Use of a Broader Determinants of Health Model for Community-Acquired Pneumonia in Seniors

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Community-acquired pneumonia (CAP) is the sixth leading cause of death in the United States and accounts for >600,000 hospital admissions annually [1]. In Canada, there are >44,000 hospitalizations annually for pneumonia and influenza [2]. Like other respiratory infections, people at the extremes of age are at greatest risk and have worse outcomes [3]. In older adults, the incidence of CAP as well as related hospitalization and mortality increase steadily with age, even when these rates are adjusted for chronic health problems, such as lung or heart conditions [4].

Despite the considerable morbidity and mortality of CAP in older people, relatively little is known about the effect of socioeconomic and environmental factors on older people’s risk of acquiring pneumonia. In contrast, biomedical factors, such as age, immunosuppression, and asthma, have been well documented as risk factors for CAP in seniors [5]. An influential conceptual model developed by Evans and Stoddart [6] identifies the importance of socioeconomic and biophysical environment, genetic endowment, health care, and prosperity interacting to influence overall health. Use of such a framework may help to achieve a comprehensive understanding of risks, causes, and outcomes, as well as provide information needed for health care planning, for CAP in older adults. This is important because respiratory infections in older adults represent the largest proportion of health care consumed for infectious diseases in Canada and the United States. Determining whether there is an association between CAP and these broader determinants (figure 1) is the first step toward delineating potential causal pathways that in turn may lead to ways to reduce the problem. This article reviews data about the effect of socioeconomic status (SES), nutrition, tobacco smoke, and air pollution on CAP at the level of individual older adults. Gaps in knowledge are identified and priorities for research in this area are suggested.

Measuring socioeconomic status, particularly in elderly persons, can be difficult because it includes both resources, such as education, income, and wealth, as well as status or rank, a function of relative positions in a hierarchy, such as social class. Because many seniors are retired and don’t earn an income, educational level is also used to capture this construct. There is some evidence to suggest that there is in fact a relationship between socioeconomic status and CAP in older adults. Low income and fewer median school years were associated with higher county rates of CAP admissions in this study, it is possible that the seniors who were actually admitted for CAP were from higher educational groups. Nevertheless, individual-level comparative studies exist that do suggest an association between CAP and low socioeconomic status. Single marital status and unemployment were found to be risks for hospital admission for CAP.
CAP in a British case-control study in which 45% of patients were >60 years old [9]. A question raised by these findings is whether the relationship relates to an increased incidence of pneumonia in this group, severity of symptoms, or variability in seeking medical care. Another factor limiting inference between socioeconomic status and CAP in this study is that single marital status and unemployment may not be an appropriate proxy for socioeconomic status. In another case-control study, only age and chronic lung disease were significant risk factors for acquiring CAP when cases were diagnosed in the community [10]. Together, these studies raise the question as to whether lower socioeconomic status is more of a predictor of hospital admission rather than CAP. That is, perhaps these persons were regarded by hospital staff as less able to take care of themselves at home [10]. Although it is plausible that increased severity of symptoms may play a role, no relationship between low socioeconomic status and greater disease severity was found in a case series of hospital admissions for CAP [11].

*Streptococcus pneumoniae,* or pneumococcus, is the most common cause of CAP in adults. One study conducted in Baltimore, Maryland, showed that community median income was a risk factor for bloodstream infection with pneumococcus in older adults [12]. After adjustment for AIDS and median income, race was no longer an important factor. Given the low prevalence of AIDS and differences in access to the health care system, these data may not applicable to Canada and other countries with publicly funded health care. Given the severity of illness with bloodstream infections, it is unlikely that this association represents variation in site of care. More data are needed to elucidate the role of socioeconomic status in CAP. The effect of socioeconomic status on CAP can be best characterized through gathering of both individual-level as well as community data. Research that used multilevel modeling to understand the relative contributions of individual versus community socioeconomic status is needed [13].

There are 2 general mechanisms for how low socioeconomic status may predispose to CAP in older adults: through increased exposure to infectious agents or through increased susceptibility to infection. The latter may be due to biological factors or due to lack of immunization. Low socioeconomic status, through crowding, may lead to increased exposure to causative bacteria, such as *S. pneumoniae,* or to exposure to viruses, such as influenza, that predispose to superinfection with bacteria (such as pneumococcus), which subsequently cause pneumonia. Although crowding has been shown to be a risk for CAP in populations as diverse as Brazilian children living in slums, inmates of US jails, and Canadian First Nations peoples, this relationship has not been thoroughly evaluated in older adults living in the community [14–16]. The best example where clustering plays a key role in respiratory infections in seniors is in long-term care facilities, where outbreaks of respiratory viral infection occur regularly and lead to high rates of CAP. However, when seniors admitted to the hospital for CAP and population-based controls were compared in one study, no significant differences in crowding, defined as the number of persons living in the home divided by the number of rooms, were noted [9]. More studies evaluating the effect of crowding need to be performed. This variable should be included in case-control studies assessing risk of CAP in seniors.

There are experimental preliminary data that lower social status may predispose to susceptibility to upper respiratory tract infection. In one study, researchers measured study participants perceived social status with an instrument developed by the MacArthur Foundation’s Network on socioeconomic status [17]. Participants were then exposed to a rhinovirus and monitored. A gradient was demonstrated in which increases in social status were associated with reduced susceptibility. Perceived social status was not associated with smoking status, sleep efficiency, alcohol consumption, exercise, or increased circulating levels of catecholamines, which are biological markers for stress.
response [17]. These findings are intriguing and need to be confirmed by other researchers. Whether perceived social status predisposes to lower respiratory tract infections, such as pneumonia, in seniors is unknown.

Nutrition may also play an important role in predisposing older adults to CAP. However, there are conflicting epidemiologic reports about which nutritional states predispose to CAP. One matched case-control study compared patients aged ≥65 years admitted to the hospital for CAP with control subjects [18]. No differences in anthropometric measurements were found between the 2 groups. However, serum albumin, prealbumin, and transferrin levels were significantly lower in patients with CAP. Protein malnutrition was the predominant type of nutritional deficit in patients with pneumonia. A limitation of this study was the choice of use of hospital-based control subjects alone, possibly leading to bias by underestimating the effect of malnutrition. In another study in which patients with CAP were matched by municipality, sex, and age with control subjects, low body mass index (BMI) was not associated with increased risk for CAP in multivariable analysis [19].

In a large prospective study, men who gained ≥40 lb (>18 kg) since the age of 21 years had a ~2-fold increased risk of CAP, compared with those who maintained their weight, whereas there was no linear relationship between BMI and CAP [20]. Among women, the multivariable risk relative (RR) of CAP according to BMI increased from 1.53 (95% CI, 1.03–2.28) for women with BMIs of 25.0–26.9 to 2.22 (95% CI, 1.56–3.18) for those with BMIs of ≥30.0 (P < .001, by test for trend). In a study that assessed risk factors for pneumonia death, men in the lowest quartile of BMI, compared with subjects in the highest quartile, were found to have a >2-fold risk of pneumonia death (RR, 2.6; 95% CI, 1.4–4.5) [21]. Although the effect was present in both sexes, it was not statistically significant in women (RR, 2.3; 95% CI, 0.9–6.0). In men, there was an inverse relationship between arm muscle area and risk of pneumonia death. Risk increased in a graded manner from the highest to lowest quartiles of arm muscle area (RR of 2.2 in the third, 2.4 in the second, and 4.5 in the lowest quartile) [22]. Women with serum albumin levels in the lowest quartiles had ≥3 times the risk of pneumonia-related death, compared with women in the highest quartile (RR, 3.6; 95% CI, 1.1–11.5). This association remained significant after adjusting for chronic conditions related to pneumonia.

Three randomized trials of multivitamin or mineral supplementation have demonstrated enhancement of surrogate markers of both innate and adaptive immunity, including enhancement of natural killer cell activity, delayed-type hypersensitivity, and lymphocyte production [23–25]. The effect of supplementation with micronutrients has also been evaluated on clinical infection in older adults and patients with diabetes in a number of clinical trials [23, 26, 27]. However, none of these studies examined CAP as a primary outcome. Overall infection rates, including upper and lower respiratory infections, were the primary outcomes assessed. One study [27] showed no benefit in older adults but a marked reduction of infection in patients with type 2 diabetes. A closer examination of these studies sheds some light on why they may have reached different conclusions than did other similar studies [28]. Many study participants with clinically apparent micronutrient deficiencies were included in 2 of these studies [23, 27]. Thus, much of the benefit of supplementation in these 2 studies may be derived from the treatment of subclinical malnutrition. In contrast, the study by Graat et al. [26], which was performed in The Netherlands and which involved healthy, well-nourished older adults, found no benefit of vitamin E or multivitamin-mineral supplementation, and even found increased severity of infectious symptoms when they occurred.

Similar studies of trace mineral supplementation, with or without vitamins, have been performed in older adults in long-term care facilities, and again, conflicting data have resulted [29, 30]. In neither of 2 studies did vitamin supplementation reduce the risk infection. However, trace minerals (zinc plus selenium) reduced the risk of infection in one study [29] and showed a positive effect that, however, did not reach statistical significance for reducing respiratory infection in the other (P = .06) [30]. Improved delayed-type hypersensitivity and influenza titers after vaccination were also noted in the zinc/selenium-treated group, but, again, pneumonia was not specifically examined. There was no difference in overall mortality.

Another potentially important risk for CAP in seniors is exposure to tobacco smoke. However, the epidemiologic evidence is in older adults is limited. Smoking any type of tobacco increased the risk for CAP in one study [31]. However, the effect of second-hand smoke on nonsmokers was not assessed. Current smoking was associated with an increased risk of CAP among men and women in another report [20]. Lifetime smoking history has been demonstrated to be an independent risk [9]. One study showed that, in adults, the risk of invasive pneumococcal diseases was 4 times greater for cigarette smokers (OR, 4.1; 95% CI, 2.4–7.3) and 2 times greater for passive smoking among nonsmokers (OR, 2.5; 95% CI, 1.2–5.1) [32]. Whether these findings apply to people aged >65 years is unknown. There is reasonable biological plausibility for this association. Respiratory ciliary ultrastructural abnormalities have been shown to be significantly higher in nonsmokers than smokers, possibly leading to impaired tracheobronchial clearance [33]. Also, the in vitro adherence of S. pneumoniae to buccal epithelial cells smokers is markedly increased in smokers, compared with nonsmokers [34]. In a random sample of seniors living in a Finnish community, IgG antibodies to several pneumococcal serotypes and to cell wall
Air pollution

Direct exposure to tobacco smoke, and air pollution represent potentially important risk factors for this infection (table 1). A high correlation between pneumococcal disease in adults and levels of sulfur dioxide has also been demonstrated [41]. These pollutants may act as irritants causing inflammation in the respiratory epithelium and exacerbating symptoms. A study performed with a murine model suggested that IL-6 in the lung may play an important role in the progression of lung inflammation and injury due to air pollutants [42]. More research is needed to help to determine whether a clinically important effect exists in older adults, a group in which the incidence of pneumonia is high [3].

Lack of immunization with influenza or pneumococcal vaccine may be more common in seniors with low socioeconomic status, possibly predisposing them to CAP. For example, a survey of adults who had recently visited outpatient clinics was conducted, and it was found that individuals with low socioeconomic status were less likely to have received influenza and pneumococcal vaccination [43]. The traditional explanation for these types of findings has been that physicians were less likely to recommend preventative services for patients who were less able to afford them. In this study, however, individuals with low socioeconomic status received recommendations to be vaccinated at the same rate as higher socioeconomic status patients. Furthermore, these findings were not dependent on whether the individuals had health insurance. The authors speculate that their results may relate to socioeconomic status–related differences in attitudes toward preventative health services. More research to understand the nature of these special barriers is needed.

Large observational studies could address many of the unexplained issues discussed here. Comparing seniors with CAP with population-based control subjects using a case-control design would be feasible way of determining the importance of socioeconomic status and environmental issues. Air monitoring units can establish gradients of air pollution across communities such that case patients can be compared with control subjects both in space and time. Both long-term (months) and short-term (days to weeks) exposures could be measured. Structural equation modeling, where pathways of causation are constructed, could be used to help explain the complex relationships amongst these variables. Nutritional assessment and immune function (through measurement of T lymphocyte function) could feasibly be performed.

In summary, CAP is an important health problem for older adults. Variables such as socioeconomic status, crowding, exposure to tobacco smoke, and air pollution represent potentially important risk factors for this infection (table 1). A better understanding of these factors and their underlying biological mechanisms is needed to develop successful health promotion strategies, such as better immunization and educational programs about nutrition. Determining the impact of air pollution on CAP in older adults is important both in terms of reducing
personal risk to older individuals and for those environmental and public health agencies charged with formulating policies to protect the health of older adults.

References