Implications of Oral Infections on Systemic Diseases in the Institutionalized Elderly With a Special Focus on Pneumonia

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Abstract

Systemic infection in the elderly patient living in a chronic care setting presents a significant burden to the health care system. The extent to which oral organisms cause systemic infections through hematogenous dissemination in the institutionalized elderly is still unknown. A more likely and common route of systemic infection by oral microorganisms is through aspiration of oropharyngeal fluids containing oral pathogenic microorganisms, which colonize the lower respiratory tract and cause pneumonia. Respiratory pathogens emerge in the dental plaque of elderly patients with very poor oral hygiene and severe periodontal disease. In the chronic care setting, aspiration of oropharyngeal fluids contaminated with these bacteria occurs in patients with diminished host defenses, resulting in bacterial pneumonia. This is also a problem in intensive care units in the hospital setting. In one study, pre-rinsing with a 0.12% chlorhexidine gluconate mouthwash significantly lowered the mortality rate from postsurgical pneumonia in patients undergoing open heart surgery. Selective digestive decontamination, a technique involving the topical application of antimicrobials to reduce the risk of colonization of the respiratory tract, has been used to reduce the incidence of nosocomial pneumonia in the acute care setting of hospitals. This technique has not been employed in the nursing home setting. Whether improving oral hygiene would also lower the risk in either of these settings has not been studied. A number of obstacles must be overcome in designing studies to investigate the relationship between oral infections and lung infections in the institutionalized elderly. Ethical issues must be addressed, and full collaboration of the medical team is required. Future studies should establish whether reducing the risk for pneumonia in the institutionalized elderly is possible through improved oral health. Ann Periodontol 1998;3:262–275.

Key Words: Oral health; systemic diseases/epidemiology; institutionalization; aged; oral hygiene; pneumonia/epidemiology.

INTRODUCTION

It is generally well documented that the elderly in long-term care facilities experience a high rate of systemic infections. Infections of the urinary and respiratory tracts are the most common, followed by skin infections.[1-3] A primary portal of entry for pathogenic microorganisms that cause systemic infections is the oral cavity. Under normal circumstances, the comensal organisms in the oral cavity are non-pathogenic. Changes in host resistance or environmental factors may produce the necessary conditions for some of these organisms to produce focal infections and adversely affect oral tissues. Additional, more virulent organisms may colonize the oral cavity once a focal infection has been established. The oral organisms that are pathogenic for dental caries and periodontal diseases are well known. However, the extent to which oral infections predispose the elderly person to systemic diseases has only recently received attention from the dental research community.

Oral infections such as caries and periodontal disease, on rare occasions, spread by the hematogenous routes to other sites of the body. There have been numerous case reports of odontogenic infections giving rise to various systemic infections such as abscesses in the brain, lung, and liver; meningitis; osteomyelitis; and prosthetic joint infections in older adults.[4] Prevalence studies, whether cross-sectional or retrospective from existing chart data, have not been conducted on the elderly in the nursing home setting to determine the incidence of bacteremia, sepsis, or life-threatening abscesses which resulted from local dental infections.

One systemic infection in the elderly that has been shown to have an oral origin is bacterial endocarditis. The majority of bacterial endocarditis infections are caused by viridans streptococci, a common oral microorganism.[5] Many of the documented cases of acute bacterial endocarditis are associated with periodontal pathogens, and the onset of the disease is often preceded by dental surgery.[6] The literature is lacking in terms of how this disease entity affects the morbidity and mortality of residents in long-term care facilities.

Another systemic infection with a possible oral origin that has been extensively studied in the elderly is pneumonia. Pneumonia is defined as an inflammation of the pulmonary parenchyma.[7] Pneumonia can result from bacterial infections, viral infections, and fungal infections. The infecting organism can be the result of cross-acquisition (from another person) or from endogenous infection. Community-acquired pneumonia is a term used to describe the pneumonia that results from cross-acquisition of microorganisms in patients living in the community.[8] It is usually caused by *Streptococcus pneumonia* or *Haemophilus influenzae*, but many other organisms have been identified in community-acquired pneumonia. Nosocomial (hospital-acquired) pneumonia refers to the pneumonia that develops in patients who are seriously ill in hospital intensive care units and is most often associated with mechanical ventilation.[9] The organisms most often isolated in nosocomial pneumonia are *Staphylococcus aureus* and Gram-negative bacilli such as *Escherichia coli* and *Pseudomonas aeruginosa*. Often, anaerobic bacteria are the primary infective organisms in bacterial pneumonia or are present in mixed infections. Because anaerobes are not routinely cultured, they are often not isolated or identified. Bacterial pneumonia caused by anaerobes, however, is readily distinguished clinically by the presence of putrid sputum.[10] Anaerobic infections are often associated with aspiration pneumonia, a term used to describe the pneumonia that results when contaminated fluids or foods are aspirated into the lungs.[10] Despite the use of vaccines to prevent community-acquired pneumonia in the elderly living in long-term care facilities, bacterial pneumonia continues to be the main cause of death in this group of the population.[11]

Many physicians recognize that the oral cavity is the starting point of many different systemic diseases. The medical literature implicating the oral cavity in the etiology of systemic illness is too extensive to be adequately reviewed in this paper. The discussion in this review will focus on pneumonia in the elderly. A Medline search produced more than 10,000 articles published in the

last 10 years that deal with pneumonia alone. Arguments will be presented in an attempt to characterize, with evidence from selected published literature dealing with pneumonia, the association between lung infections and oral infections in elderly residents of long-term care facilities.

HOST RISK FACTORS THAT PREDISPOSE NURSING HOME RESIDENTS TO LUNG INFECTION

Nursing homes in North America vary in the level of nursing care that they provide.[12] Unless the long-term care facility is associated with a teaching hospital, residents are usually not admitted to nursing homes if they require intravenous lines or mechanical ventilation. The elderly in long-term care facilities require institutionalization because they can no longer care for themselves. Residents in these homes vary greatly with respect to their ability for self care. There are homes that provide skilled, round-the-clock nursing care for residents who are confined to bed and require close supervision, and there are institutions that accept only those residents who are, for the most part, ambulatory and require minimal nursing care.

Nursing home residents usually have underlying debilitating conditions that limit their ability for self care.[12] Organic brain syndrome (Alzheimer's disease) and organic heart disease are the most common conditions. Cerebral vascular accidents and other central nervous diseases are also common. There are often multiple problems involving multiple sites, with many residents also affected by other conditions such as diabetes and chronic obstructive lung disease. Residents of nursing homes receive multiple medications for these conditions. The drugs are prescribed to control behavior, modulate sleep, and regulate body functions. Cathartics, analgesics, tranquilizers, and antibiotics are the most common drugs prescribed.[12]

A decline in host resistance in the institutionalized elderly plays a significant role in the susceptibility to infection in nursing home residents. Cell-mediated immunity and humoral immunity decline with age.[13] Primary systemic problems such as chronic lung disease, diabetes mellitus, and congestive heart failure increase the risk of death from pneumonia, indicating that the functional reserve components of the immune and inflammatory response are diminished in the elderly.[14]

The ability of the elderly to clear from the lungs bacteria that are aspirated from the oral cavity is reduced. The factors that likely combine to predispose a nursing home resident to respiratory infection from microorganisms in the oral cavity include a diminished cough reflex, dysphagia and swallowing disorders, and depressed consciousness from conditions such as cerebrovascular accidents, metabolic encephalopathy, or pharmacological sedation. The diminished protective cough reflexes in the elderly[15] were shown to be associated with aspiration pneumonia.[16] Patients with aspiration pneumonia were also shown to have swallowing problems as demonstrated by videofluoroscopy.[17,18] A prospective study of stroke patients showed that they were at risk of aspiration pneumonia within 72 hours of the cardiovascular accident.[19] Sixty-eight percent (68%) of the aspirators compared with 6% of the non-aspirators went on to develop lower respiratory tract infections. The use of intravenous fluids without oral intake did not reduce the incidence of pneumonia, indicating that dysphagia with aspiration of oral fluids alone (without feeding) is a risk factor. In another study, stroke victims with videofluoroscopic evidence of aspiration had a 20-fold increase in the incidence of pneumonia compared to non-aspirators.[20]

In the long-term care setting, aspiration of oropharyngeal secretions is indeed a primary risk factor for the development of pneumonia.[21,22] Pick et al.[23] followed neurologically debilitated residents of a long-term care VA facility and observed that 25% of the residents aspirated during the 8-month observational period. Fifty-six percent (56%) of these residents went on to develop pneumonia that was confirmed by radiological evidence; these residents were 3 times more likely to die of their pneumonia. A multivariate analysis indicated that tube feeding, presence of hyperextended neck or contractions, malnutrition, and the use of benzodi-

azepines and anticholinergics were risk factors. A change in mental status was associated with an increase in the mortality from pneumonia.[24] A higher degree of dependency with respect to daily activities of living is associated with a higher lung infection rate[25] and with higher mortality rates from these infections.[26]

INSTITUTIONAL RISK FACTORS

The nursing home setting also introduces risk factors for nosocomial lung infections.[12,27] Nursing homes are self-contained environments. Residents share bedrooms and washroom facilities. Daily group activities are encouraged. Non-ambulatory patients receive washing, bathing, toileting, and eating services at the bedside, similar to acute care hospital settings. Nursing aides and health care workers often move directly from one resident to the other to provide the service required by residents. Disease transmission from patient-to-patient contact is obviously enhanced in the nursing home setting. Perls and Herget[28] showed that, in contrast to other infections, respiratory tract infections were significantly higher in patients on an Alzheimer's unit compared with traditional nursing units, suggesting that the mobility and interaction of the Alzheimer's residents increased their risk for nosocomial infection. Nursing home residents may serve as reservoirs for antibiotic-resistant bacteria. Gastrointestinal and respiratory epidemics are frequent in the nursing home setting. Long-term care facilities are notoriously understaffed. Qualified health care professionals who are trained in the prevention of nosocomial infections are seldom primary care givers. The effectiveness of infection-control programs in nursing homes is likely not at the level that is achieved in hospitals.[29]

ORAL HEALTH OF NURSING HOME RESIDENTS

Cross-sectional studies have looked at the oral health status of the elderly in nursing homes, and it appears that, despite the close medical attention given these residents, their oral health is considered quite poor in relation to the general population.[30-38] Preventive measures used to reduce overall tooth loss in the elderly population have been attempted,[39,40] but patient motivation practices, which work well on the alert, ambulatory elderly, may not be applicable for the elderly in chronic care facilities. The actual level of oral hygiene required to prevent dental diseases in this special population group is unknown and cannot be estimated from previous studies on the general population. Some investigators claim that an improvement in the oral hygiene status of the residents can be achieved by introducing an in-service oral hygiene training program for the direct care staff.[41] However, improvement in the oral health status is not always attainable.[33,42]

RESPIRATORY ILLNESS IN THE ELDERLY: THE EXTENT OF THE PROBLEM

A large proportion of respiratory tract infections in the institutionalized elderly are caused by organisms that are normally not associated with community-acquired pneumonia. A review of studies published from 1990 to 1992 (Table 1) indicates that the incidence of true community-acquired pneumonia (caused by *S. pneumonia* or *H. influenzae*) varies depending on the age of the cohort. Fang et al.,[44] for example, found that 40% of the emergency admissions to hospitals from nursing homes for community-acquired pneumonia were caused by *S. pneumonia* or *H. influenzae*; 33% were caused by other organisms, while 26% were of unknown etiology. At least 11% of the cases were attributed to aspiration pneumonia. Similar results were found by others investigating general admissions to hospitals for severe pneumonia.[44-48] In the elderly, it appears that approximately only half of the community-acquired pneumonia cases are the result of organisms such as *S. pneumonia* or *H. influenzae* and others that have been associated with community-acquired pneumonia. A large proportion of the remaining cases are not usually isolated or

Table 1. Studies published in 1990, 1991, and 1992 reporting on pneumonia

Study	Nature of Cohort	Mean Age (years)	% of Known Isolates Typical of Community-Acquired Pneumonia*	% With Other Isolates* (possible oral origin)	% With Unknown Isolates*
Admission to hospitals for pneumonia					
Pachon et al.[43]	67 emerg. admissions for severe pneumonia	57	59	30	52
Fang et al.[44]	46 emerg. admissions from nursing homes	62	40	33	26 11% from aspiration
Fine et al.[45]	347 pneumonia admissions	62	39	26	42 4% from aspiration
Venkatesan et al.[46]	73 pneumonia admissions	79	47	1	52
Torres et al.[47]	92 respiratory admitted to resp. ICU	53	29	14	48
Burman et al.[48]	196 community pneumonia admissions	68	> 50	5	36
Nosocomial infections after admission					
Torres et al.[49]	322 ventilated hospital patients	54.4	3	44	54 aspiration a high risk
Rello et al.[50]	264 mechanically ventilated patients, 22% with pneumonia	46	28	59	52
Emori et al.[51]	approx. 35,000 –survey of hosp. patients exposed to invasive procedures	> 65 yrs.	8	50	42 18% of all infections were pneumonia
Court and Garrard[52]	36 cases of pneumonia in mechanically ventilated patients	NR	16	38	33
Schleupner and Cobb[53]	231 nosocomial infections in a VA hospital acute ward	NR	51	26	23

*% - percent of total isolates as actually reported or calculated from reported data.
NR = not reported.

identified. The pattern of nosocomial infections related to mechanical ventilation is similar (Table 1), except that fewer cases are caused by the typical community-acquired microorganisms and more cases are caused by enteric microorganisms and Gram-negative bacteria.[49-53]

Houston and colleagues[54] showed that the elderly (over 65 years) in the community with respiratory tract infection (pneumonia or bronchitis) had a lower survival rate than expected and that if only hospital admission cases are studied, two-thirds of the pneumonia cases in the community would be missed. Severe pneumonia in the elderly often requires admission to intensive care units in hospitals when the patients require mechanical ventilation. The decision to treat pneumonia in nursing homes with broad-spectrum antibiotics to avoid hospitalization is often based on clinical diagnosis alone.[55,56] If antibiotic administration is initiated early, many cases of pneumonia can be treated in the nursing home.[57] Taken together, these studies suggest that the prevalence of pneumonia in the elderly is high and that a large proportion of cases remain undiagnosed. It is difficult, then, to estimate the true prevalence of bacterial pneumonia in long-term care facilities from published data.

VENTILATOR-ASSOCIATED PNEUMONIA: ARE THERE COMMON ETIOLOGIES WITH NURSING HOME-ACQUIRED PNEUMONIA?

Pneumonia which develops within 48 hours in critically ill patients who require mechanical ventilation is nosocomial pneumonia that is believed to be directly associated with the introduction of ventilation equipment into the respiratory tract.[9] The bacteria that are most often isolated in ventilated patients are the enteric organisms. These include *P. aeruginosa, E. coli,* and other Gram-negative bacilli, as well as *S. aureus.* In the 1960s, the use of contaminated ventilation equipment was the source of many epidemics of nosocomial pneumonia where cross-acquisition of pathogenic organisms was common. Nowadays, however, strict adherence to infection-control protocols has largely eliminated the epidemics. Ventilation equipment that becomes contaminated by the patient's own bacteria during usage seems to be a significant risk factor in the etiology of nosocomial pneumonia in the hospital critical-care units.[58] A large percentage of nosocomial lung infections after ventilation with sterile equipment are believed to be the result of endogenous infections.[59,60]

When there is an attempt to obtain uncontaminated respiratory secretions from the lower respiratory tract and anaerobic cultures are carried out carefully, then a number of the undiagnosed cases can be attributed to the aspiration of anaerobic bacteria into the lungs.[10,61] Many of these anaerobes are commonly found in the oral cavity in patients with gingivitis or periodontitis. Bacteria such as the *Bacteroides* or *Porphyromonas* species, *Fusobacterium* species, and even *Actinobacillus actinomycetemcomitans,* all well-known periodontal pathogens, have been shown to cause lung infections.[10,61-65]

Details of the proposed mechanisms involved in the initiation of ventilator-associated infections[9] and nursing home pneumonia[66] have been reviewed. In both community-acquired and nosocomial pneumonia, it is believed that poor oral hygiene and severe periodontal disease increase colonization in the oropharynx and, eventually the lung, by the patient's own microorganisms, to levels that tip the balance to further infection. Enteric microorganisms can be found in severe periodontal lesions,[67,68] indicating that periodontal pockets can be a source of potential respiratory microorganisms. Although it has not been established if the stomach is the initial source of the periodontal enteric microorganisms, adherence of these potential respiratory pathogens to the oral epithelium and the dental plaque is enhanced by the presence of proteases in the saliva.[69-73] The bacteria multiply in patients with no oral hygiene and limited movement of the oral soft tissues and tongue. Growing layers of surface bacteria then detach from the epithelium, possibly with the aid of salivary enzymes.[66] In nursing homes, xerostomia may increase the risk of colonization and pneumonia because of the poor clearance of bacteria and the potential for aspiration of a proportionately larger inoculum of bacteria.[74,75] In ventilation-associated pneumonia, bacteria colonize the distal portions of the lung, because the use of an endotracheal tube cuff promotes collection and microaspiration of contaminated oropharyngeal fluids.[76-78]

The stomach is a known source of enteric bacteria in oropharyngeal secretions, especially in patients who have gastric reflux.[79,80] However, as mentioned earlier, these bacteria may also be found in undisturbed plaque. There is greater colonization of enteric bacteria in stomachs where the pH has been increased for the treatment of stress ulcers with antacids and type 2 histamine blockers.[81,82] Where there is tube feeding (gastric intubation), the source of Gram-negative bacilli in the oropharynx is the stomach. Even though it appears that the stomach is not an important source of bacteria that infect the lungs,[83] a great deal of effort has been made to eliminate the bacteria in the digestive tract to reduce the incidence of bacterial pneumonia in mechanically ventilated patients.

PREVENTIVE STRATEGIES FOR NON-PNEUMOCOCCAL PNEUMONIA

Selective Decontamination of the Digestive Tract Using Antibiotics

In the 1980s the strategy employed to reduce the incidence of nosocomial pneumonia in ventilated patients was the administration of systemic prophylactic antibiotics such as cefotaxime in combination with non-absorbable local application of a combination of an aminoglycoside, polymyxin B, and amphotericin B, a procedure that is now being called "selective decontamination of the digestive tract," or SDD.[84] Some well-conducted clinical trials have investigated the beneficial effects of topical antimicrobial prophylaxis instead of systemic antibiotics.[85-87] Stoutenbeek and van Saene[88] reviewed 26 clinical trials of selective decontamination of the digestive tract and concluded that pneumonia rates can be significantly reduced with this method. In a recent meta-analysis, Kollef[89] also concluded that a significant decrease in the incidence of nosocomial pneumonia in patients (over 1,000 patients altogether) treated with topical antimicrobial prophylaxis can be achieved. However, the studies did not demonstrate a decrease in mortality. Colonization with Gram-positive bacteria and pneumonia due to antibiotic-resistant Gram-positive bacteria appear to occur more frequently in SDD-treated patients.[90,91] In one study, Bonten et al.[92] showed that not only was colonization reduced in patients who received prophylactic topical antibiotics, but that patients in the same ICU who did not receive antibiotics also experienced a decrease in colonization, indicating that cross-acquisition may indeed play a role in the etiology of nosocomial pneumonia.

The routine use of systemic antibiotics for the control of periodontal disease has been proposed.[93] Such an approach should be useful for the control of periodontal disease in the institutional setting, since the elderly are less likely to undergo periodontal surgery because of poor postoperative compliance with oral hygiene. It would be useful to determine if the routine use of systemic antibiotics for the treatment of periodontal disease has an effect on the incidence of aspiration pneumonia. Such studies have not yet been undertaken.

Chlorhexidine Oral Rinses

Chlorhexidine gluconate administered in an oral rinse at 0.12% concentration has been routinely used in dentistry to inhibit plaque growth and reduce the severity of gingival inflammation and help in the control of periodontal disease.[94,95] Despite in vitro results that suggest Gram-negative bacteria are less susceptible to chlorhexidine than other oral bacteria,[96] a clinical trial was recently conducted to test whether a chlorhexidine oral rinse would be useful in the prevention of nosocomial pneumonia in critically ill patients.[97] The results of the study were encouraging. Three hundred fifty-three (353) patients who received open heart surgery were divided into control and test groups and followed in a prospective, double-blind, placebo-controlled clinical trial. The test group was given 0.12% chlorhexidine oral rinse and the control groups a placebo rinse. The researchers reported a 65% reduction in nosocomial pneumonia, which included a significant reduction in respiratory infections caused by Gram-negative bacteria, an overall reduction in the requirement for antibiotics, and an overall reduction in mortality in the test group. Chlorhexidine may prove to have fewer side effects than the use of broad-spectrum topical antibiotics in the selective decontamination of the oropharyngeal compartment and the prevention of nosocomial pneumonia.

Vaccination

Experience with pneumococcal vaccines and the influenza type A vaccine in the elderly would suggest that full immunity and protection against all the bacteria that cause pneumonia will not be possible. While the multivalent pneumococcal vaccine has been shown to be effective in the elderly in reducing the incidence of pneumonia,[98,99] there are problems in achieving optimum results.[100] In-

fluenza virus vaccines have also been used to reduce respiratory illness in nursing homes.[101-103] Nursing home residents with severe primary viral pneumonia are at risk of developing secondary non-pneumococcal bacterial infections or mixed infections. It would seem logical that the routine use of flu and pneumococcal vaccines in nursing homes would reduce the incidence of mixed bacterial pneumonia in nursing homes, but this has not been investigated.

In France, an attempt was made to immunize elderly patients against bronchitis by using an oral vaccine that consisted of the lyophilized fractions of 8 of the most common pathogens isolated in respiratory infections.[104] These researchers achieved a 28% reduction in the incidence of bronchitis without affecting the number of episodes of pneumonia. Because of the emergence of resistant strains of bacteria after antibiotic treatment, vaccination will be an important preventive measure to avoid the use of antibiotics on an empirical basis. This area of research will benefit from careful studies in the future.

Improving Oral Hygiene as a Strategy to Prevent Pneumonia

There has been no study investigating the usefulness of improving oral hygiene as a preventive protocol for aspiration pneumonia, although the suggestion that this may be a useful approach has been made.[66,105,106] Oral hygiene by means of mechanical plaque control is not practical in ventilated patients. The oral cavities of these patients readily colonize with enteric bacteria, even in the absence of adjusting the pH of the gastric juices; and preventing oral infections in these patients presents a particular challenge to the personnel of intensive care units. It is not surprising, then, that patients admitted to hospitals with untreated oral infections who must be mechanically ventilated are at high risk of developing nosocomial pneumonia. It is obvious, too, that there are common etiologies in aspiration pneumonia in the institutionalized elderly and the nosocomial pneumonia experienced by mechanically ventilated hospital patients. Poor oral hygiene is a common risk factor for both the nursing home resident and intensive care patient.[66] Maintaining control of oral infections in the nursing home setting, however, may present an equally difficult challenge. However, reducing the potential respiratory pathogens by improving oral health, whether through mechanical plaque control or by chemotherapy, would go a long way to reduce the risk of bacterial pneumonia in both groups of patients.

OBSTACLES TO OVERCOME IN DESIGNING CLINICAL TRIALS TO INVESTIGATE THE ASSOCIATION BETWEEN ORAL INFECTIONS AND LUNG INFECTIONS IN THE INSTITUTIONALIZED ELDERLY

Standardized Clinical Criteria for Diagnosis of Pneumonia

The clinical criteria used for the diagnosis of pneumonia in clinical trials can vary from one study to the next. In practice, the clinical diagnosis of pneumonia is generally made when there is fever, leukocytosis, persistent cough, and purulent sputum. The diagnosis is usually confirmed by the identification of new infiltrates on the chest radiograph.[7] However, elderly residents in nursing homes do not always present with fever and do not always produce sputum. Chest radiographs are difficult to obtain in the nursing home setting. To properly compare the results of various clinical trials in the future, uniform criteria for the clinical diagnosis of pneumonia must be used. Proof that oral bacteria associated with dental infections are the cause of pneumonia will require confirmation by means of reliable microbiological assessment.

Microbiological Diagnosis of Pneumonia

When a purulent sputum is produced in cases of suspected pneumonia, laboratory analysis can be helpful in the diagnosis. A Gram stain showing polymorphonucleocytes and easily identifiable bacteria, such as the pneumococcal species, will aid in the diagnosis. The sputum is always contaminated with oral organisms. Anaerobic cultures are

Table 2. Isolation techniques for evaluation of respiratory secretions

Technique	Skill Required	Contamination by Oral Pharyngeal Flora	Cooperation of Patient Required	Risk of Untoward Event	Anaerobic Culture Possible	Threshold (CFU/mL) in 1,000s	Sensitivity %	Specificity %
Expectorated sputum	–	+++	+	–	no			
Endotracheal aspirate	++	+++	++	+	no	1	73	14
Bronchoalveolar lavage	+++	+	+++	++	yes	1–10	56–83	71–100
Protected specimen brush	+++	–/+	+++	++	yes	1	65	93
Plugged telescoping catheter	+++	–/+	+++	++	yes	1	59–100	82–86
Trans-tracheal needle aspiration	+++	–	+++	+++	yes			
Trans-thoracic lung aspiration	+++	–	+++	+++	yes			

Adapted in part from Gleckman[8] and Court and Garrard.[9]
– none; +/– possible; + low; ++ moderate; +++ high.

difficult and costly to perform and are usually not done. Expectorated sputum, while it is the simplest to collect requiring minimal skill for proper collection and sampling, provides the least amount of microbiological information and should not be used in studies where the diagnosis depends on microbiological confirmation.

Definitive microbiological diagnosis will be required in clinical studies investigating the oral etiology of pneumonia. Secretions in the distal portions of the lung must be collected, uncontaminated by oral organisms. There are several techniques to collect these secretions.[107-113] None of these techniques can be easily carried out in the nursing home setting because of the risk involved, the skill required by the operator, the degree of cooperation required by the resident, and the lack of critical care equipment and emergency personnel required if an untoward event occurs. Blind aspiration of fluid in the endotracheal tube is a technique that still results in contamination by oropharyngeal secretions.[112] The use of a bronchoscope and visual aspiration of the distal areas of the lung with either a protected specimen brush or a plugged telescoping catheter are believed to increase the likelihood of collecting uncontaminated secretions. In the technique referred to as bronchoalveolar lavage, sterile saline is injected through a catheter to the infected site to sample the organisms, then aspirated. The recovered fluid is centrifuged and resuspended in a smaller volume of sterile saline. It is generally assumed to be contaminated by proximal secretions but may give similar results to the protected specimen brush.[112]

The plugged telescoping catheter requires a certain amount of skill to accomplish.[108] After careful endotracheal suctioning, a protected catheter is inserted 30 to 40 cm into the airway via the endotracheal tube until it cannot be advanced any further and then retracted a few centimeters. The inner catheter is then advanced beyond the tip by 2 or 3 cm, extruding the plug. Brief aspirations are applied with a syringe at the proximal end; the inner catheter retracted into the outer sheath; and the entire unit removed from the lung. The outer sheath is wiped dry and the distal portion cut off. The inner catheter is advanced and sterile saline flushed through to recover the aspiration. Up to 4 cm of the distal portion of the inner catheter is transected and added to the saline sample. The protected specimen brush technique employs a similar system.[112] In this technique, the inner catheter contains a sample brush that is advanced through the tip of the outer catheter to swab the infected area—usually done in conjunction with fiberoptic bronchoscopy to collect specimens under direct visual guidance. Approximately 0.001 mL of specimen is collected and then serially diluted and cultured. Both techniques are amenable for anaerobic cultures.

The direct sampling techniques are still under investigation as to their specificity and sensitivity (Table 2). The procedures can be considered reliable if the right cutoff or

thresholds are used in the quantitative analysis.[112] The use of direct sampling techniques is far superior to routine sputum specimens in eliminating false-positives, but obtaining blind samples (without the use of bronchoscopy) may be as accurate as the same techniques that rely on the use of bronchoscopy.[110,111,114]

It is difficult to imagine that any of the above techniques, other than collection of expectorated sputum, will be approved by ethical review committees to be routinely instituted in the nursing home setting for the purpose of determining the exact cause of lung infections. Invasive procedures such as these are seldom done in the nursing home setting. An alternative and reliable outcome measure will be required for future clinical trials. Consideration should be given to the use of histopathology at autopsy. This technique is considered the gold standard in diagnosing pneumonia[115] and may be the only technique that will provide a reliable microbiological diagnosis. In the future, for example, the postmortem identification of the presence of antigens of oral bacteria in the lungs of pneumonia subjects may be one of the best ways to prove that oral bacteria from periodontal pockets are causal agents of a large proportion of pneumonia cases. Unfortunately, since many cases of pneumonia are successfully treated without microbiological diagnosis, limiting any future study to only those cases that can be confirmed postmortem will introduce selection bias.

MEASURING OUTCOMES IN CLINICAL TRIALS AND THE COST ASSOCIATED WITH NURSING HOME PNEUMONIA CAUSED BY POOR ORAL HEALTH

To investigate the impact that oral infections and the resulting aspiration pneumonia have on the morbidity and mortality of nursing home residents, consistent outcome measures must be used. In each resident where the definitive microbiological diagnosis is possible, morbidity and mortality statistics should be obtained. For those with existing severe pneumonia who are admitted to hospitals, more complex diagnostic tests can be performed and accurate diagnoses made. However, in the nursing home setting, the researcher interested in investigating the link between oral infection and lung infections may have to rely on postmortem diagnosis. In addition to the selection bias mentioned above, there is a concern that it will be necessary to determine if the pneumonia was the cause of death or a consequence of a terminal illness just prior to death.

ETHICAL ISSUES

Clinical trials involving nursing home residents are difficult to carry out successfully. Informed consent must be provided by the residents recruited into the clinical trial. Ethical review boards will likely prohibit the prospective experimentation on human subjects unable to give informed consent. It is precisely the patients who are cognitively impaired who are at greater risk of developing pneumonia for the reasons presented in this review. Many institutions have policies to allow residents and their families to enforce "do not resuscitate (DNR)" and "do not hospitalize (DNH)" orders. The aggressive administration of antimicrobials may be considered medical intervention beyond that which is necessary to sustain life and may be refused.[116] Some physicians who care for the elderly in institutions may still take Osler's view that pneumonia is the "old man's friend." Nearly 100 years ago, Osler[117] stated that "Pneumonia may well be the friend of the aged. Taken off by it in acute, short, often painless illness, the old escape those 'cold gradations of decay' that make the last state of all so distressing." Future research will undoubtedly provide new evidence that controlling periodontal disease and other oral infections in patients susceptible to lung infection, whether in the chronic or acute care setting, will result in fewer lung infections. Recognition by the medical profession that this problem exists will likely lead to the involvement of the dental profession in the design of more effective preventive programs in reducing the incidence of lung infections.

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