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Authors
Wroe, Peter C
Finkelstein, Jonathan A
Ray, G Thomas
et al.

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Aging Population and Future Burden of Pneumococcal Pneumonia in the United States

Peter C. Wroe,[1,a] Jonathan A. Finkelstein,[1,2] G. Thomas Ray,[3] Jeffrey A. Linder,[4] Kristen M. Johnson,[1,b] Sheryl Rifas-Shiman,[1] Matthew R. Moore,[5] and Susan S. Huang[6]

[1]Department of Population Medicine, Harvard Medical School and Harvard Pilgrim Health Care Institute, Boston, Massachusetts; [2]Division of General Pediatrics, Children's Hospital Boston, Massachusetts; [3]Division of Research, Kaiser Permanente, Oakland, California; [4]Division of General Medicine and Primary Care, Department of Medicine, Brigham and Women's Hospital and Harvard Medical School, Boston, Massachusetts; [5]Centers for Disease Control and Prevention, Atlanta, Georgia; and [6]Division of Infectious Diseases and Health Policy Research Institute, University of California, Irvine School of Medicine

Pneumococcal pneumonia is concentrated among the elderly. Using a decision analytic model, we projected the future incidence of pneumococcal pneumonia and associated healthcare utilization and costs accounting for an aging US population. Between 2004 and 2040, as the population increases by 38%, pneumococcal pneumonia hospitalizations will increase by 96% (from 401 000 to 790 000), because population growth is fastest in older age groups experiencing the highest rates of pneumococcal disease. Absent intervention, the total cost of pneumococcal pneumonia will increase by $2.5 billion annually, and the demand for healthcare services for pneumococcal pneumonia, especially inpatient capacity, will double in coming decades.

Between 2000 and 2040, the number of Americans aged ≥65 years will more than double, and the proportion of the total population in that age group will increase from an estimated 12% to 20% [1]. As the population gets older, it will be important to prepare for the impact of this demographic shift on the healthcare system. Much attention has been paid to the rising burden of chronic illnesses such as diabetes mellitus, arthritis, and Alzheimer disease and to the rising demand for long-term care associated with these illnesses [2–6]. It is also useful, however, to examine the effect of the shifting age distribution on the burden of common acute conditions.

Despite some success of immunization programs, *Streptococcus pneumoniae* remains a major cause, in all ages, of a variety of clinical syndromes, including pneumonia. We previously showed that pneumonia, especially among the elderly, is the driving force behind the significant disease burden and costs attributable to pneumococcal illness. We estimated that there were 866 000 episodes of pneumococcal pneumonia in the United States in 2004, including 401 000 hospitalizations, with a direct cost of $2.5 billion (2007 dollars) [7]. Adults aged ≥65 years accounted for 60% of the hospitalizations attributable to pneumococcal pneumonia [7]. It is, therefore, reasonable to expect the disease incidence and costs attributable to pneumococcal pneumonia to rise as an increasing proportion of the population becomes ≥65 years old. Although we cannot predict future mitigating factors such as new vaccines, or future exacerbating factors such as increasing antibiotic resistance, it is informative to quantify the effect that a growing and aging population could have on the national burden of pneumococcal pneumonia. Doing so may inform preparations for the impact on healthcare delivery systems, physician and nursing workforce, long-term care needs, and overall costs, as well as increase efforts on targeted vaccine uptake and other preventive strategies.

METHODS

Using the decision tree–based probabilistic model developed previously [7], we estimated the impact of population growth and projected future shifts in the age distribution of the US population on the national burden of pneumococcal pneumonia. We determined national population estimates for 2004, 2010, 2020, 2030, and 2040 from US Census Bureau projections [1, 8]. We applied 2004 rates of pneumonia to future population projections in order to assess potential changes in the number of episodes of overall pneumonia and pneumococcal pneumonia, as well as the associated healthcare utilization, outcomes, and costs due to pneumococcal pneumonia in the coming decades. Age-specific pneumococcal pneumonia incidence estimates (2004) were determined for the following age groups: <5, 5–<18, 18–<50, 50–<65, 65–<75, 75–<85, and ≥85 years. We also calculated proportional increases in the

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[a]Present affiliation: The Pritzker School of Medicine, University of Chicago, Illinois.
[b]Present affiliation: Drexel University School of Public Health, Philadelphia, Pennsylvania.
Correspondence: Susan S. Huang, MD, MPH, University of California, Irvine School of Medicine, Division of Infectious Diseases, 101 The City Drive S, City Tower, Suite 400, ZC 4081, Orange, CA 92868-3217 (sshuang@uci.edu).

population and compared these to increases in overall prevalence and cost of pneumococcal pneumonia.

Projected Pneumonia Incidence Inputs

We have described the model inputs in detail elsewhere [7]. In brief, we used the medical literature and expert panel sources to estimate the fraction of outpatient and inpatient pneumonia due to pneumococcus. The estimated annual incidence of outpatient pneumonia (*International Classification of Diseases, Ninth Revision* [*ICD-9*] codes 480–486 and 487.0) from all pathogens by age group was obtained from the National Ambulatory Medical Care Survey and the National Hospital Ambulatory Medical Care Survey for 2002–2005 [9, 10]. For outpatient pneumonia, including emergency department visits, we only included visits at which an antibiotic was prescribed and which did not result in direct hospital admission. Direct admissions from outpatient or the emergency department were counted only once as inpatient pneumonia cases.

We measured the annual incidence of inpatient pneumonia from all pathogens by age group using *ICD-9* codes 480–486 and 487.0, limited to the primary diagnosis, from the 2004 National Hospital Discharge Survey [11].

We used the resulting incidence estimates for outpatient and inpatient pneumonia by age, along with 2004 Census Bureau estimates, to determine annual population-based rates of illness for each age group. We applied these age-specific rates of all-pathogen pneumonia to age-specific population estimates for 2010, 2020, 2030, and 2040, and the resulting incidence projections were used to assess the burden of pneumococcal pneumonia at each time point.

Pneumococcal Burden Model

Model inputs were the same as those used previously to assess the burden of pneumococcal disease in 2004 and were based upon national healthcare utilization and cost data, Centers for Disease Control and Prevention (CDC) data from the Active Bacterial Core Surveillance system, existing literature, and expert panel opinion to inform parameter values [7]. With regard to rates of treatment failure, prolonged courses of illness or hospitalization, mortality, and other measures, literature review and expert panel research were conducted with specific regard to pneumococcal disease, with the understanding that associated sequelae and costs may differ substantially from those due to viral pneumonia or other nonpneumococcal sources of community-acquired or nosocomial infection. One major model estimate, largely determined by the expert panel, was the percentage of all-cause pneumonia due to pneumococcus (20% for outpatient, 30% for inpatient).

Other than projections for all-cause incidence of outpatient and inpatient pneumonia, all other incidence, healthcare utilization, and cost projections are specific to pneumococcal pneumonia. Model outcomes included the number of pneumococcal episodes of outpatient and inpatient pneumonia, as well as the healthcare utilization and costs associated with those episodes. Costs were assessed on an age-specific basis and included direct costs of outpatient and emergency department visits, outpatient antibiotics, inpatient stays, readmission costs, nursing home visits and other postacute care, and other out-of-pocket expenditures (eg, parking). All costs are reported in 2007 dollars.

This study was exempted from human subjects research oversight by the Harvard Pilgrim Health Care institutional review board.

RESULTS

The overall population of the United States is expected to increase by 38%, from 294 million to 406 million, between 2004 and 2040. The elderly (≥65 years) population will grow from 36 million to 81 million, and the oldest old (≥85 years) population will nearly triple, from 5 million to 14 million.

Outpatient Pneumonia

For all-cause outpatient pneumonia, we estimated an increase from 2.5 million episodes in 2004 to 3.5 million episodes in 2040. Specific to pneumococcal pneumonia, we estimated 490 000 cases of outpatient pneumococcal pneumonia in 2004; 520 000 in 2010; 580 000 in 2020; 640 000 in 2030; and 700 000 in 2040. This reflects a 43% increase in the absolute number of outpatient pneumococcal pneumonia episodes between 2004 and 2040. The fraction of outpatient pneumonia accounted for by the elderly will increase from 15% in 2004 to 23% in 2040, due to disproportionate population growth in the oldest age groups. The fraction of outpatient pneumonia accounted for by the oldest old will increase from 2% to 4%. Population-wide, this reflects a small increase from 1.67 cases per 1000 persons in 2004 to 1.73 cases per 1000 persons in 2040.

Inpatient Pneumonia

Hospitalizations due to all-cause pneumonia are projected to increase by nearly 100%, from 1.3 million to 2.6 million, between 2004 and 2040. This corresponds to an increase in hospitalizations due to pneumococcal pneumonia from 400 000 to 790 000 over the same period, with 87% of this increase occurring among the elderly and 14% among the oldest old. Figure 1 shows projected numbers of pneumococcal pneumonia hospitalizations for all years studied, stratified by age. If the growth of the population were proportional across all ages, we would expect an increase of approximately 150 000 pneumococcal pneumonia hospitalizations. The additional expected increase of almost 240 000 hospitalizations is due to the oldest age groups growing faster than the rest of the population. With adjustment for population growth, this reflects a 42% increase in the overall rate of hospitalization, from

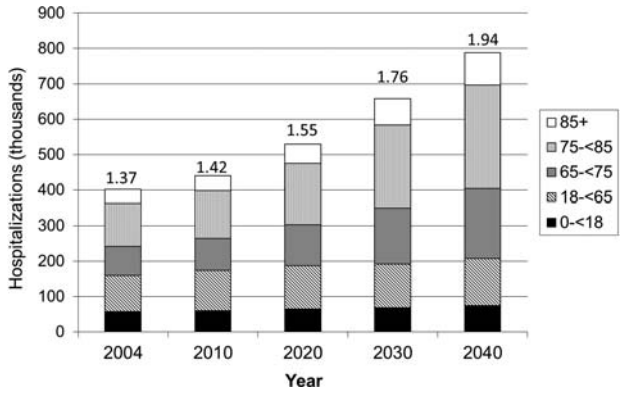

Figure 1. Estimated pneumococcal pneumonia hospitalizations by year, stratified by age. Age-specific incidence was held constant for all years studied. Numbers over each bar represent all-age incidence of pneumococcal pneumonia hospitalization per 1000 persons in the population. Incidence is projected to increase from 1.37 per 1000 persons to 1.94 per 1000 persons between 2004 and 2040.

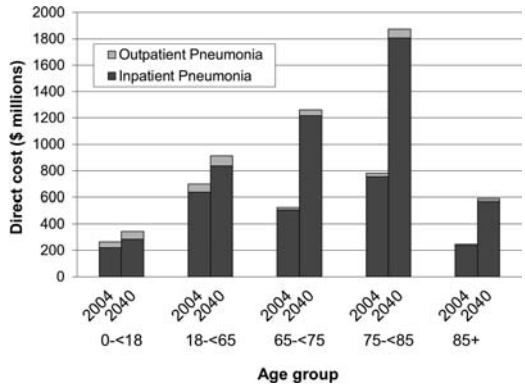

Figure 2. Direct costs by age of outpatient and inpatient pneumococcal pneumonia, 2004 and 2040. All costs are held constant in 2007 dollars.

1.37 (2004) to 1.94 (2040) pneumococcal pneumonia hospitalizations per 1000 persons in the population.

Total inpatient days due to pneumococcal pneumonia are projected to increase from 2 million in 2004 to 4.1 million in 2040, and predicted deaths due to pneumococcal pneumonia are projected to increase from 19 000 to 42 000 over the same period. This corresponds to an increase in deaths among the elderly from 16 000 in 2004 to 39 000 in 2040, and from 2500 to 6200 among the oldest old.

Costs

In 2007 dollars, total direct costs are predicted to double from $2.5 billion in 2004 to $5.0 billion in 2040, with the largest proportional increase in costs taking place between 2020 and 2030 (25% increase from $3.3 billion to $4.2 billion). The vast majority (93%–95%) of direct costs in all years studied were due to inpatient episodes. Figure 2 compares the estimated age-specific costs due to outpatient and inpatient pneumococcal pneumonia for 2004 and 2040.

DISCUSSION

Streptococcus pneumoniae, and specifically pneumococcal pneumonia, is likely to remain a significant contributor to the burden of disease and healthcare costs in the United States as the population ages, even in an era of routine vaccination. Inpatient episodes currently account for the majority of these costs and disproportionately occur among the elderly [7].

The increasing elderly population will account for an estimated growth of 45 million people by 2040. If age-specific incidence rates of pneumococcal pneumonia remain stable, we estimate that outpatient pneumococcal pneumonia visits will increase by 43% and hospitalizations due to pneumococcal pneumonia will increase by close to 100% between 2004 and 2040, with the vast majority of this increase occurring among the elderly. This will translate to a considerable increase in the demand for healthcare services, especially inpatient capacity and workforce, to handle this increased need.

The economic implications of the aging population are significant as well, especially because our estimates assume no change in the unit costs of medical care. Using 2007 dollars, we project that the aging population alone will increase direct costs due to pneumococcal pneumonia by $2.5 billion dollars, a doubling of cost burden between 2004 and 2040. Actual costs would be expected to be even higher because this analysis does not examine the indirect costs of missed work due to illness and long-term productivity loss due to death because of uncertainty in how these estimates will change in future decades.

The results of this analysis should be interpreted in the context of several limitations. First, we did not account for possible changes in pneumonia incidence—or in the proportion of pneumonia incidence attributable to pneumococcus—due to new vaccines, improved vaccine uptake, or other future public health initiatives. We assumed that age-specific incidence, hospitalization, and mortality due to pneumococcal pneumonia would be stable. In addition, the introduction of the 13-valent pneumococcal conjugate vaccine is a real intervention that has taken place since the data used in this analysis were collected and could affect future burden estimates. Second, our model did not adjust for potential changes in the distribution of comorbidity among the elderly, which could significantly impact future rates of pneumonia hospitalization [12]. We also do not account for the possible effect on pneumococcal pneumonia incidence due to shifts in the ethnic or socioeconomic distribution of the population. Third, we cannot account for changes in how healthcare is delivered. In

the future, a greater proportion of pneumonia episodes may be able to be treated in the outpatient or home setting. Alternatively, other improvements in care could reduce mortality or costs due to pneumonia [13]. Finally, changing antibiotic resistance and unit costs of healthcare, which we did not account for, may increase or decrease the expected health and economic burden of pneumococcal pneumonia. Despite its uncertainties, this analysis demonstrates that the effect of the aging population alone has the potential to produce a steep increase in the number of cases of pneumococcal pneumonia, with resulting healthcare utilization and costs. It further highlights the urgent need for preparatory strategies for disease prevention and healthcare capacity in terms of hospitals, clinics, skilled nursing facilities, and healthcare provider workforce resources, as well as measures to ensure economic health for US medical care.

Notes

Disclaimer. The findings and conclusions in this paper are those of the authors and do not necessarily represent the views of the CDC.

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Potential conflicts of interest. J. A. L. has received research grants from Pfizer to study electronic adverse drug event reporting and Roche to study use of anti-influenza medications. G. T. R. has received research support from Pfizer, GlaxoSmithKline, and Merck. All other authors report no potential conflicts.

All authors have submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Conflicts that the editors consider relevant to the content of the manuscript have been disclosed.

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