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Modifiable Risk Factors for Pneumonia Requiring Hospitalization among Community-Dwelling Older Adults: The Health, Aging, and Body Composition Study

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Abstract

Background—Pneumonia requiring hospitalization remains a major public health problem among community-dwelling older adults. Impaired oral hygiene is a modifiable risk factor for healthcare-associated pneumonia, but its role in community-acquired pneumonia is unclear.

Objectives—To identify novel modifiable risk factors, focusing on oral hygiene, for pneumonia requiring hospitalization among community-dwelling older adults.

Design—Prospective observational cohort study

Setting—Memphis, Tennessee and Pittsburgh, Pennsylvania

Participants—Of 3075 well-functioning community-dwelling adults aged 70–79 years enrolled in the Health, Aging, and Body Composition Study from 1997–1998, 1441 had complete data, dental exam within six months of baseline, and were eligible for this study.

Measurements—The primary outcome was pneumonia requiring hospitalization through 2008.

Results—Of 1441 participants, 193 were hospitalized for pneumonia. In a multivariable model, male gender (HR 2.07, 95%CI 1.51–2.83), white race (HR 1.44, 95%CI 1.03–2.01), history of pneumonia (HR 3.09, 95%CI 1.86–5.14), pack-years of smoking (HR 1.006, 95%CI 1.001–1.011), and percent predicted FEV1 (moderate vs. mild/normal lung function [HR 1.78, 95%CI 1.28–2.48], severe vs. mild/normal lung function [HR 2.90, 95%CI 1.51–5.57]) were non-modifiable risk factors for pneumonia. Incident mobility limitation (HR 1.77, 95%CI 1.32–2.38) and higher mean oral plaque score (HR 1.29, 95%CI 1.02–1.64) were modifiable risk factors for pneumonia.

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Author Contributions: MJM, NDR, DCB, TBH, ABN, SY, RJW, SK, and VQ were involved in study concept and design. DCD, TBH, ABN, RJW, and SK were involved in acquisition of subjects and/or data. All authors were involved in analysis and interpretation of data, and preparation of manuscript.

Average Attributable Fractions revealed that 11.5% of pneumonias were attributed to incident mobility limitation and 10.3% to mean oral plaque score ≥1.

Conclusion—Incident mobility limitation and higher mean oral plaque score were two modifiable risk factors attributable for 22% of pneumonias requiring hospitalization. These data suggest innovative opportunities for pneumonia prevention among community-dwelling older adults.

Keywords

pneumonia; community-dwelling; risk factors

INTRODUCTION

Pneumonia remains a major public health problem. In the United States, it is a common cause for hospitalization and mortality, particularly among older adults.[1,2] As reported in the National Hospital Discharge Survey, the overall rate of pneumonia requiring hospitalization in 2007 was 35.2 per 10,000 population; among persons ≥ 65 years (i.e., older adults), the rate was 161.0 per 10,000 population.[2] Hospitalization for pneumonia among community dwelling, well functioning older adults has as serious a prognosis as hospitalization for congestive heart failure, stroke, or major fracture.[3] A variety of host and environmental risk factors have been reported for community acquired pneumonia (CAP) among older adults,[4–8] but many are not modifiable. Identifying potentially modifiable risk factors can inform pneumonia prevention strategies. Medication use has been implicated to reduce (i.e., ACE-inhibitors, statins)[9] or increase (i.e., inhaled and high dose oral steroids,[5,10] gastric acid suppressant use[9,11]) the risk of CAP, and is potentially modifiable. Vaccinations (i.e., influenza, *S. pneumoniae*) have demonstrated health benefits, but they have not been shown to reduce all cause pneumonia among older adults.[12–14]

Previous work in older adults residing in nursing homes identified inadequate oral care and swallowing difficulty as independent modifiable risk factors for pneumonia.[15] Other studies of older adults report that dental plaque is a reservoir for pathogens causing hospital-acquired pneumonia[16] and ventilator-associated pneumonia.[17] Clinical trials have demonstrated that oral antiseptic administration reduces oral bacterial pathogens and the incidence of ventilator-associated pneumonia.[18–25] The primary objective of this study was to identify novel modifiable risk factors for pneumonia requiring hospitalization, particularly focusing on oral hygiene, among older adult community-dwellers.

METHODS

Study Population

This study analyzed a subset of participants enrolled in the ongoing Health, Aging, and Body Composition (Health ABC) study: a prospective cohort of 3075 community-dwelling older adults that could perform activities of daily living, walk a quarter mile, and climb 10 steps without resting. Participants in Health ABC were enrolled in Memphis, Tennessee and Pittsburgh, Pennsylvania from 1997–1998, and prospective surveillance data collected through 2008 were available for analyses. Our primary study objective was to identify potentially modifiable risk factors for pneumonia, including oral hygiene which was assessed during year 2 of the Health ABC study. Therefore, only participants with a dental exam were included (N=1975) and the date of the dental exam was considered the baseline date. Dental exams were performed once on each participant based on the availability of dental hygienists at the two participating sites. Of these participants, those without a mean oral plaque score (N=319), without a baseline interview within six months of dental exam

(N=81), and with missing data for covariates (N=134) were excluded, leaving 1441 participants for our analyses (Figure 1).

Of the 1634 participants excluded from our study, there were no significant differences in age or gender compared to those included. However, there was a statistically significant difference ($p<0.05$) between those excluded and included for the number of black participants (47.3% vs. 35.3%), participants from Memphis (59.6% vs. 39.8%), incident mobility limitation (55.1% vs. 43.0%), and number of pneumonia outcomes (N=338, 20.7% vs. N=193, 13.4%).

The Health ABC study was approved by the institutional review boards of the University of Pittsburgh, the University of Tennessee, Memphis, and the University of California, San Francisco (coordinating center). All participants provided written informed consent. Our study was exempt from additional review by the Human Investigation Committee at Yale University since all data were de-identified.

Variables

Pneumonia—The primary outcome was pneumonia requiring hospitalization as adjudicated by the Health ABC outcomes adjudication committee and previously reported.[3,26,27] Adjudicators used a combination of discharge summary, diagnoses by International Classification of Diseases, ninth edition (ICD-9), admission history and physical examination, and radiology reports to ascertain pneumonia requiring hospitalization. The diagnosis of pneumonia was made in the hospital and confirmed by the adjudication committee based on a combination of clinical signs, symptoms, and radiographic findings. Clinical symptoms and signs included cough, fever, sputum production, or rales and/or dullness to percussion during physical examination. Radiographic findings included new or progressive infiltrate, consolidation, and cavitation with or without pleural effusion on chest x-ray. Only the first episode of pneumonia requiring hospitalization was utilized for our analyses.

Oral care—Dental exam assessments included mean oral plaque score, furcation, presence of root fragments, caries, bleeding on probing, and tooth mobility.[28] Plaque was scored using a standardized method previously described on natural teeth. The mean oral plaque score represented the sum of scores divided by the number of teeth evaluated (0-no plaque, 1-film of plaque on tooth, 2-moderate soft deposits in the gingival pocket or plaque seen by the naked eye, 3-abundant soft deposits in the gingival pocket or on the tooth). Four subjective ratings may then be assigned: 0 = excellent, 0.1–0.9 = good, 1.0–1.9 = fair, 2.0–3.0 = poor.[29,30] Presence of full or partial dentures was recorded, but denture plaque was not assessed. Self-reported measures of oral health were also assessed including history of periodontal disease, reason for lost teeth, number of annual dentist visits, and self-reported overall oral health. Mean oral plaque score ≥1 was used in this study to indicate impaired oral hygiene as previously reported in other cohorts of older adults.[31]

Other covariates—Baseline characteristics including age, gender, race, and enrollment site were recorded. History of pneumonia was defined as pneumonia prior to dental exam while enrolled in Health ABC, or within five years prior to enrollment using Health Care Financing Administration hospitalization/outpatient data for five years prior to baseline. Forced expiratory volume in 1st second (FEV1) was measured in Year 1. The percent predicted FEV1 was calculated and categorized into three groups: mild lung disease to normal lung function (≥80%), moderate lung disease (50–79%), and severe lung disease (<50%).[32]

Several covariates were measured longitudinally prior to censoring (i.e., pneumonia, death, loss to follow-up, end of surveillance). Comorbidities that were present at baseline, or during the surveillance period, were recorded including cancer, coronary heart disease (CHD), chronic lung disease, depression, diabetes, hypertension, and stroke. Each comorbidity was defined by self-report, medications reported, clinical or biological criteria at baseline and during study surveillance. Medications prescribed at baseline or during surveillance were recorded (available in years 1–3, 5, 6, 8, 10, and 11 of Health ABC; Year 1 corresponds to 1997–1998) including: angiotensin-converting enzyme inhibitors, antacids, H2 blockers, proton pump inhibitors, inhaled and oral steroids, sedatives (i.e., opioids, alcohol, barbiturates, benzodiazepines, valproic acid, antipsychotics, lithium, other anxiolytics, and chlorpromazine), and statins. Participants brought medications ingested in the previous two weeks to each study visit. Vaccination status, including *S. pneumoniae* (available in years 1 and 6) and annual influenza vaccines (available in years 2 through 6), were recorded. Body Mass Index (BMI) was assessed in years 1, 3, and 6; BMI changes were calculated for two intervals (years 1–3 and 3–6), and an increase or decrease of ≥ 5 percent defined a BMI gain or loss. Participant BMI was divided into four groups, based on previous definitions in Health ABC:[30] stable BMI was defined as no change in BMI; gain in BMI was defined as a gain in one or both intervals; loss in BMI was defined as a loss in one or both intervals; and change in BMI was defined as a gain in one interval and a loss in the other interval. Active smoking was assessed in years 2, 3, 5, and 8–11. The number of times active smoking was reported over the seven time points was recorded, and a proportion of time of active smoking was calculated. Lifetime smoking was measured by pack-years of smoking reported in Year 1. Development of incident mobility limitation was assessed every six months. Incident mobility limitation was defined by self-reported difficulty in walking ¼ mile or climbing 10 steps for two consecutive 6-month follow-up contacts. The first report of difficulty was characterized as the incident date. Self-reported measures of mobility limitation are well-correlated with objective measures,[33] they have been shown to underestimate mobility difficulty,[34] and they have been used as outcome measurements in other reports.[35]

Statistical Analysis

Proportions or means for demographic and clinical characteristics for all participants were calculated. Bivariate analyses examined the association between host characteristics and time to incident pneumonia using Cox regression models. Kendall's Tau-b correlations coefficients were calculated among all characteristics; those greater than 0.3 were considered highly correlated. Based on bivariate models, the characteristic with the weaker association from each highly correlated pair was eliminated. From the remaining characteristics, forward selection was performed to determine the characteristics associated with pneumonia in the multivariable Cox model. Subsequently, age, gender, and race were then forced in the model, and forward selection was repeated to determine the final characteristics in the model. Since not all participants were prescribed statins, and statin use could represent a healthy user effect, the final multivariable time to pneumonia model was stratified by self-reported statin use. This controlled for confounding between medication usage and pneumonia risk factors and resulted in a single set of adjusted hazard ratios. To ensure that the final multivariable model was not sensitive to the selection procedure, we used backward selection forcing in the same demographic factors with identical results. Internal validity for the final multivariable Cox regression model was tested by creating 1000 bootstrap samples with replacement of the original sample and refitting the model for each sample. Nonparametric 95% confidence intervals based on the bootstrap samples were calculated. The differences of hazard ratios between the original sample and median of 1000 bootstrapping samples were calculated providing an estimate of bias. The average attributable fraction (AAF)[36,37] was calculated to estimate the additive and order-free

contributions of the characteristics to incident pneumonia with nonparametric 95% confidence intervals from 1000 bootstrapped samples. AAF is a composite measure of the hazard ratio and prevalence of a given risk factor. The AAF of all risk factors can be summed to provide the total contribution of all risk factors on the pneumonia outcome. All statistical tests were 2-tailed, and $P < 0.05$ was considered to indicate statistical significance. Analyses were performed using SAS version 9.2 (SAS Institute, Cary, NC) and MATLAB Version 7.13.0.564 (R2011b) (MathWorks. Inc., Natick, MA).

RESULTS

Of the 1441 participants eligible for this study, 193 participants had pneumonia requiring hospitalization during the observation period of 1998–2008 (Figure 1). Of these 193 participants, 159 had clinical signs, symptoms and radiographic findings, 21 had only radiographic findings, and 13 had only clinical signs and symptoms. The overall rate of pneumonia requiring hospitalization was 163.1 pneumonias per 10,000 person-years. The median number of years to pneumonia was 5.60 (SD 2.64 years). Baseline participant characteristics and risk factors for pneumonia requiring hospitalization are listed in Table 1. Age, male gender, percent predicted FEV1, history of pneumonia, H2 blocker use, statin use, smoking status, pack years of smoking, loss in BMI, unstable BMI, incident mobility limitation, and mean oral plaque score had statistically significant associations with pneumonia requiring hospitalization. There were 662 participants with mean oral plaque score between 1 and 2 (111 with pneumonia, 551 without pneumonia) and 33 participants with mean oral plaque score >2 (4 with pneumonia, 29 without pneumonia). The mean oral plaque score for the entire cohort was in the “good” range at 0.84 (0.95 in those who developed pneumonia, 0.82 in those who did not develop pneumonia). Because of missing data on other measures of oral care (i.e., presence of gum disease, lost teeth because of gum disease, number of visits to the dentist on an annual basis, self reported overall oral health, furcation, presence of root fragments, caries, bleeding on probing, and tooth mobility), these variables were included in bivariate analyses only on the subset in which we had complete data. Of these other measures of oral care, the only variable associated with pneumonia in bivariate analyses was self-reported loss of teeth because of gum disease (N=1385, Hazard Ratio [HR] 1.69, 95% confidence interval [CI] 1.14–2.52). Subsequent analyses were only conducted on the complete cohort of participants (N=1441); therefore, the additional measures of oral care were not included in the multivariable model.

In a multivariable Cox model, the five significant non-modifiable risk factors associated with pneumonia were male gender (HR 2.07, 95% CI 1.51–2.83), white race (HR 1.44, 95% CI 1.03–2.01), pack-years of smoking (HR 1.01, 95% CI 1.00–1.01), history of pneumonia (HR 3.09, 95% CI 1.86–5.14), and percent predicted FEV1 (moderate vs. mild/normal lung function [HR 1.78, 95% CI 1.28–2.48], severe vs. mild/normal lung function [HR 2.90, 95% CI 1.51–5.57]). There was no correlation between pack-years of smoking and percent predicted FEV1 (Kendall’s Tau b = −0.16). Only two modifiable risk factors were associated with pneumonia requiring hospitalization: incident mobility limitation (HR 1.77, 95% CI 1.32–2.38) and mean oral plaque score (HR 1.29, 95% CI 1.02–1.64). These hazard ratios were internally validated by bootstrapping and the differences in original and bootstrapping samples were less than 3% for all risk factors (Figure 2). AAF were calculated to determine how much pneumonia would be reduced if each of these risk factors were eliminated and how much of pneumonia could be attributed to the non-modifiable risk factors. Specifically, 11.5% of pneumonias requiring hospitalization was attributed to incident mobility limitation and 10.3% to mean oral plaque score ≥1. These results were validated via bootstrapping with differences in original and bootstrapping samples for AAF demonstrated to be less than 0.5% (Table 2).

DISCUSSION

This study of well-functioning community-dwelling older adults had several important findings. The most novel finding was that higher mean oral plaque score, reflective of impaired oral hygiene, was a modifiable risk factor for pneumonia requiring hospitalization and it accounted for 10.3% of the AAF. Incident mobility limitation, reflective of functional decline, was another modifiable risk factor accounting for 11.5% of AAF. A prior history of pneumonia, pack-years of smoking, severity of lung function, male gender and white race were significant risk factors for pneumonia requiring hospitalization, although they were non-modifiable.

Aspiration of pathogenic bacteria, present in oral and dental plaque, has been a postulated mechanism of pneumonia development among hospitalized patients, nursing home residents, and ventilated patients. Observational data have shown that lack of a recent dental exam was a risk factor for pneumonia among nursing home residents,[15] and a visit to a dentist in the previous month was protective for CAP.[5] Dental plaque has been identified as a reservoir of respiratory pathogens causing healthcare associated pneumonia among nursing home residents and ventilated ICU patients.[16,17] The association of higher mean oral plaque score with pneumonia from this study adds to this body of evidence, and demonstrates that impaired oral hygiene is a risk factor for pneumonia requiring hospitalization among community-dwelling older adults as well.

Participants at baseline in this study had no difficulty performing activities of daily living, thereby representing a functionally intact subset of older adults that may have routinely performed self oral care. The mean oral plaque score for the entire cohort was in the “good” range at 0.84 (0.95 in those who developed pneumonia, 0.82 in those who did not develop pneumonia) with only 33 participants with mean oral plaque scores over two. Nonetheless, the association of higher mean oral plaque score with pneumonia in this cohort suggests that further improvement in oral care despite adequate care at baseline may improve pneumonia outcomes. Enhanced oral care (e.g., more frequent tooth and gum brushing, daily use of oral chlorhexidine mouthwash) represents a simple and easily administered intervention that has the potential to remove pathogenic bacteria and improve the swallowing reflex.[38,39] Oral chlorhexidine has been shown to be effective in other populations[40] and could be self-administered to community-dwelling older adults as a potential pneumonia prevention strategy if evidence demonstrated that it could reduce pneumonia in future trials. However, chlorhexidine is a prescription medicine, and the requirement for self-administration among community-dwellers may limit its practical utility as a pneumonia prevention strategy.

Poor functional status has been identified as a risk factor for CAP in previous work.[4] Longitudinal studies among older adults have demonstrated that regular physical activity can improve physical performance, reduce risk of physical disability, and potentially delay functional decline.[41–47] Physical activity programs have been shown to improve functional outcomes in older adults.[48–51] In this study, among baseline well-functioning older adults, incident development of mobility limitation was associated with pneumonia requiring hospitalization. It is plausible that mobility limitation prompted the hospitalization during the pneumonia event, rather than serving as a risk for pneumonia development. In addition, it is also possible that as mobility limitation ensues, oral hygiene begins to decline as well, and oral hygiene may be the greater pneumonia risk factor. Therefore, our data cannot clarify whether incident mobility limitation is associated with pneumonia, only pneumonia requiring hospitalization in older adults, or is only a marker of end stage chronic disease, but it represents an interesting avenue of future investigation. The association of male gender with greater risk of pneumonia requiring hospitalization is consistent with prior associations of male gender and risk of ventilator-associated pneumonia, possibly related to hormonal

influence on cellular immunity.[52,53] Additionally, the assessment of active smoking was limited by the fact that only 8% of the cohort actively smoked. Nevertheless, pack-years of smoking was identified as a non-modifiable risk factor for pneumonia.

The greatest strength of this study was that it represented prospective follow up of a large cohort of community-dwelling older adults, in which two modifiable pneumonia risk factors were identified and internally validated. Nonetheless, our study had limitations. First, a dental exam was only performed once. Changes in dental care, or longitudinal observations of dental plaque, were not captured in the Health ABC cohort. Second, adjudication of pneumonia in Health ABC required hospital diagnosis of pneumonia and clinical signs, symptoms, or radiographic abnormalities. Pneumonias that did not require hospitalization or healthcare associated pneumonias were not captured. The vast majority of participants with adjudicated pneumonia had clinical signs, symptoms, and radiographic abnormalities, and the HR were similar in this subset compared to all adjudicated pneumonias. Third, only white and black races were enrolled, potentially limiting generalizability of these findings to other races. Nevertheless, the rate of pneumonia observed in this study (163 cases per 10,000 population) was remarkably similar to that observed nationally in 2007 (161 cases per 10,000 population)[2] suggesting that the pneumonia definition, and the Health ABC cohort results, are generalizable. Fourth, not all patients had equal opportunity or risk for being prescribed certain medications, so risk or protective effects of specific medications could not be assessed. Fifth, 1100 Health ABC participants had no dental exam performed, and this group of participants had 338 episodes of pneumonia. It is possible that this group of excluded participants could have had worse oral hygiene since the rate of pneumonia was higher in this group. Finally, influenza and pneumococcal vaccinations were only recorded in certain years; since vaccinations did not demonstrate a protective effect in this cohort, it is possible that incomplete data rather than a lack of effect is responsible for this finding.

The two modifiable risk factors for pneumonia requiring hospitalization in this study (i.e., high oral plaque score and incident mobility limitation) accounted for a combined 22% of attributable risk for pneumonia requiring hospitalization. Although 51% of risk was attributable to non-modifiable risk factors (i.e., male sex, white race, history of pneumonia, pack-years of smoking, and percent predicted FEV1), aspiration of oral flora may play an important role in the development of pneumonia among community-dwelling older adults, similar to those hospitalized and institutionalized. Functional impairment has been identified to have negative health consequences among older adults including risk of pneumonia development. Although these two risk factors could be modifiable, implementation of interventions to change these risk factors would require a cognitively intact group of older adults that could self-administer care. It is unclear whether such interventions could be implemented in real world practice. Nevertheless, these findings suggest novel intervention strategies to test for pneumonia prevention among community-dwelling older adults.

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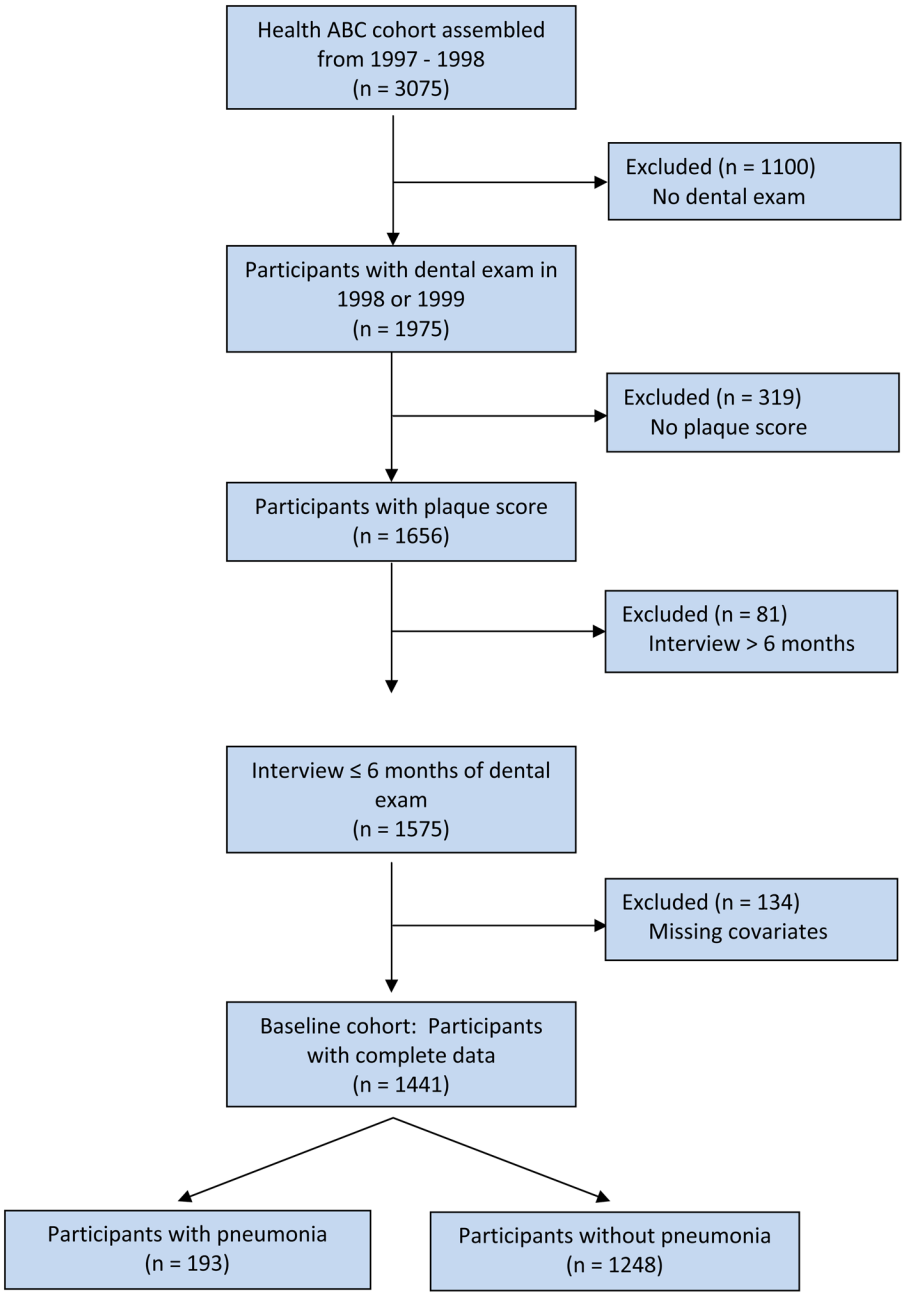

Figure 1.
Flow Chart of Participants

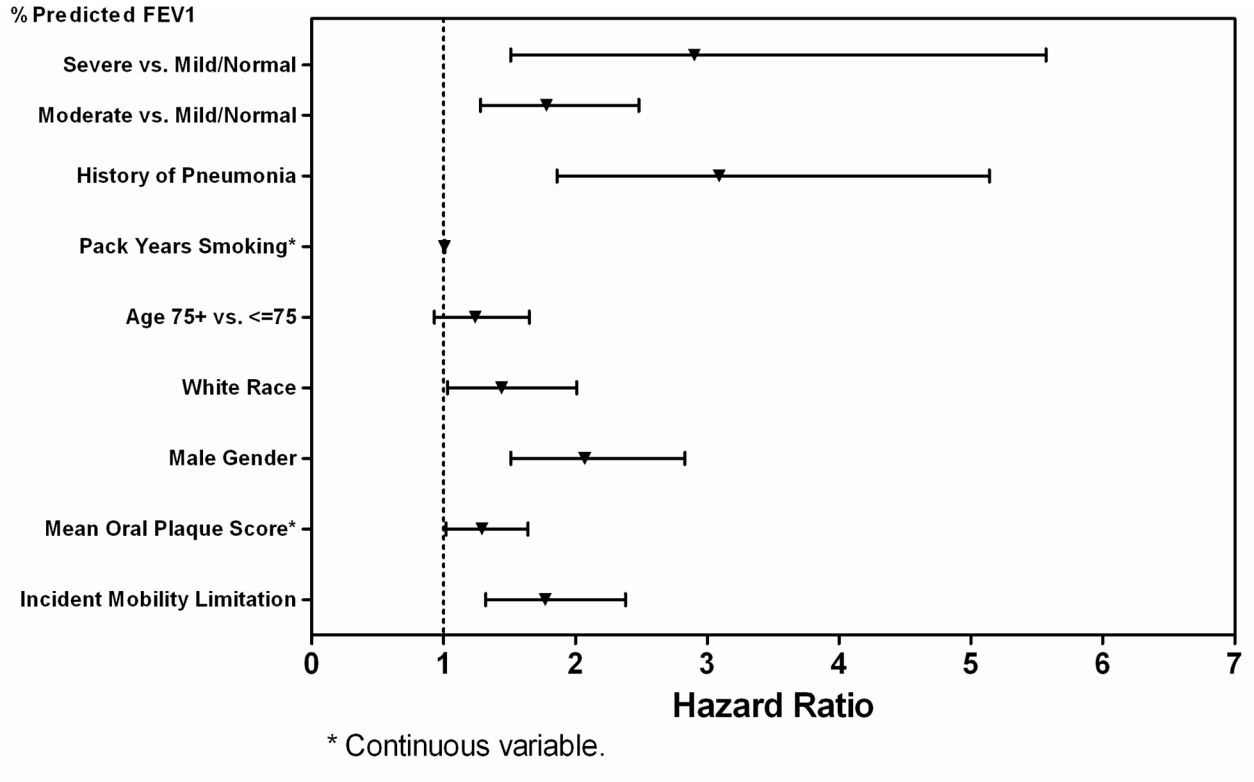

Figure 2.
Hazard Ratios from Multivariable Cox Model of Risk Factors

Modifiable Risk Factor	Hazard Ratio [HR] (95% Confidence Interval [CI])	HR (95% CI) from bootstrapping samples	Percent differenc e in HR
Mean Oral Plaque Score	1.29 (1.02-1.64)	1.31 (1.02-1.66)	-1.25%
Incident Mobility Limitation	1.77 (1.32-2.38)	1.81 (1.29-2.45)	-1.89%
Non-Modifiable Risk Factor			
Male Gender	2.07 (1.51-2.83)	2.12 (1.49-2.97)	-2.19%
White Race	1.44 (1.03-2.01)	1.48 (1.05-2.07)	-2.81%
Age 75+years vs. ≤75 years	1.24 (0.93-1.65)	1.25 (0.93-1.67)	-0.54%
Pack years smoking	1.01 (1.00-1.01)	1.01 (1.00-1.01)	0.01%
History of pneumonia	3.09 (1.86-5.14)	3.18 (1.62-5.08)	-2.59%
% Predicted FEV1			
Moderate vs. Mild/Normal	1.78 (1.28-2.48)	1.80 (1.29-2.46)	-1.35%
Severe vs. Mild/Normal	2.90 (1.51-5.57)	2.98 (1.26-5.41)	-2.56%

Table 1

Baseline Clinical Characteristics of Participants and Bivariate Cox Model of Risk Factors Associated with Pneumonia Requiring Hospitalization

	Overall N (%)	Pneumonia N (%)	No Pneumonia N (%)	Hazard Ratio (95% Confidence Intervals)	P value
	(N=1441)	(N=193)	(N=1248)		
Age *mean (SD)*	74.7 (2.88)	75.2 (2.77)	74.7 (2.89)	1.07 (1.02–1.12)	0.009
Age ≤75 years	887 (61.6)	107 (55.4)	780 (62.5)	Reference	0.03
Age >75 years	554 (38.5)	86 (44.6)	468 (37.5)	1.37 (1.03–1.82)	
Male gender	719 (49.9)	125 (65.8)	594 (47.6)	2.07 (1.54–2.78)	<0.0001
White	509 (35.3)	58 (30.1)	451 (36.1)	1.19 (0.87–1.62)	0.27
Pittsburgh	867 (60.2))	108 (56.0)	759 (60.8)	Reference	0.15
Memphis	574 (39.8)	85 (44.0)	489 (39.2)	0.81 (0.61–1.08)	
Cancer	474 (32.9)	61 (31.6)	413 (33.1)	1.03 (0.76–1.40)	0.84
CHD	467 (32.4)	70 (36.3)	397 (31.8)	1.25 (0.93–1.68)	0.13
Chronic Lung Disease	296 (20.5)	49 (25.4)	247 (19.8)	1.20 (0.87–1.66)	0.28
Depression	512 (35.5)	60 (31.1)	452 (36.2)	0.77 (0.57–1.04)	0.09
Diabetes	405 (28.1)	56 (29.0)	349 (28.0)	1.05 (0.77–1.43)	0.75
Hypertension	1268 (88.0)	169 (87.6)	1099 (88.1)	0.85 (0.56–1.31)	0.47
Stroke	173 (12.0)	24 (12.4)	149 (11.9)	1.20 (0.78–1.84)	0.41
Number of Comorbidities *mean (SD)*	2.49 (1.25)	2.53 (1.23)	2.49 (1.26)	1.03 (0.92–1.15)	0.64
% predicted FEV1					
Mild-Normal (≥80%)	1155 (80.1)	132 (68.4)	1023 (82.0)	Reference	
Moderate (50≤%FEV1<80)	255 (17.7)	51 (26.4)	204 (16.4)	2.10 (1.52–2.90)	<0.0001
Severe (<50%)	31 (2.2)	10 (5.2)	21 (1.7)	3.84 (2.02–7.31)	<0.0001
History of Pneumonia	408 (28.3)	63 (32.6)	345 (27.6)	2.91 (1.77–4.78)	<0.0001

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	Overall N (%)	Pneumonia N (%)	No Pneumonia N (%)	Hazard Ratio (95% Confidence Intervals)	P value
	(N=1441)	(N=193)	(N=1248)		
ACE Inhibitors	762 (52.9)	95 (49.2)	667 (53.5)	0.79 (0.60–1.05)	0.10
Antacids	423 (29.6)	51 (26.4)	372 (29.8)	0.81 (0.59–1.11)	0.18
Gastrointestinal Agents	718 (49.8)	96 (49.7)	622 (49.8)	0.93 (0.70–1.23)	0.60
H2 Blockers	284 (19.7)	49 (25.4)	235 (18.8)	1.38 (1.00–1.91)	0.05
Inhaled Steroids	98 (6.8)	18 (9.3)	80 (6.4)	1.43 (0.88–2.32)	0.15
Oral Steroids	106 (7.4)	16 (7.8)	91 (7.3)	1.09 (0.64–1.85)	0.75
Proton Pump Inhibitors	331 (23.0)	41 (21.2)	290 (23.2)	0.81 (0.57–1.14)	0.23
Sedatives	442 (30.7)	66 (34.2)	376 (30.1)	1.15 (0.85–1.54)	0.37
Statins	609 (42.3)	70 (36.3)	539 (43.2)	0.67 (0.50–0.90)	0.0075
Mean oral plaque score, *mean (SD)*	0.84 (0.60)	0.95 (0.55)	0.82 (0.61)	1.42 (1.14–1.77)	0.0018
Mean oral plaque score, <1	746 (51.8)	78 (40.4)	668 (53.5)	Reference	
Mean oral plaque score, ≥1	695 (48.2)	115 (59.6)	580 (46.5)	1.70 (1.27–2.26)	0.0003
Smoking					
Never	685 (47.5)	72 (37.3)	613 (49.1)	Reference	
Current	113 (7.8)	18 (9.3)	95 (7.6)	1.945 (1.16–3.26)	0.0116
Former	643 (44.6)	103 (53.4)	540 (43.2)	1.68 (1.24–2.27)	0.0007
Pack-years smoking	16.5 (25.88)	23.1 (32.23)	15.5 (24.62)	1.011 (1.007–1.016)	<0.0001
Stable BMI	847 (58.8)	106 (54.9)	741 (59.4)	Reference	
Gain in BMI	223 (15.5)	25 (12.6)	198 (15.9)	0.85 (0.55–1.32)	0.48
Loss in BMI	288 (20.0)	45 (23.3)	243 (19.5)	1.44 (1.01–2.04)	0.04
Unstable BMI	83 (5.8)	17 (8.8)	66 (5.3)	1.66 (1.00–2.77)	0.05
Flu Shots *mean (SD)*	0.75 (0.36)	0.76 (0.35)	0.75 (0.22)	1.04 (0.69–1.55)	0.86
Pneumovax	550 (38.2)	83 (43.0)	467 (37.4)	1.19 (0.90–1.59)	0.23

	Overall N (%)	Pneumonia N (%)	No Pneumonia N (%)	Hazard Ratio (95% Confidence Intervals)	P value
	(N=1441)	(N=193)	(N=1248)		
Incident Mobility Limitation	608 (42.2)	98 (50.8)	510 (40.9)	1.68 (1.26–2.22)	0.0003

Table 2

Average Attributable Fractions (AAF) for Risk Factors

Modifiable Risk Factor	AAF from original sample	AAF from bootstrapping samples	95% Confidence Intervals*
Incident Mobility Limitation	11.5%	11.6%	5.6–18.8%
Mean oral plaque score ≥1	10.3%	10.3%	2.2–19.0%
Non-Modifiable Risk Factor			
Male gender	17.4%	17.5%	9.1–26.9%
White race	12.2%	12.4%	3.5–21.5%
Pack years smoking (ever vs. never)	7.5%	7.2%	0–15.7%
% Predicted FEV1 (moderate/severe vs. mild/normal)	7.1%	7.0%	3.0–11.9%
Age 75+years vs. ≤75 years	4.1%	4.0%	0–9.7%
History of pneumonia	3.0%	3.0%	1.1–5.6%
Total	73.1%	73.0%	

* 95% confidence intervals were based on 1000 nonparametric bootstrapped replicates of the model reported in the table of Figure 2.