

# Risk Factors for Pneumonia and Other Lower Respiratory Tract Infections in Elderly Residents of Long-term Care Facilities

Mark Loeb, MD; Allison McGeer, MD; Margaret McArthur, RN; Stephen Walter, PhD; Andrew E. Simor, MD

**Background:** Little is known about the risk factors, outcome, and impact of pneumonia and other lower respiratory tract infections (LRTIs) in residents of long-term care facilities.

**Objective:** To determine the risk factors and the effect of these infections on functional status and clinical course.

**Methods:** Active surveillance for these infections was conducted for 475 residents in 5 nursing homes from July 1, 1993, through June 30, 1996. Information regarding potential risk factors for these infections, functional status, transfers to hospital, and death was also obtained.

**Results:** Two hundred seventy-two episodes of pneumonia and other LRTIs occurred in 170 residents during 228 757 days of surveillance for an incidence of 1.2 episodes per 1000 resident-days. Multivariable analysis revealed that older age (odds ratio [OR], 1.7; 95% confidence interval [CI], 1.1-2.6 per 10-year interval;  $P = .01$ ), male sex (OR, 1.9; 95% CI, 1.1-3.5;  $P = .03$ ), swallowing difficulty (OR, 2.0; 95%

CI, 1.2-3.3;  $P = .01$ ), and the inability to take oral medications (OR, 8.3; 95% CI, 1.4-50.3;  $P = .02$ ) were significant risk factors for pneumonia; receipt of influenza vaccine (OR, 0.4; 95% CI, 0.3-0.5;  $P = .01$ ) was protective. Age (OR, 1.6 [95% CI, 1.0-2.5] per 10-year interval;  $P = .05$ ) and immobility (OR, 2.6; 95% CI, 1.8-3.8;  $P = .01$ ) were significant risk factors for other LRTIs, and influenza vaccination was protective (OR, 0.3; 95% CI, 0.2-0.4;  $P = .01$ ). Residents with pneumonia (OR, 0.7; 95% CI, 0.3-1.4;  $P = .31$ ) or with other LRTIs (OR, 0.5; 95% CI, 0.2-1.1;  $P = .43$ ) were no more likely to have a deterioration in functional status than individuals in whom infection did not develop.

**Conclusions:** Swallowing difficulty and lack of influenza vaccination are important, modifiable risks for pneumonia and other LRTIs in elderly residents of long-term care facilities. Our findings challenge the commonly held belief that pneumonia leads to long-term decline in functional status in this population.

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From the Division of Infectious Diseases, Department of Laboratory Medicine, Hamilton Health Sciences Corporation (Dr Loeb), and the Department of Clinical Epidemiology and Biostatistics (Dr Walter), McMaster University, Hamilton; the Department of Microbiology and the Division of Infectious Diseases, Mount Sinai and Princess Margaret Hospitals (Dr McGeer and Ms McArthur), the Department of Laboratory Medicine and Pathobiology, University of Toronto (Drs McGeer and Simor), and the Baycrest Centre for Geriatric Care (Dr Simor), Toronto; and the Department of Microbiology and the Division of Infectious Diseases, Sunnybrook and Women's College Health Sciences Centre, North York (Dr Simor), Ontario.

**P**NEUMONIA AND other lower respiratory tract infections (LRTIs) in elderly residents of long-term care facilities are common and serious. The estimated incidence of pneumonia ranges from 0.6 to 2.6 episodes per 1000 resident-days,<sup>1-8</sup> and reported case fatality rates range from 6.5% to 40%.<sup>9-14</sup> Pneumonia is the most common reason for transfer of nursing home residents to acute care hospitals; nearly one third of nursing home residents with pneumonia require hospital admission.<sup>9,15</sup> To develop appropriate preventive strategies for pneumonia and other LRTIs in long-term care facilities, risk factors need to be well-defined. Limited data exist regarding risk factors for respiratory tract infections in elderly residents of long-term care facilities, and results from previous studies have been conflicting. Variables reported as risk factors include swallowing difficulty, chronic obstructive lung disease, smoking, lack of pneumococcal vaccination, and immobility. Most of these studies, conducted res-

pectively, were limited by selection bias and a lack of standardized outcome assessments, had inadequate sample size or follow-up, or did not adjust for confounding variables in the analysis.<sup>8,16-20</sup>

We conducted a 3-year multiple-center cohort study of respiratory tract infection in a large group of nursing home residents. We assessed potential risk factors for pneumonia and other LRTIs. We also evaluated changes in functional status and clinical course (hospitalization and mortality).

## RESULTS

Four hundred seventy-five residents were enrolled in the 3-year study. Two hundred fifty-four residents (53.5%) were observed for at least 1 year, 180 (37.9%) for at least 2 years, and 79 (16.6%) for 3 years, for a median follow-up of 411 days. Demographic and functional characteristics of the 254 participating and 497 nonparticipating residents who were present in the nursing homes at the beginning of the

## SUBJECTS AND METHODS

### IDENTIFICATION OF COHORT

Residents of 5 metropolitan Toronto, Ontario, nursing homes at any time from July 1, 1993, through June 30, 1996, were eligible for enrollment. The nursing homes were residential long-term care facilities for elderly individuals who required from 1½ to 3 hours of nursing care daily. The median bed size of the 5 homes was 254 (range, 88-437). All residents or their substitute decision makers were approached regarding the study, and informed consent was required for participation. Each participating nursing home and the institutional review board of the University of Toronto, Toronto, approved the study.

### BASELINE ASSESSMENT

Baseline demographic and clinical data were obtained at study entry for each participant. Potential risk factors for pneumonia or other LRTIs that were evaluated included age, sex, history of 3 or more respiratory tract infections in the previous year, swallowing difficulty, ability to take oral medications, functional status, history of smoking, receipt of influenza and pneumococcal vaccines, use of minor or major tranquilizers, use of antidepressants, chronic lung disease, congestive heart failure, stroke, cancer, and diabetes mellitus. For our purposes, swallowing difficulty during eating was determined by documentation in the medical chart, resulting in a formal swallowing assessment or a change in diet or feeding practice. Determination of the ability to take oral medications was based on assessment by nursing home staff. Functional status was assessed at study entry using the Activities of Daily Living (ADL) index by Katz et al.<sup>21</sup> Immobility was defined for the purposes of this study as an ADL score of F or G (dependent in bathing, dressing, transferring, going to the toilet, continence, and/or feeding).

### FOLLOW-UP

Residents from the 5 nursing homes were observed until the end of the study (June 30, 1996) unless they died or were transferred to another long-term care facility. Demographic and clinical variables obtained at baseline were updated yearly. Functional status was assessed at 3-month intervals and at 1 and 3 months following a respiratory tract infection. Surveillance for pneumonia and other LRTIs was conducted 3 times weekly by a study nurse trained in infection control. In addition, nursing and medical staff notified the study nurse about all residents with new respiratory tract symptoms, fever, a change in mental or functional status, or suspected infection. Records of antibiotic medication received, chest radiography, and the medical charts of all residents who required hospitalization were reviewed. If pneumonia was suspected, chest radiographs were obtained within 48 hours of treatment. Clinical symptoms and signs and any prescribed antimicrobial therapy were documented. Decisions regarding treatment were at the discretion of the attending physician. Death was attributed to infection if it occurred within 2 weeks of the onset of symptoms and if there were no other identifiable causes.

### DEFINITIONS OF RESPIRATORY TRACT INFECTION

Standardized definitions of infection were used for infection surveillance.<sup>22</sup> Pneumonia was defined by the presence of compatible radiological findings and 2 of the following symptoms or signs: new or increased cough, new or increased sputum production, fever ( $\geq 38^{\circ}\text{C}$ ), pleuritic chest pain, new or increased chest examination findings, new or increased shortness of breath or respiratory rate of greater than 25 breaths/min, or worsening functional status. Other LRTI (primarily bronchitis) was defined by the presence of at least 3 of these symptoms or signs and the absence of radiological findings (or chest radiographs not obtained).

study were evaluated and found to be similar (**Table 1**), although study participants were more likely to have received influenza vaccine in the previous year ( $P = .008$ ). The mean age of study residents was 85 years (range, 59-105 years); 192 (75.6%) were women.

A total of 272 episodes of pneumonia and other LRTIs occurred in 170 residents during 228 757 resident-days of surveillance. Chest radiographs were obtained in 249 (91.5%) of the episodes of infection. There were 155 episodes of pneumonia in 113 residents and 117 episodes of other LRTIs in 89 residents. Thirty-two residents had episodes of both. The overall incidence of these respiratory tract infections was 1.2 episodes per 1000 resident-days. The overall annual influenza vaccination rate in the 5 facilities during the study was 83% (range, 60%-96%). The mean pneumococcal vaccination rate was 21% (range, 0%-66%).

### PNEUMONIA

Of the 113 residents who had pneumonia, 80 (70.7%) had 1 episode, 26 (23.0%) had 2 episodes, 5 (4.4%) had 3 episodes, and 2 (1.8%) had 4 episodes. There were 0.7

episodes of pneumonia per 1000 resident-days. The cumulative incidence of first episodes of pneumonia was 18% (95% confidence interval [CI], 14%-22%) at 1 year, 28% (95% CI, 22%-32%) at 2 years, and 34% (95% CI, 28%-40%) at 3 years (**Figure**, top). When first episodes of pneumonia were examined using univariate analysis, individuals with pneumonia were more likely to be older (odds ratio [OR], 1.7 [95% CI, 1.2-2.5];  $P = .01$ ), male (OR, 1.98 [95% CI, 1.2-3.2];  $P = .01$ ), and to have swallowing difficulty (OR, 1.6 [95% CI, 1.1-2.4];  $P = .03$ ). They were less likely to have received influenza vaccine in the year before pneumonia developed (OR, 0.4 [95% CI, 0.3-0.6];  $P = .01$ ) (**Table 2**). In univariate analysis, the only variable associated with recurrent episodes of pneumonia was immobility (OR, 2.1 [95% CI, 1.0-3.3];  $P = .01$ ), although this factor did not appear to be associated with the development of the first episode of infection.

The following potential risk factors were retained for the multivariable analysis: influenza vaccination, sex, history of respiratory tract infections, colonization with gram-negative bacteria, pneumococcal vaccination, swallowing difficulty, ability to take oral medications, and age.

## MICROBIOLOGICAL INVESTIGATIONS

Nasopharyngeal swabs were obtained within 72 hours of the onset of symptoms for direct detection of respiratory tract viral antigens using direct immunofluorescence and for isolation of respiratory tract viruses (influenza, parainfluenza, respiratory syncytial virus, and adenovirus). Polymerase chain reaction for *Chlamydia pneumoniae* was also performed from nasopharyngeal swabs during the last year of the study.<sup>23,24</sup> Acute and convalescent serum samples were obtained 2 to 4 weeks apart for serologic testing using complement fixation for respiratory tract viruses and *Mycoplasma pneumoniae* and using indirect immunofluorescence for *Legionella* species. Serologic testing for detection of *C pneumoniae* antibodies was performed using microimmunofluorescence.

Blood and sputum cultures were obtained whenever possible from residents with respiratory tract infection. Sputum specimens were cultured only if more than 25 polymorphonuclear leukocytes and fewer than 10 squamous epithelial cells were present per low-power field on results of Gram stain. The significance of blood or sputum culture isolates was determined using previously published guidelines.<sup>14</sup> Throat swabs to detect oropharyngeal colonization with gram-negative bacteria were obtained from all residents at baseline, at 6-month intervals throughout the study, and at the onset of symptoms of respiratory tract infection. Growth of aerobic and facultatively anaerobic gram-negative bacilli was recorded and quantitated as previously described.<sup>25</sup>

## STATISTICAL ANALYSIS

Data entry and analysis were performed using commercially available software (SAS, version 6.04, SAS Institute, Cary, NC; and BMDP, version 90 (Biomedical Data Programs, Los Angeles, Calif). Kaplan-Meier survival estimates were used to construct cumulative incidence

curves to assess the risk for development of pneumonia and other LRTIs. Univariate analysis for risk factors of first episodes of pneumonia and other LRTIs was performed. The following variables were treated as intervals by considering the number of years that residents were exposed to them: influenza vaccination, swallowing difficulty, use of minor tranquilizers, use of major tranquilizers, oropharyngeal colonization with gram-negative bacteria, immobility, and years after pneumococcal vaccination. Logistic regression models were built to identify risk factors for pneumonia and other LRTIs. Variables with  $P < .20$  in univariate analysis were entered as candidate risk factors; final models were selected using a backward stepwise algorithm. To avoid the problem of within-subject dependence of infection episodes, only the first episode of respiratory tract infection was included in the analysis. To minimize potential confounding by location-specific factors, nursing home site was forced into the logistic regression model.

Since functional status of study participants was assessed every 3 months, the effect of LRTI on functional status could be determined using a matched analysis. For residents with infection, the change between the last functional assessment before the event and the first assessment at least 3 months after the event was treated as an ordered variable (improved, worse, or no change). Residents with infections were matched to residents without infection who underwent functional assessment at the same time. A matched  $\chi^2$  test was performed to compare the distributions of ADL scores within pairs of residents.<sup>26</sup> To determine the effect of pneumonia or LRTI on the rate of functional decline, a within-subject matched analysis was performed. The functional status at baseline of residents who had experienced a respiratory tract infection was compared with functional status just before the event, and the difference was treated as an ordered variable (improved, worse, or no change). Similarly, functional status determined at least 3 months after the event was compared with functional status at the last follow-up. The trends in functional decline before and after the event were then compared.

Older age (OR, 1.7; 95% CI, 1.1-2.6 per 10-year interval;  $P = .01$ ), male sex (OR, 1.9; 95% CI, 1.1-3.5;  $P = .03$ ), swallowing difficulty (OR, 2.0; 95% CI, 1.2-3.3;  $P = .01$ ), and the inability to take oral medications (OR, 8.3; 95% CI, 1.4-50.3;  $P = .02$ ) remained significant in the multivariable model, increasing the risk for pneumonia. Having received influenza vaccination (OR, 0.4; 95% CI, 0.3-0.5;  $P = .01$ ) was protective against the development of pneumonia (**Table 3**).

## OTHER LRTIs

Of the 89 residents who had other LRTIs, 66 (74.1%) had a single episode, 18 (20.2%) had 2 episodes, and 5 (5.6%) had 3 episodes. There were 0.5 episodes of LRTI per 1000 resident-days. The cumulative incidence of first episodes of other LRTI was 14% (95% CI, 10%-17%) at 1 year, 20% (95% CI, 16%-25%) at 2 years, and 24% (95% CI, 18%-29%) at 3 years (Figure, bottom). Univariate analysis revealed that residents in whom these infections developed were more likely to be older (OR, 1.9; 95% CI, 1.3-2.8;  $P = .01$ ) and to be immobile (OR, 1.6; 95% CI, 1.2-2.1;  $P = .01$ ). They were less likely to have

been male (OR, 0.5; 95% CI, 0.2-1.0;  $P = .04$ ) or to have received influenza (OR, 0.3; 95% CI, 0.2-0.5;  $P = .01$ ) or pneumococcal vaccination (OR, 0.8; 95% CI, 0.6-0.9;  $P = .01$ ) (Table 2). Residents with recurrent lower respiratory tract infections were more likely to be immobile (OR, 1.8; 95% CI, 1.0-3.2;  $P = .04$ ).

The following potential risk factors were retained for multivariable analysis: influenza vaccination, immobility, age, history of respiratory tract infections, pneumococcal vaccination, sex, and swallowing difficulty. Age (OR, 1.6 [95% CI, 1.0-2.5] per 10-year interval;  $P = .05$ ) and immobility (OR, 2.6 [95% CI, 1.8-3.8];  $P = .01$ ) remained in the model as significant risk factors, whereas influenza vaccination was a significant protective factor (OR, 0.3 [95% CI, 0.2-0.4];  $P = .01$ ) (Table 3).

## MICROBIOLOGICAL FINDINGS

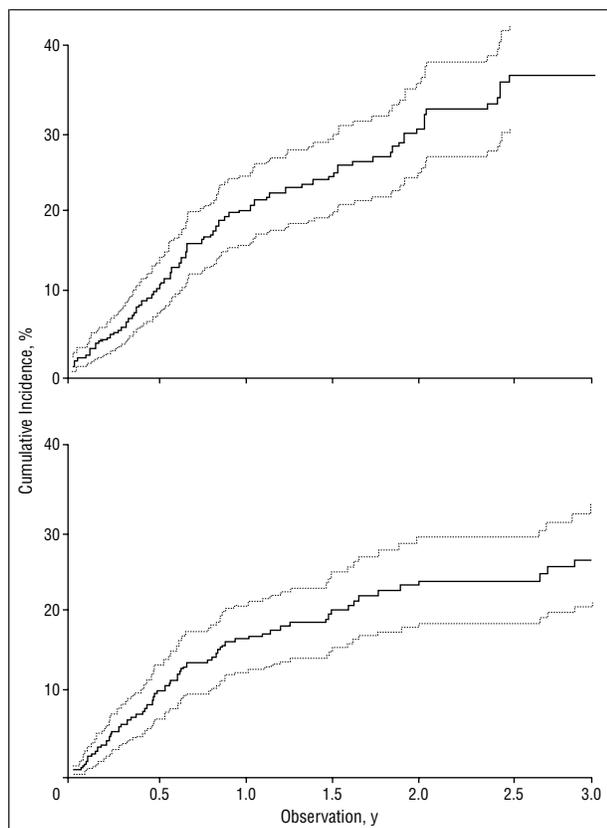
Of the 272 episodes of pneumonia and other lower respiratory tract infections, blood cultures were obtained in 100 (36.8%), sputum cultures in 24 (8.8%), nasopharyngeal swabs in 166 (61.0%), and paired acute and con-

**Table 1. Comparison of Selected Demographic and Clinical Characteristics of Study vs Nonstudy Residents at the Beginning of the Study (July 1, 1993)\***

Characteristic	Not Enrolled in Study (n = 497)	Enrolled in Study (n = 254)	P
Mean age, y	85.1	86.1	.11
Mean length of residence, y	3.3	3.2	.59
No. male/female	129:368	62:192	.61
Chronic lung disease	65 (13.1)	33 (13.0)	.97
CNS disease†	408 (82.1)	206 (81.1)	.72
Diabetes mellitus	60 (12.0)	25 (9.8)	.36
Received influenza vaccine in previous year	278 (55.9)	175 (68.9)	.008
Received pneumococcal vaccine	229 (46.1)	104 (40.9)	.18
Receiving major tranquilizer	109 (21.9)	43 (16.9)	.11
Receiving minor tranquilizer	70 (14.1)	33 (13.0)	.68
Totally dependent in all ADL	99 (19.9)	51 (20.1)	.96

\*CNS indicates central nervous system; ADL, Activities of Daily Living index by Katz et al.<sup>21</sup> Unless otherwise indicated, data are given as No. (percentage).

†Includes dementia, stroke, and Parkinson disease.



Cumulative incidence of first episodes of pneumonia (top) and other lower respiratory tract infections (bottom) in nursing home residents. Dashed lines represent 95% confidence intervals.

valescent serum samples in 151 (55.5%). **Table 4** summarizes the results of the microbiologic investigations. There was no difference in the distribution of microbial agents identified in residents with pneumonia or other LRTIs. The most common etiologic agents identified were respiratory tract viruses, occurring in 60 (36.1%) of 166 episodes tested. *Chlamydia pneumoniae* was not detected using polymerase chain reaction in any of the 45 residents undergoing evaluation, although 3 other residents had serologic evidence of a recent *C pneumoniae* infection. Two residents with *Escherichia coli* bacteremia

had pneumonia without a urinary or other identified source of infection.

#### CLINICAL COURSE AND OUTCOME

Antimicrobial therapy was prescribed for every episode of pneumonia or other LRTI. Residents were transferred to hospital within 2 weeks of onset of symptoms in 48 (31.0%) of the 155 episodes of pneumonia. In contrast, only 11 episodes (9.4%) of other LRTIs resulted in transfer to hospital ( $P = .01$ ). Individuals who were older were less likely to be transferred to hospital (OR, 0.9 per year [95% CI, 0.9-1.0];  $P = .01$ ). None of the other variables assessed, including sex, history of respiratory tract infections, swallowing difficulty, ability to take oral medications, immobility, history of smoking, receipt of influenza and pneumococcal vaccines, use of minor or major tranquilizers, chronic lung disease, congestive heart failure, stroke, cancer, oropharyngeal colonization with gram-negative bacilli, or treatment with broad-spectrum antibiotics (eg, ciprofloxacin hydrochloride, a combination of trimethoprim sulfate and sulfamethoxazole, extended-spectrum cephalosporins, and a combination of amoxicillin and clavulanate potassium), was associated with hospital transfer.

Case fatality rates for residents with pneumonia and other LRTIs did not differ; 10 residents (8.8%) in whom pneumonia developed and 7 (7.9%) with other LRTIs died within 2 weeks of the infection ( $P = .98$ ). The case fatality rate for residents transferred to hospital was 21% compared with 7% for those treated in the nursing homes ( $P = .02$ ). Of the 17 residents who died, death was attributed to the infection itself in 13 (76.5%).

Sixty residents in whom first episodes of pneumonia developed and 39 residents with first episodes of other LRTIs could be matched to individuals in whom infection did not develop. Residents with pneumonia (OR, 0.7 [95% CI, 0.3-1.4];  $P = .31$ ) and those with other LRTIs (OR, 0.5 [95% CI, 0.2-1.1];  $P = .43$ ) were no more likely to have a deterioration in functional status than individuals in whom infection did not develop. The rate of decline in functional status was significantly greater before the infection than after for residents with pneumo-

**Table 2. Univariate Analysis of Potential Risk Factors for Pneumonia and Other LRTIs\***

Potential Risk Factor	Pneumonia			LRTI		
	Residents With/Without Pneumonia†	OR‡ (95% CI)	P	Residents With/Without Other LRTIs†	OR‡ (95% CI)	P
Age, mean (SD), y	85.8 (8.2)/83.5 (7.5)	1.7 (1.2-2.5)	.01	86.9 (7.4)/83.5 (7.5)	1.9 (1.3-2.8)	.01
Male sex, %	38/24	1.98 (1.22-3.20)	.01	13/24	0.50 (0.22-0.99)	.05
History of smoking, %	4/5	0.73 (0.17-2.53)	.57	3/5	0.52 (0.06-2.30)	.54
Inability to take oral medications, %	3/1	4.10 (0.62-15.75)	.18	1.5/1	1.50 (0.16-14.90)	.71
History of ≥3 RTIs in year before study entry, %	2/0.3	6.36 (0.33-376.3)	.12	3/0.3	9.29 (0.47-549.90)	.06
Chronic lung disease, %	11/9	1.27 (0.57-2.80)	.54	13/9	1.54 (0.64-3.64)	.31
Stroke, %	11/11	1.02 (0.46-2.20)	.96	13/11	1.22 (0.51-2.82)	.63
Congestive heart failure, %	4/6	0.71 (0.17-2.24)	.53	3/6	0.51 (0.06-2.25)	.34
Cancer, %	8/7	1.23 (0.48-3.08)	.63	4/7	0.65 (0.12-2.28)	.47
Diabetes mellitus, %	12/10	1.25 (0.58-2.67)	.54	11/10	1.03 (0.39-2.61)	.94
Oropharyngeal colonization with gram-negative bacteria, mean (SD), y	0.64 (0.93)/0.49 (0.88)	1.20 (0.08-1.50)	.18	0.64 (0.94)/0.49 (0.88)	1.18 (1.10-1.55)	.22
Swallowing difficulty, mean (SD), y	0.27 (0.58)/0.14 (0.46)	1.60 (1.06-2.42)	.03	0.24 (0.49)/0.14 (0.45)	1.49 (0.92-2.42)	.11
Exposure to influenza vaccination, mean (SD), y	1.1 (0.7)/1.8 (1.1)	0.43 (0.32-0.57)	.01	0.86 (0.75)/1.8 (1.1)	0.34 (0.24-0.48)	.01
Exposure to pneumococcal vaccine, mean (SD), y	1.2 (1.4)/1.5 (1.5)	0.86 (0.74-1.00)	.06	0.97 (1.3)/1.5 (1.5)	0.77 (0.64-0.93)	.01
Exposure to minor tranquilizers, mean (SD), y	0.94 (0.89)/0.98 (0.93)	0.95 (0.74-1.21)	.68	0.98 (0.93)/1.1 (0.91)	1.10 (0.83-1.45)	.47
Exposure to major tranquilizers, mean (SD), y	0.68 (0.69)/0.73 (0.80)	1.07 (0.84-1.73)	.78	0.75 (0.84)/0.73 (0.80)	1.08 (0.63-1.87)	.76
Immobility, mean (SD), y	0.91 (0.90)/0.82 (0.93)	1.10 (0.87-1.20)	.43	1.3 (1.1)/0.8 (0.93)	1.60 (1.22-2.06)	.01

\*LRTI indicates lower respiratory tract infection; RTI, respiratory tract infection; OR, odds ratio; and CI, confidence interval.

†For continuous variables, data are given as mean (SD).

‡Odds ratio refers to 1 year of exposure for all continuous variables except age, for which OR is a 10-year interval.

**Table 3. Risk Factors for Development of First Episodes of LRTI Among Residents of Nursing Homes by Multivariable Analysis\***

Variable	Adjusted OR (95% CI)†	P
<b>Pneumonia</b>		
Age	1.7 (1.1-2.6)	.01
Swallowing difficulty	2.0 (1.2-3.3)	.01
Influenza vaccination	0.4 (0.3-0.5)	.01
Male sex	1.9 (1.1-3.5)	.03
Inability to take oral medication	8.3 (1.4-50.3)	.02
<b>Other LRTI</b>		
Age	1.6 (1.0-2.5)	.05
Immobility	2.6 (1.8-3.8)	.01
Influenza vaccination	0.3 (0.2-0.4)	.01

\*LRTI indicates lower respiratory tract infection; OR, odds ratio; and CI, confidence interval.

†Odds ratio refers to 1 year of exposure for all continuous variables except age, for which OR is a 10-year interval.

nia (OR, 0.3 [95% CI, 0.1-0.4];  $P = .01$ ), but the difference was not significant for residents with other LRTIs (OR, 0.4 [95% CI, 0.1-1.2];  $P = .40$ ).

### COMMENT

We assessed risk factors for pneumonia and other LRTIs in a large cohort of nursing home residents observed up to 3 years. We also studied the effect of these infections on functional status and rates of transfer to hospital. The

observed respiratory tract infection rate of 1.2 per 1000 resident-days was within the range of previous reports (0.6-2.6 per 1000 resident-days).<sup>1-8</sup> Hospitalization and mortality rates in this study were also similar to those previously reported.<sup>6,9-14</sup>

Swallowing difficulty and an inability to take oral medications were independent risk factors for the development of pneumonia. These likely represented surrogate markers for aspiration in our study. Depression of swallowing reflexes in patients with aspiration pneumonia has been previously demonstrated,<sup>27</sup> and in a study assessing pulmonary aspiration in a long-term care setting, 56% of aspiration events progressed to pneumonia.<sup>28</sup> In our study, the development of pneumonia but not of other LRTIs was associated with surrogate markers of aspiration, possibly because aspiration is likely to be the dominant mechanism for pneumonia in the elderly, whereas other respiratory tract infections are more likely to be caused by viruses and to be unrelated to aspiration. Our findings are in keeping with the results of a study of community-acquired pneumonia in the elderly, where aspiration was determined to be an independent risk factor for pneumonia.<sup>29</sup> Difficulty with swallowing oropharyngeal secretions was also associated with pneumonia in a small case-control study in a long-term care facility.<sup>8</sup> Therefore, strategies directed at preventing aspiration may be useful in preventing pneumonia in elderly nursing home residents. Some measures that deserve further study include altering the consistency of the diet, the positioning of residents (especially during feeding), and the frequency and timing of meals.

**Table 4. Pathogenic Microorganisms Identified in Nursing Home Residents With Pneumonia or Other LRTIs\***

Infectious Agent	Identification Method, No. of Residents				Total No. of Residents
	Viral Isolation and/or Antigen Detection	Seroconversion†	Sputum Culture	Blood Culture	
Influenza virus type A‡	5	6	...	...	10
Influenza virus type B§	2	8	...	...	8
Parainfluenza virus§	35	7	...	...	40
Respiratory syncytial virus‡	1	2	...	...	2
<i>Chlamydia pneumoniae</i>	...	3	...	...	3
<i>Mycoplasma pneumoniae</i>	...	1	...	...	1
<i>Legionella sainthelensi</i>	...	1	...	...	1
<i>Haemophilus influenzae</i>	...	...	3	0	3
<i>Staphylococcus aureus</i>	...	...	3	0	3
<i>Streptococcus pneumoniae</i>	...	...	1	0	1
<i>Escherichia coli</i>	...	...	0	2	2
<i>Klebsiella pneumoniae</i>	...	...	1	0	1

\*LRTI indicates lower respiratory tract infection; ellipses, test not done or not relevant.

†Defined as at least 4-fold change in antibody titers in acute and convalescent serum samples.

‡One resident had viral antigens detected using nasopharyngeal specimen and seroconversion.

§Two residents had viral antigens detected using nasopharyngeal specimens and seroconversion.

Although oropharyngeal colonization with gram-negative bacteria has been associated with increased debility and mortality in the elderly,<sup>25</sup> it is uncertain whether such colonization leads to the development of pneumonia.<sup>25,30</sup> We did not find gram-negative oropharyngeal colonization to be a risk factor for pneumonia or other LRTIs.

Receipt of influenza vaccine was found to be a significant protective factor, associated with lower rates of respiratory tract infection, although influenza immunization rates in the study facilities were suboptimal (less than 80%). Volunteer bias, with study participants being more likely to have been vaccinated but less predisposed to infection, may have led to an overestimation of vaccine efficacy. Enrolled residents were, in fact, more likely to have received the vaccine than nonparticipants, although no differences in chronic underlying illnesses or other potential risk factors were identified. Moreover, the effectiveness of influenza vaccination in our study was similar to that determined in a recent meta-analysis with pooled estimates of vaccine efficacy of 53% to 56%.<sup>31</sup> These results confirm the importance of annual influenza vaccination for residents of long-term care facilities.

Pneumococcal vaccination was found to be protective in univariate analysis for other LRTIs (OR, 0.8 [95% CI, 0.6-0.9];  $P = .01$ ) and to be of borderline significance for pneumonia (OR, 0.9 [95% CI, 0.7-1.0];  $P = .06$ ). However, pneumococcal vaccination did not remain significant in the logistic regression models. Despite the uncertain efficacy of pneumococcal vaccination in preventing pneumonia, vaccination has been shown to be a cost-effective intervention for the prevention of invasive pneumococcal disease in the elderly.<sup>32-35</sup> The low average pneumococcal vaccination rate and the wide variability in the proportion of residents vaccinated among the nursing homes in our study (0%-66%) is a concern. These results suggest that considerable improvement in use of pneumococcal vaccine needs to be made for residents of long-term care facilities.

Our findings did not indicate that pneumonia or other LRTIs lead to sustained functional decline in nurs-

ing home residents. Functional decline occurred in infected and noninfected residents. However, neither pneumonia nor other LRTIs had a significant effect on functional status when infected individuals were compared with control subjects. Furthermore, the rate of decline of functional status was greater before than after pneumonia or other LRTIs, although the difference was not statistically significant in the latter. Although an alternative explanation for this may be that there was a floor effect in functional assessment in time, such that a more rapid decline would be expected early and smaller declines later, the fact that there were no differences when infected residents were compared with noninfected residents provides strong evidence that there is not a sustained significant effect of pneumonia or LRTI on functional status in this population.

There have been relatively few studies of nursing home-acquired pneumonia that have included extensive investigations to determine the microbial cause in sporadic infections (not associated with an outbreak). It is difficult to obtain sputum or other respiratory tract specimens for culture from nursing home residents, and tests to detect viral or other atypical respiratory tract pathogens are infrequently performed. Therefore, it is often impossible to identify the specific etiologic agent.<sup>13</sup> A specific microbial cause could be identified in only a few patients in this study; however, our results indicate that viral respiratory tract infections are common and frequently lead to the development of pneumonia in elderly nursing home residents.<sup>36,37</sup> Although nursing home outbreaks of infection due to *Legionella pneumophila* and *C pneumoniae* have been described,<sup>38-40</sup> our findings also confirm that infections due to *Legionella* species, *C pneumoniae*, or *M pneumoniae* occur infrequently in the institutionalized elderly.<sup>36,41-43</sup>

Strengths of our study include the prospective design, the large study population size, the long observation, and the intensive infection surveillance using standardized definitions of infection. Thus, we believe all episodes of pneumonia and LRTIs among residents in the

nursing homes were identified during the 3 years of study. Residents of the long-term care facilities in our study were demographically similar to those in most nursing homes in Ontario, and we believe the results of this multiple-center study are applicable to most other free-standing, community-based nursing homes in North America. Our findings, however, may not apply to Veterans Affairs facilities or other types of long-term care facilities such as chronic care hospitals or rehabilitation centers.

Our study identifies several important modifiable risk factors for the development of pneumonia and other LRTIs in elderly nursing home residents. We found that although these infections may be associated with impaired cognitive and/or functional status at onset of symptoms, they do not lead to long-term decline in functional status. Lack of influenza vaccination constituted an important risk for pneumonia and other LRTIs, confirming the importance of yearly immunization. Swallowing difficulty was also found to be a significant risk factor for pneumonia. Interventions aimed at reducing the risk for aspiration should be evaluated as a method for preventing pneumonia in residents of long-term care facilities.

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Reprints: Andrew E. Simor, MD, Department of Microbiology, Sunnybrook Health Science Centre, B121-2075 Bayview Ave, North York, Ontario, Canada M4N 3M5 (e-mail: andrew.simor@sunnybrook.on.ca).

## REFERENCES

- Jackson MM, Fierer J, Barrett-Connor E, et al. Intensive surveillance for infections in a three-year study of nursing home patients. *Am J Epidemiol*. 1992;135:685-696.
- Farber BF, Brennen C, Puntereri AJ, Brody JP. A prospective study of nosocomial infections in a chronic care facility. *J Am Geriatr Soc*. 1984;32:499-502.
- Nicolle LE, McIntyre M, Zacharias H, MacDonell JA. Twelve-month surveillance of infections in institutionalized elderly men. *J Am Geriatr Soc*. 1984;32:513-519.
- Schickler JM, Franson TR, Duthie ER Jr, LeClair SM. Comparison of methods for calculation and depiction of incidence of infection rates in long-term care facilities. *J Clin Epidemiol*. 1988;41:757-761.
- Scheckler WE, Peterson PJ. Infections and infection control among residents of eight rural Wisconsin nursing homes. *Arch Intern Med*. 1986;146:1981-1984.
- Muder RR, Brennen C, Swenson DL, Wagener M. Pneumonia in a long-term care facility: a prospective study of outcome. *Arch Intern Med*. 1996;156:2365-2370.
- Alvarez S, Shell CG, Woolley TW, Berk SL, Smith JK. Nosocomial infections in long-term care facilities. *J Gerontol*. 1988;43:M9-M17.
- Harkness GA, Bentley DW, Roghman KJ. Risk factors for nosocomial pneumonia in the elderly. *Am J Med*. 1990;34:457-463.
- Delegau J, Guay D, Straub K, Luxenberg MG. Effectiveness of oral antibiotic treatment in nursing home-acquired pneumonia. *J Am Geriatr Soc*. 1995;43:245-251.
- Starzewski AR, Allen SC, Vargas E, Lye M. Clinical prognostic indices of fatality in elderly patients admitted to hospital with acute pneumonia. *Age Ageing*. 1988;17:181-186.
- Mehr DR, Foxman B, Colombo P. Risk factors for mortality from lower respiratory infections in nursing home patients. *J Fam Pract*. 1992;34:585-591.
- Peterson PK, Stein D, Guay DRP, et al. Prospective study of lower respiratory tract infections in an extended-care nursing home program: potential role of oral ciprofloxacin. *Am J Med*. 1988;85:164-171.
- Marrie TJ, Durant H, Yates L. Community-acquired pneumonia requiring hospitalization: 5-year prospective study. *Rev Infect Dis*. 1989;11:586-599.
- Fang G-D, Fine M, Orloff J, et al. New and emerging etiologies for community-acquired pneumonia with implications for therapy: a prospective multicenter study of 359 cases. *Medicine (Baltimore)*. 1990;69:307-316.
- Dempsey CL. Nursing home pneumonia: outcomes from a clinical process improvement program. *Pharmacotherapy*. 1995;15(suppl):335-385.
- Setia U, Serventi I, Lorenz P. Nosocomial infections among patients in a long-term care facility: spectrum, prevalence, and risk factors. *Am J Infect Control*. 1985;13:57-62.
- Jacobson C, Strausbaugh LJ. Incidence and impact of infection in a nursing home care unit. *Am J Infect Control*. 1990;18:151-159.
- Beck-Sague C, Banerjee S, Jarvis WR. Infectious diseases and mortality among US nursing home residents. *Am J Public Health*. 1993;83:1739-1742.
- Franson TR, Duthie EH Jr, Cooper JE, Van Oudenhoven G, Hoffmann RG. Prevalence survey of infections and their predisposing factors at a hospital-based nursing home care unit. *J Am Geriatr Soc*. 1986;34:95-100.
- Magaziner J, Tenney JH, Deforge B, Hebel R, Muncie HL Jr, Warren JW. Prevalence and characteristics of nursing home-acquired infections in the aged. *J Am Geriatr Soc*. 1991;39:1071-1078.
- Katz S, Downs TD, Cash HR, Frotz RD. Progress in development of the index of ADL. *Gerontologist*. 1970;10:20-30.
- McGeer A, Campbell B, Emori TG, et al. Definitions of infection for surveillance in long-term care facilities. *Am J Infect Control*. 1991;19:1-7.
- Campbell LA, Melgrosa MP, Hamilton DJ, Juo C-C, Grayston JT. Detection of *Chlamydia pneumoniae* by polymerase chain reaction. *J Clin Microbiol*. 1992;30:434-439.
- Gaydos CA, Quinn TC, Eiden JJ. Identification of *Chlamydia pneumoniae* by DNA amplification of the 16S rRNA gene. *J Clin Microbiol*. 1992;30:796-800.
- Nicolle LE, McLeod J, McIntyre M, MacDonell JA. Significance of pharyngeal colonization with aerobic gram-negative bacilli in elderly institutionalized men. *Age Ageing*. 1986;15:47-52.
- Fleiss JL, Everitt BS. Comparing the marginal totals of square contingency tables. *Br J Math Stat Psychol*. 1971;24:117-123.
- Nakazawa H, Sekizawa K, Ujicie Y, Sasaki H, Takishima T. Risk of aspiration pneumonia in the elderly [letter]. *Chest*. 1993;103:1636-1637.
- Pick N, McDonald A, Bennett NN, et al. Pulmonary aspiration in a long-term care setting: clinical and laboratory observations and an analysis of risk factors. *J Am Geriatr Soc*. 1996;44:763-768.
- Riquelme R, Torres A, El-Ebiary M, et al. Community-acquired pneumonia in the elderly: a multivariate analysis of risk and prognostic factors. *Am J Respir Crit Care Med*. 1996;154:1450-1455.
- Irwin RS, Whitaker S, Pratter MR, Millard CE, Tarpey JT, Corwin RW. The transiency of oropharyngeal colonization with gram negative bacilli in residents of a skilled nursing facility. *Chest*. 1982;81:31-35.
- Gross PA, Hermogenes AW, Sacks HS, Lau J, Levandowski RA. The efficacy of influenza vaccine in elderly persons: a meta-analysis and review of the literature. *Ann Intern Med*. 1995;123:518-527.
- Sims RV, Steinmann WC, McConville JH, King LR, Zwick WC, Schwartz JS. The clinical effectiveness of pneumococcal vaccine in the elderly. *Ann Intern Med*. 1988;108:653-657.
- Sisk JE, Moskowitz AJ, Whang W, et al. Cost-effectiveness of vaccination against pneumococcal bacteremia among elderly people. *JAMA*. 1997;278:1333-1339.
- Fedson DS. Pneumococcal vaccination in the prevention of community-acquired pneumonia: an optimistic view of cost-effectiveness. *Semin Respir Infect*. 1993;8:285-293.
- Centers for Disease Control and Prevention. Prevention of pneumococcal disease: recommendations of the Advisory Committee on Immunization Practices (ACIP). *MMWR Morb Mortal Wkly Rep*. 1997;46(No. RR-8):1-24.
- Arroyo JC, Jordan W, Milligan L. Upper respiratory tract infection and serum antibody responses in nursing home patients. *Am J Infect Control*. 1988;16:152-158.
- Falsey AR, Treanor JJ, Betts RF, Walsh EE. Viral respiratory infections in the institutionalized elderly: clinical and epidemiologic findings. *J Am Geriatr Soc*. 1992;40:115-119.
- Brennen C, Vickers RM, Yu VL, Puntereri A, Yee YC. Discovery of occult legionella pneumonia in a long stay hospital: results of prospective serological survey. *BMJ*. 1987;295:306-307.
- Mafasaki S, Kohno S, Koga H, et al. An outbreak of Legionnaire's pneumonia in a nursing home. *Intern Med*. 1992;31:508-512.
- Troy CJ, Peeling RW, Ellis AG, et al. *Chlamydia pneumoniae* as a new source of infectious outbreaks in nursing homes [published correction appears in *JAMA*. 1997;278:118]. *JAMA*. 1997;277:1214-1218.
- Storch G, Hayes PS, Hill DL, Baine WB. Prevalence of antibody to *Legionella pneumophila* in middle-aged and elderly Americans. *J Infect Dis*. 1979;140:784-788.
- Drinka PJ, Gauerke C, Voeks S, et al. Pneumonia in a nursing home. *J Gen Intern Med*. 1994;9:650-652.
- Orr PH, Peeling RW, Fast M, et al. Serological study of responses to selected pathogens causing respiratory tract infection in the institutionalized elderly. *Clin Infect Dis*. 1996;23:1240-1245.