g. The intensity of surveillance for a given area should be maintained at the same level during any surveillance period. If surveillance is not continuous, it may be carried out for a fixed number of months per year, provided that the infection under surveillance is not seasonal or, if seasonal, that this fact is taken into account when the surveillance periods are selected^(818;827).

AIII

h. All the elements of surveillance should be used with consistency over time. This includes the application of surveillance definitions and method of rate calculation^(821;827).

AIII

i. Data should be collected to determine specific risk factors for healthcare-associated pneumonia and related procedures^(817;821;836). In healthcare facilities, data should also be collected to determine specific causative microorganisms and antimicrobial susceptibility patterns⁽⁸²⁶⁾.

BII

j. Infection rates should be calculated periodically (such as monthly, quarterly, annually), recorded, and analyzed^(10;827;828;831).

AIII

k. The number of patient/resident/client days at risk or device usage-days should be used as denominators to express rates^(10;821;831;836).

AII

l. Surveillance data should be analyzed promptly, reported back to the relevant healthcare personnel and administration, and infection prevention and control measures recommended in response to identified problems^(10;812;816;818;831;948).

AII

m. Routine surveillance cultures of personnel, the inanimate environment, or healthcare equipment should not be performed⁽⁴³⁴⁾.

AIII

n. Routine surveillance cultures of the respiratory tract, gastric contents, etc., are not useful and should not be performed^(949;950).

AII

o. The data collection and process of surveillance should undergo periodic evaluation and validation for quality control and to ensure accuracy⁽⁸²⁷⁾.

BIII

p. In conjunction with surveillance, the use of quality improvement initiatives, such as the formation of multidisciplinary teams, targeted education, and dissemination of data, should be considered in efforts to prevent VAP^(820;842-846;945).

AII

APPENDIX A : PHAC IP&C Guideline Development Process

Literature Search – Inclusions/Exclusions

A thorough literature search was performed in collaboration with the nurse consultant and the writer. The search results were reviewed, and articles that did not meet the criteria for the guideline were eliminated. Abstracts of remaining articles were examined; those that were not appropriate study designs or that failed to meet specific methodological criteria were eliminated. As the essence of the guideline was further defined, additional searches were conducted to ensure all relevant literature was captured. All searches covered the period from 1996 onwards.

Formulation of Recommendations

This Guideline provides evidence-based recommendations. Guideline recommendations were graded to differentiate between those based on strong evidence and those based on weak evidence. Grading did not relate to the importance of the recommendation, but to the strength of the supporting evidence and, in particular, to the predictive power of the study designs from which that data were obtained. Assignment of a level of evidence and determination of the associated grade of recommendation was done by the writer and was reviewed and approved by the co-chairs and all Guideline Working Group members. When recommendations were not unanimous, difference of opinion was formally recorded and the reasons for disagreement noted for the information audit trail. It is important to note that no real divergence of opinion occurred for this guideline, however when a difference of opinion occurred, debate took place and a solution was found and accepted.

Where scientific evidence was lacking, the consensus of experts was used to formulate a recommendation. The grading system is outlined in Appendix B.

Editorial Independence

This guideline was funded by the Public Health Agency of Canada.

All Members of the Guideline Working Group have declared no competing interest in relation to the guideline. It was incumbent upon each member to declare any interests or connections with relevant pharmaceutical companies or other organizations if their personal situation changed.

The guidelines outlined herein are part of a series that has been developed over a period of years under the guidance of the 2005 Steering Committee on Infection Prevention and Control Guidelines.

The following individuals formed the Steering Committee on Infection Prevention and Control Guidelines:

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- Dr. John Conly, University of Calgary, Calgary, Alberta
- Dr. Charles Frenette, Sherbrooke University, Greenfield Park, Quebec
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APPENDIX B : Public Health Agency of Canada - Guideline Evidence-Based Rating System

Three categories rank the strength of evidence for a recommendation, and three grades describe the quality of supportive studies for that recommendation. This format uses an evidence-based approach through the critical scrutiny of evidence from clinical trials research and well-designed experimental and observational studies, and places less emphasis on descriptive studies, clinical intuition, and recalled experiences. The rating scale is outlined in the table below.

Table: Strength and quality of evidence for recommendations

Categories for the Strength of Each Recommendation	
CATEGORY	DEFINITION
A	Good evidence to support a recommendation for or against use
B	Moderate evidence to support a recommendation for or against use
C	Insufficient evidence to support a recommendation for or against use
Categories for the Quality of Evidence	
GRADE	DEFINITION
I	Evidence from at least one properly randomized, controlled trial
II	Evidence from at least one well-designed clinical trial without randomization, from cohort or case-controlled analytic studies, preferably from more than one centre, from multiple time series, or from dramatic results in uncontrolled experiments
III	Evidence from opinions of respected authorities on the basis of clinical experience, descriptive studies, or reports of expert committees

Note: If established regulations are quoted in a document, no ratings are assigned to these legislative requirements.

APPENDIX C : Possible Sampling Sites for Legionella spp. in Healthcare Facilities

Possible Sampling Sites for Legionella spp. in Healthcare Facilities^(204;354)

- **Potable water system**
 - incoming water main
 - water softener
 - holding tanks/cisterns
 - water heater tanks (at the inflow and outflow sites)
- **Potable water outlets, especially those located in or near case-patients' rooms**
 - faucets or taps
 - showers
- **Cooling tower/evaporative condenser**
 - Make-up water (e.g., water added to the system to replace that lost by evaporation, drift, leakage)
 - Basin (e.g., area under the tower for collection of cooled water)
 - Sump (e.g., section of basin from which cooled water returns to heat source)
 - Heat source (e.g., chillers)
- **Humidifiers (e.g., nebulizers)**
 - Bubblers for oxygen
 - Water used for respiratory therapy equipment (e.g., medication jet nebulizers)
- **Other Sources**
 - Ice machines
 - Decorative fountains
 - Irrigation equipment
 - Fire/sprinkler system (if recently used)
 - Whirlpools, spas

Glossary of Terms

Acute care facility	A hospital where lengths of stay average < 30 days and where a variety of services are provided, including surgery and intensive care.
Ambulatory care	Any medical services provided to patients who are not admitted to inpatient hospital units. For the purpose of this document, ambulatory care settings include emergency departments, hospital-based and stand-alone clinics, and outpatient diagnostic and treatment facilities (e.g., bronchoscopy suites, pulmonary function laboratories, ambulatory surgery centres).
Antimicrobial-resistant organism	A microorganism that has developed resistance to the action of several antimicrobial agents and that is of special clinical or epidemiologic significance. Organisms included in this group are MRSA, vancomycin-resistant <i>Enterococci</i> , penicillin-resistant pneumococcus, certain Gram-negative bacilli resistant to all penicillins and cephalosporins, and multi-drug resistant <i>Mycobacterium tuberculosis</i> . Other microorganisms may be added to this list if antibiotic resistance is judged to be significant in a specific healthcare facility or patient population, at the discretion of the infection prevention and control program or local, regional, or national authorities.
Antimicrobial agent	A product that kills or suppresses the growth of microorganisms.
Aseptic	Conditions and procedures used to exclude the introduction of microbial contamination.
Biofilm	A structured community of bacterial cells enclosed in a self-produced polymeric matrix and adherent to an inert or living surface. The development of adherent microcolonies leads eventually to the production of a continuous biofilm on the colonized surface. Bacteria within biofilms tend to be more resistant to antibiotics and biocides.
Cleaning	The physical removal of foreign material, e.g., dust, soil, organic material such as blood, secretions, excretions, and microorganisms, from items. Cleaning physically removes rather than kills microorganisms. It is accomplished with water, detergents, and mechanical action. The terms "decontamination" and "sanitation" may be used for this process in certain settings, e.g., central service or dietetics. Cleaning reduces or eliminates the reservoirs of potential pathogenic organisms. Cleaning agents are the most common chemicals used in housekeeping activity.
Colonization	Presence of microorganisms in or on a host with growth and multiplication but without tissue invasion or cellular injury.

Contamination	The presence of microorganisms on inanimate objects (e.g., clothing, surgical instruments) or microorganisms transported transiently on body surfaces, such as hands, or in substances (e.g., water, food, milk).
Critical items	Instruments or devices that enter sterile tissues, including the vascular system. Critical items present a high risk of infection if the item is contaminated with any microorganisms, including bacterial spores. Reprocessing critical items involves meticulous cleaning followed by sterilization.
Decontamination	The removal of disease-producing microorganisms to leave an item safe for further handling.
Disease	Clinical expression of infection; signs and/or symptoms are produced.
Disinfectant	A chemical agent that kills most disease-producing microorganisms, but not necessarily bacterial spores. Disinfectants are used on inanimate objects, including medical devices.
Disinfection	The inactivation of disease-producing microorganisms. Disinfection does not destroy bacterial spores. Disinfectants are used on inanimate objects; antiseptics are used on living tissue. Disinfection usually involves chemicals, heat, or ultraviolet light. Levels of chemical disinfection vary with the type of product used.
Healthcare-associated pneumonia	Pneumonia and acute lower respiratory tract infections associated with health care provided in a variety of settings. For the purpose of this document, healthcare settings include acute and long-term care facilities, ambulatory care, and home care.
High-level disinfection	Level of disinfection required when processing semi-critical items. High-level disinfection processes destroy vegetative bacteria, mycobacteria, fungi, and enveloped (lipid) and non-enveloped (non-lipid) viruses, but not necessarily bacterial spores. High-level disinfectant chemicals (also called chemosterilants) must be capable of sterilization when contact time is extended. Items must be thoroughly cleaned prior to high-level disinfection.
Immunocompromised	Increased susceptibility to infection. In this document the term refers to patients with congenital or acquired immunodeficiency or immunodeficiency due to chemotherapeutic agents or hematologic malignancies.

Infection	The entry and multiplication of an infectious agent in the tissues of the host: (a) inapparent (asymptomatic, subclinical) infection: an infectious process running a course similar to that of clinical disease but below the threshold of clinical symptoms, (b) apparent (symptomatic, clinical) infection: one resulting in clinical signs and symptoms (disease).
Intermediate-level disinfection	Level of disinfection required for some semi-critical items. Intermediate-level disinfectants kill vegetative bacteria, most viruses, and most fungi but not bacterial spores.
Long-term care (LTC)	Refers to the care delivered in a diverse group of residential settings, ranging from institutions for the developmentally disabled to nursing homes for the elderly and pediatric chronic care facilities. Nursing homes for the elderly are the most predominant type of LTC facility. LTC facilities are different from other healthcare settings in that for most residents it is their home, and an atmosphere of community is fostered through common eating, living, and recreational areas.
Low-level disinfection	Level of disinfection required when processing non-critical items or some environmental surfaces. Low-level disinfectants kill most vegetative bacteria and some fungi as well as enveloped viruses (e.g., hepatitis B and C, hantavirus, and HIV). Low-level disinfectants do not kill mycobacteria or bacterial spores. Low-level disinfectants are used to clean environmental surfaces.
Non-critical items	Items that either touch only intact skin but not mucous membranes or do not directly touch the patient. Reprocessing of non-critical items involves cleaning and/or low-level disinfection.
Outbreak	An excess over the expected incidence of disease within a geographic area during a specified time period, synonymous with epidemic.
Pulmonary function testing	The flow or volume of air a person can inhale or exhale measured by devices such as wedge spirometers, rolling seal spirometers, or peak flow meters.
Pulse oximetry	Oxygen saturation measured by passing light through intact skin on finger, toe, or earlobe. Sensor probe may be a reusable clip-on ear or finger probe or a reusable or disposable wrap-around.
Semi-critical items	Devices that come in contact with non-intact skin or mucous membranes but ordinarily do not penetrate them. Reprocessing semi-critical items involves meticulous cleaning followed preferably by high-level disinfection.

Sterilization	The destruction of all forms of microbial life, including bacteria, viruses, spores, and fungi. Items must be cleaned thoroughly before effective sterilization can take place.
Transcutaneous oxygen analyzer	PtcCO ₂ and PtcO ₂ measured through intact skin by means of an oxygen analyzer heated electrode (primarily used on infants).

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