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Disability and Cognitive Impairment Are Risk Factors for Pneumonia-Related Mortality in Older Adults

MARCEL E. SALIVE, MD, MPH
SUZANNE SATTERFIELD, MD
ADRIAN M. OSTFELD, MD
ROBERT B. WALLACE, MD
RICHARD J. HAVLIK, MD, MPH

Dr. Salive is Epidemiologist and Dr. Havlik is Associate Director, Epidemiology, Demography and Biometry Program, National Institute on Aging, National Institutes of Health. Dr. Satterfield is with Channing Laboratory, Department of Medicine, Harvard Medical School, and the East Boston Neighborhood Health Center, Boston. Dr. Ostfeld is Professor, Department of Epidemiology and Public Health, Yale University School of Medicine, New Haven, CT. Dr. Wallace is Professor and Head, Department of Preventive Medicine and Environmental Health, University of Iowa, Iowa City.

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Tearsheet requests to Dr. Salive, Gateway Building, Suite 3C309, 7201 Wisconsin Ave., Bethesda, MD 20892; tel. 301-496-1178.

Synopsis

The role of functional and cognitive limitations in the risk of pneumonia-related mortality in older adults was examined. As part of a cohort study in 3 communities (East Boston, MA; New Haven, CT; and Iowa and Washington Counties, IA), 6,234 women and 4,035 men ages 65 or older completed baseline interviews between 1981 and 1983 and were followed for up to 6 years. Sex-specific Cox proportional-hazards regression models were used to examine the association of baseline physical and cognitive functioning with report of pneumonia (ICD9 480–486) as an underlying, immediate, or contributing cause of death.

During followup, a total of 243 men and 160 women died with pneumonia. Adjusting for age, race, education, evidence of five chronic diseases, and smoking status, a significantly increased risk of pneumonia mortality ($P < 0.05$) was found for limitations in activities of daily living and cognitive impairment among both men and women. Inability to walk a half mile, climb stairs, or perform heavy housework was significantly associated with increased risk of pneumonia mortality for women but not for men in the same multivariate models. Men and women whose body-mass index was above the median had significantly lower risk of pneumonia mortality compared with those in the lowest quartile. Further elucidation of the sequence between physical and cognitive impairment and risk of pneumonia will be important in reducing pneumonia-associated morbidity and mortality.

DESPITE GREAT PROGRESS against infectious disease in this century, pneumonia remains the leading infectious cause of death, particularly among older adults. Pneumonia-influenza is the fifth leading cause of death among persons ages 65 and older in the United States. More than 65,000 older persons

died from pneumonia in 1988, representing 88 percent of all pneumonia deaths (*1*).

After reaching a nadir in 1982, the pneumonia mortality rate subsequently increased by more than 25 percent (*1,2*). This jump, attributed to multiple influenza outbreaks (*3*), occurred in the face of a national goal to reduce pneumonia deaths in older adults (*4*). Pneumonia is also a major cause of hospitalization in older persons; in 1988 it accounted for 456,000 hospitalizations among Medicare beneficiaries and was the leading cause of hospitalization among those ages 85 and older (*5*). About 18 percent of Medicare beneficiaries hospitalized for pneumonia die within 30 days from all causes (*6*).

Although pneumonia has great public health importance, the reasons for its persistence as a cause of mortality are little understood. Pneumonia has long been known as the "old man's friend," described by some as the terminal illness among elders with chronic disease (*7*). Thus pneumonia-related mortality may occur through a synergism among poor nutrition, declining host defenses, and advanced chronic diseases, that are prominent in older persons (*7,8*).

Although Schneider (*8*) called for population-based studies of infectious diseases to examine their relationship with possible risk factors, only a few of the ensuing reports have taken such an approach. LaCroix reported that age, sex, and history of congestive heart failure, stroke, cancer, and diabetes were associated with increased risk of pneumonia death in a nationally representative sample (*9*). Low body-mass index and arm muscle area, markers of nutritional status, were associated with pneumonia mortality in men, while an association with low serum albumin was reported for women (*9*). Older diabetics reportedly have elevated mortality because of pneumonia and influenza (*10*). Retrospective and clinical studies of pneumonia have also implicated chronic disease comorbidity, including dementia, seizure disorder, and chronic obstructive pulmonary disease as risk factors for pneumonia (*11,12*). Prior hospitalization, a nonspecific marker of illness or injury, was also related to pneumonia (*13*).

We hypothesized that functional disability and cognitive impairment might, through malnutrition and subsequent decreased host defenses (*7*), increase the risk of subsequent pneumonia-related mortality. Three communities of the Established Populations for the Epidemiologic Studies of the Elderly (EPESE) provide an opportunity to examine this relationship in a large prospective study with adjustment for other known risk factors.

'We hypothesized that functional disability and cognitive impairment might, through malnutrition and subsequent decreased host defenses, increase the risk of subsequent pneumonia-related mortality.'

Materials and Methods

Study populations. The data for this report are from three communities of the EPESE, a collaborative longitudinal study of older men and women, initiated and funded by the Epidemiology, Demography and Biometry Program of the National Institute on Aging. Details of the methods have been reported elsewhere (*14–18*).

Between 1981 and 1983, approximately 10,300 participants ages 65 and older were enrolled at East Boston, MA; Iowa and Washington counties, IA; and New Haven, CT. Full community surveys were conducted in East Boston and rural Iowa. Of the eligible community residents, 3,809 (84 percent) in East Boston and 3,673 (80 percent) in rural Iowa completed initial interviews. The New Haven population was drawn from a stratified random sample defined according to housing status, with an oversampling of men. Of those who were eligible, 2,812 (82 percent) completed initial interviews in New Haven. Trained interviewers conducted the household baseline surveys and six annual followup interviews by telephone or in person. Among those initially interviewed, the response rates for the followup interviews were above 95 percent in each community.

The followup interviews ascertained the major EPESE outcomes: hospitalization, institutionalization, functional status, and vital status. Information on vital status during followup came first from interviews with proxies and local newspaper obituaries. Additional corroboration was provided by the National Death Index, linked 18 months after the completion of followup. We then requested death certificates. Information from the death certificates was coded by a single nosologist using the ninth revision of the International Classification of Diseases (ICD-9) (*19*).

We evaluated the relation of prior disability with pneumonia at the time of death. To examine pneumonia as a "terminal illness" (*7*) and because intensive clinical study of older pneumonia patients often reveals no pathogen (*20,21*), we elected to

Table 1. Percentage distribution of selected baseline characteristics by sex, Established Populations for the Epidemiologic Studies of the Elderly, 1981–83

Characteristic	Men (N = 4,035)	Women (N = 6,234)
Age (mean years)	73.8	74.7
Education (mean years)	9.8	10.0
Body-mass index (kg/m^2):		
75 percentile	28.6	29.4
median	26.2	25.6
25 percentile	23.7	22.7
Race:		
White	94.7	93.7
Black	4.7	5.6
Other	0.6	0.6
Smoking status:		
Never	34.9	74.3
Former	45.3	13.1
Current:		
fewer than 20 cigarettes a day	8.3	6.4
20 cigarettes a day or more	11.4	6.2
Consumed alcohol in previous year	73.5	53.9
Exercises	62.7	48.8
Disease history:		
Diabetes	13.4	12.5
Cancer with hospitalization	8.0	13.2
Hip fracture	3.0	4.7
Stroke	7.1	5.0
Heart attack	16.8	8.9
Use of congestive heart failure medication	7.8	10.0
Respiratory symptoms	32.2	29.3
Ability to climb stairs, walk half mile and do heavy housework:		
Able to do all	60.0	49.3
Unable to do one or more	40.0	50.7
Activity of daily living limitations:		
None	94.0	94.0
One	3.2	3.4
Two or more	2.8	2.6
Cognitive function:		
Normal	77.6	77.4
Mild-moderate impairment	11.0	11.9
Severe impairment	3.3	4.7
SPMSQ missing	8.1	6.0

NOTE: SPMSQ = Short Portable Mental Status Questionnaire.

group all reported pneumonias (ICD-9 480–486) together for analysis, identified from all fields on the death certificate, whether an underlying, immediate, or contributing cause of death.

All disability measures and other potential risk factors for pneumonia were determined at the initial interview in the home. We examined disability measures from Rosow's and Breslau's Guttman health scale for the aged (*22*), limitations of activities of daily living, and cognitive impairment. Disability, as measured by the scale, was present if the participant reported inability to climb a flight of stairs, perform heavy housework, or walk a half-mile without help (*22*). Limitations in six activities of daily living (walking, bathing, dressing, eating, transferring from bed to chair, and using the toilet) were coded as the sum (0 to 2 or more) of those that the person was unable to perform or required help from another person (*23,24*). Cognitive function was tested with the Short Portable Mental Status Questionnaire (SPMSQ) (*25,26*) and classified as no impairment (0–2 errors) scored as 0, mild-moderate impairment (3–4 errors) scored as 1, and severe impairment (5 or more errors) scored as 2. The SPMSQ was not used in the case of proxy respondents.

During the initial interview, information on age, sex, race, chronic conditions diagnosed by a physician (or by other health care providers in East Boston), and health habits were also obtained. Years of education were grouped as no high school, some to completion of high school, or some college.

Cigarette smoking has been associated with pneumonia mortality (*27–31*). Smoking status was classified as current smoker, former smoker, or never smoker. Number of cigarettes smoked per day by current smokers was grouped as fewer than 20 or 20 or more to examine intensity of smoking.

A lifetime history of each of five conditions (heart attack, stroke, cancer, diabetes mellitus, and hip fracture) was coded as present if the participant reported that a health care provider said that the diagnosis was definite. Diagnosis of cancer accompanied by hospitalization was examined as a marker of more severe disease. Use of medications for congestive heart failure was examined, since participants had not been questioned regarding the condition. This was considered positive if the participant reported taking both a digitalis preparation and a diuretic agent during the preceding 2 weeks.

Body-mass index was computed as weight in kilograms divided by the square of height in meters from self-reported data and divided into quartiles for both men and women. Alcohol consumption in the previous year was assessed by combining questions pertaining to intake of beer, wine, and liquor. Alcohol consumption in ounces per day was computed using the Framingham equation (*32*). Exercise was assessed by combining several site-specific questions relating to gardening, walking, and more vigorous exercise.

The only questions asked in all sites related to respiratory function measured current symptoms—shortness of breath, coughing, wheezing, or production of phlegm (*33*). The only site-specific variables considered for this analysis related to respiratory function because of their importance in relation to subsequent pneumonia. Self-reports of

Table 2. Pneumonia mortality rates[1] according to age, sex, and location, Established Population for the Epidemiologic Studies of the Elderly, 1981–90

Age, sex	East Boston		New Haven		Iowa		All sites	
	Rate[2]	Person-years	Rate[1]	Person-years	Rate[1]	Person-years	Rate[1]	Person-years
Men								
Age (years):								
65–74	5.70	4,210	1.03	2,920	2.55	3,528	3.38	10,658
75–84	18.88	2,807	9.69	2,065	9.92	2,822	13.13	7,694
85 and older	58.04	724	47.60	567	50.95	726	52.55	2,017
All[2]	14.58	7,741	7.94	5,552	9.21	7,076	10.87	20,369
Women								
Age (years):								
65–74	0.89	6,726	1.64	3,668	1.01	4,949	1.11	15,343
75–84	4.01	5,483	2.74	3,654	4.08	5,388	3.72	14,525
85 and older	17.76	1,520	19.94	1,304	20.04	1,796	19.26	4,620
All[2]	3.39	13,729	3.61	8,626	3.68	12,133	3.56	34,488

[1] Rate per 1,000 person-years of pneumonia as underlying, immediate, or contributing cause of death.

[2] Rate is age-adjusted to the population of the 3 communities at baseline.

prior physician diagnosis of asthma or emphysema, chronic bronchitis, or other lung diseases were determined in Iowa only. Peak expiratory flow, measured in East Boston only (*34*), was grouped into quartiles for analysis.

The group in this study was drawn from baseline participants with up to 6 years of followup. We subsequently excluded those few persons without a subsequent interview and with an unknown date of death. The final sample therefore included 10,269 participants (distributed across the communities as follows: 3,809 in East Boston, 3,663 in Iowa, and 2,797 in New Haven).

Statistical analysis. The incidence rates of pneumonia mortality per 1,000 person-years were examined according to community, sex, and age. Person-years were calculated by totaling the time between the initial interview and death, the last interview, or the end of the sixth year of followup, whichever came first, for all participants according to age. Direct age-adjustment was performed using the baseline combined population of the three sites as the standard population (*35*). Sex-specific analyses were performed because of the known differences in pneumonia mortality between men and women (*1,3,9*). Men and women were compared with respect to other potential risk factors for pneumonia. Cox proportional-hazards regression models were used to calculate the relative risk for the measures of interest adjusted for age, race, and education. Initially, three separate models were examined for history of chronic diseases, health behaviors and body-mass index, and functional status measures. A final model was analyzed using those variables from the initial models that were significant at the $P < 0.1$ level. Overall estimates of relative risk were computed from Cox regression models stratified by community using the blocking option of SAS PROC PHGLM (*36*).

'Our report describes pneumonia-associated mortality among cohorts of adults ages 65 or older in three communities and highlights factors that might be useful in designing and implementing preventive strategies.'

Results

The participants' average age at baseline was about 74 years for men and 75 years for women (table 1). The cohort was largely white, with 5–6 percent black (nearly all in New Haven) and less than 1 percent from other racial groups. Smoking patterns differed; more men were current and former smokers compared with women. Men had higher rates of recent alcohol consumption and exercise compared with women. The most commonly reported conditions included diabetes and heart attack. Eight percent of men and 10 percent of women reported current use of medications for congestive heart failure (digitalis and a diuretic). Forty percent of men and 51 percent of women were unable to walk a half-mile, climb a flight of stairs, or perform heavy housework without help. Limitations in activities of daily living were less common, reported by only 6 percent of men and women. Cognitive impairment was detected in 14–16 percent of participants; 6–8 percent did not complete that portion of the interview.

Table 3. Relation of chronic disease, health behavior, and disability risk factors to pneumonia mortality in sex-specific regression models, Established Populations for the Epidemiologic Studies of the Elderly, 1981–90

Characteristics	Men		Women	
	Relative risk[1]	95 percent CI	Relative risk[1]	95 percent CI
	Chronic Diseases Model[2]			
History of:				
Diabetes	1.9	1.4,2.6	1.7	1.1,2.6
Cancer with hospitalization	1.2	0.8,2.0	1.1	0.7,1.7
Hip fracture	1.5	0.8,2.6	1.6	1.0,2.8
Stroke	1.5	1.0,2.3	1.5	0.9,2.7
Heart attack	1.2	0.9,1.7	1.0	0.6,1.7
CHF medication use	1.7	1.2,2.6	1.3	0.8,2.0
Respiratory symptoms	1.2	0.9,1.6	1.2	0.8,1.7
	Health Behaviors and Body-Mass Index Model[2]			
Body-mass index:				
Lowest quartile	(1.0)	...	(1.0)	...
Second quartile	0.7	0.5,1.0	0.5	0.3,0.9
Third quartile	0.7	0.5,1.0	0.5	0.3,0.8
Highest quartile	0.5	0.3,0.7	0.4	0.2,0.7
Smoking status:				
Never	(1.0)	...	(1.0)	...
Former	1.9	1.4,2.6	1.0	0.6,1.8
Current:				
Fewer than 20 cigarettes a day	1.1	0.6,1.9	1.1	0.5,2.5
20 or more cigarettes a day	2.0	1.3,3.3	2.2	1.1,4.5
Consumed alcohol in previous year (no)	1.0	0.8,1.4	1.3	1.0,1.9
Exercises (yes)	0.6	0.5,0.8	0.7	0.5,1.0
	Physical and Cognitive Function Model[2]			
Ability to climb stairs, walk half mile, and do heavy housework:				
Disability	1.7	1.3,2.3	2.2	1.5,3.3
ADL limitations:				
Disability[3]	1.7	1.3,2.1	1.5	1.1,2.0
Cognitive function:				
Limitation[4]	1.4	1.2,1.8	1.6	1.2,2.0
SPMSQ missing	1.5	1.0,2.4	2.7	1.7,4.6

[1] Relative risk computed from sex-specific Cox regression models based on pneumonia deaths of 243 men and 160 women.
[2] Relative risk adjusted for main effects shown plus age, race, and education.
[3] Coded as the number of limitations: 0=0, 1=1, 2=2 or more. Relative risk shown for one limitation.
[4] Coded as the number of errors on SPMSQ: 0 = no impairment, 1 = mild-moderate impairment, 2 = severe impairment. Relative risk shown for mild-moderate impairment.
CI = confidence interval; CHF = congestive heart failure; ADL = activities of daily living; SPMSQ = Short Portable Mental Status Questionnaire.

The 10,269 participants were observed for a total of 54,857 person-years during the 6 years of followup. During that time, 403 persons (243 men and 160 women) had pneumonia reported on their death certificate, representing 11 percent of all deaths. Of the 403 pneumonia-related deaths, an example of the major underlying causes of death included pneumonia (N=162, 40 percent); cardiovascular disease (N=106, 26 percent); cancer (N=60, 15 percent) and other respiratory diseases (ICD-9 460–479, 487–519) (N=22, 5 percent). The proportion of pneumonia-related deaths to deaths from other respiratory diseases was elevated compared with all other deaths; this proportion was not elevated for cardiovascular disease and cancer.

The age-adjusted pneumonia death rate per 1,000 person-years was 4.3 for men and 1.4 for women, examining the underlying cause of death only. Rates of pneumonia mortality (using all death certificate mentions) varied by age, site, and sex (table 2). These rates were about threefold higher among men compared with women; the only subgroup where women's rates exceeded men's was among New Havenites ages 65–74. Among men, pneumonia rates were highest among the oldest old (those ages 85 or older) and in East Boston residents.

Model building. A history of diabetes (both sexes) and use of congestive heart failure medications (men) were significantly associated with pneumonia-related mortality (table 3). Respiratory symptoms and history of cancer requiring hospitalization were not significantly associated with pneumonia mortality and were dropped from further modeling. Body-mass index and exercise were inversely associated with pneumonia death for both sexes. Those who exercised had a relative risk of pneumonia-related mortality 30 to 40 percent lower than those who were less active. Former smokers (men) and current heavy (20 or more cigarettes per day) smokers were at higher risk for pneumonia mortality. Alcohol consumption in the year prior to the baseline survey was not significantly associated with pneumonia-related death; alcohol consumption in ounces per day did not exhibit a consistent relationship either (data not shown). Thus alcohol consumption was not used in the final model. Measures of physical disability and cognitive impairment were associated with subsequent pneumonia-related mortality when adjusted for age, race, and education.

Final multivariate model. In the final model, which included age, race, education, history of chronic conditions, smoking, body-mass index, and exercise, the measures of disability remained significant independent risk factors for pneumonia mortality with slightly lower relative risks than in the initial

analysis (table 4). Inability to walk a half-mile, climb stairs, or do heavy housework had a relative risk of 1.3 in men ($P=0.08$) and 1.9 in women ($P=0.002$). A single limitation was associated with a relative risk of 1.6 in men ($P < 0.001$) and 1.4 in women ($P=0.03$); having two or more limitations was associated with a relative risk of 2.7 in men and 1.9 in women. Mild to moderate cognitive impairment was associated with a 40-percent increased risk of pneumonia mortality in both men and women, with severe cognitive impairment associated with a relative risk of 1.9–2.0 for pneumonia death. Missing data on the cognitive function test were not related consistently to pneumonia death: it was significantly protective in Iowa men (risk rate 0.12, 95 percent CI 0.02,0.72, $P=0.02$), but significantly associated with increased risk among East Boston women (risk rate 3.2, 95 percent CI 1.3,8.2, $P=0.01$), and weakly associated with increased risk in the other site-sex combinations.

The highest two quartiles of body-mass index had significantly reduced risk of pneumonia compared with the lowest quartile in the same multivariate models. The other statistically significant predictive variables in the final model exhibited consistent relationships in the three sites. All other variables that were significantly associated with pneumonia mortality at a single site remained significant in the final models, with two exceptions: hip fracture among Iowa men (relative risk 2.7, $P=0.02$) and heart attack among New Haven women (relative risk 2.5, $P=0.03$).

In East Boston, those with the lowest quartile of peak expiratory flow had increased risk of pneumonia mortality (compared with the highest quartile) for both men (relative risk 2.6, 95 percent CI 1.7,3.9) and women (relative risk 2.8, 95 percent CI 1.4,5.7). Self-reported emphysema, chronic bronchitis, or other lung disease was not significantly associated with pneumonia mortality in Iowa, adjusting for all variables in the final model; self-reported asthma was not an independent risk factor either in this site.

To confirm the results, we limited the analysis to cases in which pneumonia was the *underlying* cause of death in another multivariate Cox proportional-hazards model, using the same dependent variables as the final model. The results were consistent with the analyses reported previously, particularly for the disability variables (data not shown).

To examine the role of institutionalization in pneumonia mortality, we examined reported site of death and evidence of a nursing home stay. Of the 403 participants who died with pneumonia, 208 (52 percent) had evidence of a nursing home stay after baseline, compared with only 32 percent among all other deaths ($P < 0.001$). Of those with pneumonia, 116 (29 percent) died in the nursing home, in contrast with 20 percent of all other deaths ($P < 0.001$).

Table 4. Final model of the relation of chronic disease, health behavior, and disability risk factors to pneumonia mortality, Established Population for the Epidemiologic Studies of the Elderly, 1981–90

Characteristic	Men		Women	
	Relative risk[1]	95 percent CI	Relative risk[1]	95 percent CI
Age (10-year difference)	2.4	2.0,2.9	2.1	1.6,2.7
History of:				
Diabetes	1.9	1.3,2.6	1.6	1.04,2.5
Hip fracture	1.2	0.7,2.2	1.3	0.8,2.3
Stroke	1.1	0.7,1.6	1.1	0.6,2.1
Heart attack	1.3	0.9,1.8	1.1	0.6,1.8
CHF medication use	1.7	1.1,2.4	1.2	0.8,2.0
Body-mass index:				
Lowest quartile	(1.0)	...	(1.0)	...
Second quartile	0.7	0.5,1.06	0.6	0.4,0.9
Third quartile	0.6	0.4,0.9	0.5	0.3,0.8
Highest quartile	0.5	0.3,0.8	0.4	0.2,0.8
Smoking status:				
Never	(1.0)		(1.0)	
Former	1.7	1.3,2.4	1.0	0.6,1.8
Current:				
Fewer than 20 cigarettes a day	0.9	0.5,1.7	1.2	0.6,2.7
20 or more cigarettes a day	2.0	1.2,3.2	2.4	1.2,4.8
Exercises (yes)	0.9	0.6,1.1	0.9	0.6,1.3
Ability to climb stairs, walk half mile, and do heavy housework: disability	1.3	0.96,1.9	1.9	1.3,3.0
Activities of daily living: disability[2]	1.6	1.3,2.0	1.4	1.04,1.9
Cognitive impairment:				
Impairment[3]	1.4	1.10,1.8	1.4	1.08,1.8
SPMSQ missing	1.1	0.6,1.9	1.9	0.93,3.8

[1] Relative risks computed from sex-specific Cox regression models including race, education, peak expiratory flow (East Boston), emphysema (Iowa), and all main effects listed.

[2] Coded as the number of limitations: 0=0, 1=1, 2=2 or more. Relative risk shown for one limitation.

[3] Coded as the number of errors on SPMSQ: 0 = no impairment, 1 = mild-moderate impairment, 2 = severe impairment. Relative risk shown for mild-moderate impairment.

CI = confidence interval; CHF = congestive heart failure; SPMSQ = Short portable mental status questionnaire.

Discussion

Our report describes pneumonia-associated mortality among cohorts of adults ages 65 or older in three communities and highlights factors that might

'Elucidation of the intervening sequence between impairment and risk of pneumonia mortality will be important in achieving the national objective for reducing pneumonia-associated morbidity.'

be useful in designing and implementing preventive strategies. Moderate and severe disability as well as cognitive impairment were independent risk factors for subsequent pneumonia death. The nursing home appears to be an intervening factor in the majority of pneumonia-related deaths. Increased risk was also consistently associated with being male, increasing age, cigarette smoking, low body-mass index, and history of diabetes mellitus. Stratification revealed little that could explain the sex differences in risk of pneumonia death.

The large number of older adults studied had quite complete followup for vital status, and death certificates were obtained in nearly all cases. Several limitations of the data, however, deserve consideration. The majority of deaths were reported by the physician without specifying an organism on the death certificate. This is consistent with clinical reports from older patients (*20,21*). Some cases of pneumonia may not have been reported on the death certificate (*37*), but our use of all reports of pneumonia probably minimized misclassification. The accuracy of reported pneumonia was not assessed, although others have reported 73-percent accuracy in an autopsy series (*38*).

Vaccination history was not ascertained in this study, although few elders nationwide received pneumococcal and influenza vaccine in the mid-1980s, despite reimbursement by the Medicare program (*39,40*). Pneumococcal vaccine efficacy may decline with aging, and in any case it does not prevent pneumonias caused by other organisms (*41*). We also did not assess additional nutritional and immunologic markers. The use of medication history as a marker for congestive heart failure may have resulted in some misclassification. During the 6 years of followup, the participants' risk factor status could change, for example, with the development of disability or disease, resulting in some underestimation of relative risk of pneumonia mortality. We chose not to use time-dependent covariates, however, because the measures were reassessed at different intervals, from 1 to 3 years; a few variables were dropped from followup surveys.

One potentially significant drawback of this study was the lack of a good measure of chronic lung disease. Respiratory symptoms (shortness of breath, coughing, wheezing, or production of phlegm) were not associated with pneumonia mortality. Although self-reported chronic lung disease, measured only in Iowa, was associated with pneumonia in models with fewer variables, it was not an independent factor in the final multivariate model, possibly due to low power or confounding. Peak expiratory flow, although strongly related to pneumonia mortality, was measured only in East Boston. The East Boston data suggest, however, that respiratory function and disability are not strong confounders, and both independently predict risk for pneumonia mortality. Overall, we believe that many of the identified problems would have a small effect, probably toward the null hypothesis, and that our conclusions are valid.

Two measures of functional disability, the Rosow-Breslau scale (in women) and activities of daily living (men and women), were independent risk factors for pneumonia mortality. They are probably independent because of the hierarchical nature of disability, in that inability to walk a half-mile, climb stairs, or do heavy housework without help is a milder impairment than requiring help for activities for daily living (*42*). To our knowledge, this is the first demonstrated association of disability with a specific cause of death, although disability has been associated with all-cause mortality (*43*). Our measure of exercise was confounded by disability in this analysis and was not independently associated with pneumonia mortality in the final model (table 4).

Cognitive impairment was also independently associated with pneumonia mortality in this analysis. Both mild to moderate and severe impairments were associated with increased risk for pneumonia-related death. Although it has been reported that cognitive impairment increases risk of all-cause mortality (*44*), our observation extends that finding to a specific cause of death. Our results are also consistent with the observed association of dementia with pneumococcal pneumonia (*12*). The higher use of proxies in Iowa for male farmers working at the time of baseline interview probably explains the inconsistent finding regarding missing cognitive functioning data and pneumonia mortality. In women from Iowa and both sexes from the other sites, proxies were generally used at baseline most commonly for the cognitively impaired. Alternatively, this finding could be a statistical artifact.

In these cohorts that were exclusively commu-

nity-dwelling at baseline, institutionalization appears to play a prominent role in pneumonia-associated mortality, consistent with prior reports from nursing homes (*45*). Functional and cognitive impairment, most likely from underlying disease and deconditioning together with social factors, ultimately contribute to placement in a nursing home (*17*). Inability to perform activities of daily living (such as feeding) could lead to worsening nutritional status (*18*) and subsequently to poor immunologic status (*7*). Institutional status increases risk of nosocomial infection and may predispose to pneumonia. Cognitive impairment may also affect the gag reflex and predispose to aspiration followed by pneumonia.

Our outcome measure, pneumonia mortality, reflects both the risk of pneumonia and its case-fatality rate, both of which could be related to disability and institutionalization (*17,46,47*). Data on cases of pneumonia would be required to distinguish between these possibilities. We plan to evaluate further the temporal sequence in these cohorts using the longitudinal interview data, as well as more recently obtained information on hospitalizations reported to the Health Care Financing Administration.

Although some pneumonia deaths may not be preventable, there may be points where therapeutic or preventive intervention can be employed. Elucidation of the intervening sequence between impairment and risk of pneumonia mortality will be important in achieving the national objective for reducing pneumonia-associated morbidity (*48*).

The major modes of pneumonia prevention include immunization against influenza and pneumococcus and the judicious use of amantadine chemoprophylaxis. Although the Immunization Practices Advisory Committee recommends that all older adults be vaccinated against both pathogens (*49,50*), others have proposed only vaccinating high-risk persons (*51*). However, 85 percent of the men and 77 percent of the women in these three communities had at least one of the risk factors identified in table 4. Thus, the apparent disagreement may be moot, and we encourage continuing the policy of vaccinating all older adults. Moreover, added emphasis on prevention among the mildly disabled of all ages, particularly women, such as those unable to climb stairs, walk half a mile, or do heavy housework, should be considered. Evaluation of vaccine effectiveness across the spectrum of disability would help resolve the issue of whether vaccination early in the course of disability contributes to the prevention of pneumonia or its complications. Research into interventions that would alter the course of disability is also needed, particularly with respect to their effect on longer term patient outcomes such as pneumonia mortality.

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