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Inner City Asthma

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SYNOPSIS

The inner city has long been recognized as an area of high asthma morbidity and mortality. A wide range of factors interact to create this environment. These factors include well-recognized asthma risk factors that are not specific to the inner city, the structure and delivery of health care, the location and function of the urban environment, and social inequities. This article will review these facets and discuss successful and unsuccessful interventions in order to understand what is needed to solve this problem.

Keywords

asthma; inner city; severity; poverty; disparities; intervention

Scope of the Problem

Prevalence

In the United States “current asthma” increased at a rate of 1.4% per year between 2001 through 2010 among children and adolescents 17 years and younger so that by 2008–2010 the prevalence reached 9.5%.¹ Asthma prevalence varies among racial/ethnic groups, African-American children have 1.6 times the level of current asthma than white children.² Asthma prevalence varies greatly among the Hispanic groups in the U.S. Puerto Rican children have among the highest prevalence, approximately 2.4 times white children, while Mexican-American children have levels lower than white children.^{2,3} Differences in prevalence can represent true differences in disease or differences in diagnosis. An analyses of children 3 to 17 years with reporting wheezing in the past year from the 1999 National Health Interview Study (NHIS) found that compared to non-Hispanic white children, the adjusted relative risk for reporting a diagnosis of asthma was elevated for Puerto Rican (1.43), for non-Hispanic black (1.22), and for Mexican American children (1.19).⁴

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Suggesting that part of the reported differences in prevalence can be explained by differential rates of diagnosis.

In addition to varying among different racial/ethnic groups, asthma prevalence can vary both across and within neighborhoods. Neighborhoods with the highest asthma prevalence tend to have high minority concentration and low income levels. In Chicago, the neighborhood prevalence of asthma ranges from 0% to 44% with the highest levels seen in African-American and Hispanic neighborhoods.⁵ Within a single neighborhood in New York City, asthma prevalence has been reported at 5.3% for Dominicans and other Latinos versus 13.2% for Puerto Ricans.⁶

The factors contributing to the high prevalence of asthma in Puerto Rican children are not clear. Despite having higher SES, lower rates of prematurity, and less exposure to prenatal smoke exposure, the prevalence of asthma is higher in Puerto Rican children living in Puerto Rico as compared to Puerto Rican children living in the south Bronx.⁷ Differences in prevalence between island resident Puerto Rican children and those living in mainland US are not due to increased severity when GINA severity criteria and pulmonary function are considered, but island Puerto Rican children have higher rate of emergency room visits and lowest use of inhaled steroids.⁸ Differences in perception of disease may contribute to the differences noted among Puerto Rican children. Comparison of subjective estimates of peak flow rates (PEFR) compared to measurement of PEFR over a 5 week period among 512 children ages 7 to 16 years of age living in Puerto Rico and Rhode Island found that Island Puerto Ricans had lowest accuracy of estimating their PEFR with Rhode Island Latinos somewhat better. However, both groups were significantly worse than non-Hispanic white children. The authors also reported that self-reported asthma morbidity increased as ability to estimate the pulmonary function decreased.⁹

Morbidity and Mortality

Data from a national database report in 2006 indicate that asthma was the reason for 3.4 million visits to physician offices, 500,000 visits to hospital outpatient departments, 593,000 emergency visits, and 155,000 hospitalizations. In 2005, there were 167 deaths from asthma in children and adolescents (the vast majority of asthma deaths occur in the elderly). African-American children and adolescents had 7.6 times higher death rate, 2.6 times higher ED visits, 3 times higher hospitalization, but 20% lower non-emergency asthma ambulatory care than whites. Data on Hispanics at the national level are more limited, but ED usage by this ethnic group is approximately double that of whites while having a similar asthma death rate. The disparities gap between African Americans and whites for hospitalizations and mortality has not decreased over the past 30 years.^{1,2}

Contributing Factors

Disease Severity

Reduced responsiveness to therapy for intrinsic or extrinsic reasons has been considered as a possible explanation for the higher rates of morbidity and mortality found among poor and minority children and adolescents. However, a number of studies such as the Inner City Asthma Consortium Asthma Control Evaluation (ACE) study¹⁰ and the BreathMobile¹¹

found that, after providing high quality, comprehensive asthma care and the ability to obtain the needed medication, the vast majority of poor and minority children and adolescents with asthma can be well controlled.

Although proportionally more ED visits occur in children who live in low income, urban environments, the severity of asthma exacerbations does not appear to differ between children of varying socioeconomic strata. As part of the Multicenter Airway Research Collaboration, 40 EDs across the US evaluated 1,095 children and adolescents 2 to 17 years of age presenting with an attack of asthma. In multivariate analyses, after controlling for socioeconomic factors, race/ethnicity was not related to respiratory distress at presentation nor outcomes as measured by a pulmonary index score which included severity of wheeze, respiratory rate and accessory muscle use, ED management, hospitalization for asthma or outcome 2-weeks after discharge from the ED.¹²

One explanation for the increased burden of asthma in low income, urban, minority children and adolescents may lie on the role of physician's and patient's perception of severity and need for treatment. Among 3,494 adult asthmatics in 15 managed care organizations in the US, the severity of asthma estimated from patient reported symptoms was compared to physician estimates of severity. Physicians were more likely to estimate the severity of asthma lower than the patient's perception of severity among blacks as compared to whites patients (OR=1.39, 95% CI 1.08–1.79). This underestimation was associated with under treatment with ICS.¹³

Poverty

To better understand the differences in morbidity and mortality, the social environment in which these children and adolescents live must be considered.

In 2012 the percentage of African-American (36.7%) and Hispanic (33.8%) children living in poverty was almost 3 times that of white children (12.3%). This disparity in poverty among children has not decreased since 2000.¹⁴ However, the relation between asthma prevalence and income is complex. Analyses of the 1997 NHIS for children and adolescents <18 years of age found that, after controlling for relevant confounders, only among families living on income less than ½ the federal poverty level was asthma prevalence increased in African-American compared to white children.¹⁵ Using a composite socioeconomic index in 8 to 21 year old participants in the GALA II and SAGE II studies (large asthma genetic studies focusing on African American and Latinos), the investigators found that, among African-American children, asthma prevalence increased while the index decreased. In contrast, Mexican-American children showed a decrease in asthma prevalence as the socioeconomic index decreased. These findings did not change when acculturation was taken into account.¹⁶

Comparisons based solely on income do not adequately explain the disparities between the racial/ethnic groups in the US. Controlling for income, African-American and Puerto Rican populations, compared to whites, live in neighborhoods with poorer quality of life due to less economic investment, lower quality schools and less access to medical services.¹⁷ While racial segregation has declined in the US, African Americans as a group continue to

experience the highest level of housing segregation.¹⁸ Worse community functioning as measured by increased crime, incarceration rate, or exposure to violence has been associated with higher asthma prevalence,¹⁹ lower adherence to inhaled corticosteroids²⁰ and more asthma symptoms.²¹

A more complete understanding of the role of socioeconomic status (SES) in health disparities is hindered by the conceptualization of SES. Many studies operationalize SES with two variables: family income, with or without adjustment for family size, and education level. Other important individual factors, such as wealth, and non-individual factors, such as the social and physical environment that includes residence in a poor neighborhood, are not taken into account. A study of asthma readmission rates among 1 to 16 year old children in the Cincinnati OH area, where African-American children had approximately twice the readmission rate of white children, used two approaches to understand the reasons for this racial difference. Conventional SES variables (income, education) explained approximately 8% of the difference while the addition of variables such as car or house ownership, marriage status, looking for work and source to borrow money from, increased the ability to explain the difference to almost 41%.²² A neighborhood analysis of childhood (1 to 16 years of age) asthma admission rates from Hamilton County, Ohio found that neighborhood-level education, car access, and population density explained the majority ($R^2=0.55$) of the neighborhood variation in asthma admissions.²³ It is important to note that simply placing a large number of variables in a statistical model is not an optimal methodology compared to using more advanced statistical approaches such as propensity scores to better account for SES differences between racial/ethnic groups.

Quality of Care

Uncontrolled asthma results in higher health care use. In a study by Guilbert et al, children with uncontrolled asthma (ACT score ≤ 19) had an OR of 4.6 for an asthma-related doctor's visit and OR of 1.7 for an ED visit compared to children with well-controlled asthma, over a 9 month period.²⁴ Access to quality care is an important factor in how asthma is controlled. In a study of asthma hospital readmissions among 1 to 16 year old children in Ohio, the readmission rate was lowest among children with private insurance and good access to care.²⁵

Disparities exist in how poor and minority children are treated. Minority children frequently have lower use of controller medication and higher use of reliever medication to control their asthma.²⁶ Among children 1 to 6 years of age who were hospitalized for asthma, minority children were less likely to be prescribed a nebulizer on discharge than white children.²⁷ Hispanic children with asthma received fewer inhaled steroid prescriptions regardless whether they received their care at a private practice or a clinic.²⁸ Even within a system with equal access, military dependents covered by Tricare Prime, African-American and Hispanic children had higher rates of emergency department visits and hospitalizations, while being less likely to receive care from an asthma specialist.²⁹

In addition to being prescribed proper treatment for asthma, it is important that children use the treatment. Lack of adherence to inhaled corticosteroids has been associated with exacerbations; for example, with every 25% increase in adherence to ICS there was a

decrease of 11% in asthma exacerbations among adults.³⁰ Factors found to be associated with adherence include the family's belief about the need for the medication, the parental expectation about asthma control, non-English speaking, and family organization \functioning.^{31,32} Neighborhood factors such as crime level have also been related to adherence.²⁰ Of course, increasing adherence may have relatively little impact if the child is prescribed inadequate dose of a controller medication: a community study of 5 to 12 year olds found that, although 76% reported to be using daily controller medication, 74% were on inadequate controller dose.³³ Prescribing an inadequate dose can also lead to worse adherence because patients or their families may question the benefit when efficacy is low.

While guidelines exist as to how to manage asthma, care must be taken to ensure that the method or tool employed is appropriate for the population. For example, written action plans are often used as a measure of good quality of care. However, when the impact of action plans is evaluated they are not always found to be effective.³⁴ An evaluation of 30 asthma action plans used by 27 state Departments of Health determined that readability was at 7th grade level instead of the 3rd to 5th level that is recommended for low literate populations. Based on ease of use and readability, over 40% of these action plans were considered unsuitable.³⁵

Allergens\Sensitization

Exposure and sensitization to allergens play an important role in asthma morbidity. Increased exposure to certain allergen such as mite or cockroach is associated with increased rate of sensitization.^{36,37} and sensitization and exposure to allergens such as those deriving from cockroaches,³⁸ mice,³⁹ rats,⁴⁰ or molds are associated with increased asthma symptoms and health care utilization.

Exposure to indoor allergens varies widely based on many factors, several of which are linked to poverty. Older homes, poor condition of the house (e.g. cracks in the wall, water leaks), and low family income are associated with increased levels of cockroach, mite and mouse allergens.⁴¹⁻⁴³ Urban areas and high rise apartment buildings are specifically linked to increased cockroach allergen.⁴² Single family homes and high bedroom humidity are associated with mite allergen.⁴¹ Pet (cat or dog) ownership is the most important marker of pet allergens.⁴⁴ As pet ownership increases with increasing income these allergens are relatively less common in poor urban areas.⁴⁴ Exposure in the bedroom appears to be the most important in regards to developing sensitization.³⁷ Much effort has been directed at lowering allergen exposure in the home specifically the bedroom, but it has also been shown that high levels of allergen and mold exposure can occur at school or daycare.^{45,46}

Data from the US population collected in the National Health and Nutrition Survey (NHANES) show that non-Hispanic African Americans and Mexican Americans have higher rates of allergen sensitization than non-Hispanic whites.⁴⁷ African-American and Mexican-American children, 6 to 16 years of age, have higher rates of sensitization to allergens shown to be associated with asthma morbidity such as cockroach and dust mite.⁴⁸ At present it is not known if these differences are solely due to differential exposure to allergens or if genetic differences plays a role.

Housing

Housing quality in poor neighborhoods plays an important role in exposing the child or adolescent to a variety of asthma triggers. Public housing has been associated with some of the highest prevalence of asthma.⁴⁹ Data from the Puerto Rican Asthma Project in New York City found buildings with serious or medium level housing code violations had higher home allergen levels after adjustment for other neighborhood characteristics.⁵⁰ A New York City study of 7 to 8 years old children living in high asthma prevalence area found higher levels of cockroach, cat, and mouse allergens in their homes as compared to children living in low asthma prevalence areas.⁵¹

Conflicting data exist as to whether or not the homes of children with asthma differ from those without asthma within the same community. In a study conducted in Baltimore, MD, no difference in the levels of indoor pollutants (PM_{2.5}, PM₁₀, NO₂, O₃) and allergens (cat, dust mite, cockroach, dog, and mouse) was found when the homes of children 2 to 6 years of age with and without asthma were compared.⁵² In contrast a multi-city study across the US using the Environmental Relative Moldiness Index (ERMI), which was developed by the EPA and HUD to quantify mold contamination in housing, found that within the same geographic area, homes of people with asthma had higher relative burden of mold compared to the homes of people without asthma.⁵³

Environmental Tobacco Smoke

Exposure to environmental tobacco smoke (ETS) is associated with increased asthma prevalence, symptoms, asthma-related school absenteeism, asthma exacerbations and decreased pulmonary function among children and adolescents.^{54,55} The highest rates of active cigarette smoking are among the poor and those with low education.⁵⁶ Analysis of NHANES data from 2005–2010 showed that 53.2% of the children and adolescents with asthma who did not use tobacco products were exposed to ETS based on elevated serum cotinine levels. This increased to 70.1% among low-income children and adolescents. The level of exposure to ETS has been decreasing since 1988 but the rate of decrease has slowed considerably since 2004.⁵⁷ The factors most strongly associated with ETS exposure among inner-city children are the number of smokers in the house and younger age.⁵⁸

Nitrogen Dioxide

Nitrogen dioxide (NO₂) is a common respiratory irritant in inner-city homes. This is mostly due to the high use of gas stoves. High levels of NO₂ have been associated with an increase in asthma symptoms.^{59,60} The National Cooperative Inner City Asthma Study (NCICAS) found the effect of NO₂ on the children who were not allergen skin test positive. The authors speculated that the sensitized children were not immune to the effects of nitrogen dioxide but rather the prevalent allergen exposure in the children's homes was causing the sensitized children to have such high level of symptoms that the effect of nitrogen dioxide was not seen.⁶⁰

Outdoor Pollution

Air pollution has repeatedly been demonstrated to play an important role in asthma. Five of the six criteria pollutants (nitrogen oxides, particulate matter, ozone, sulfur dioxide, carbon

monoxide) monitored by the EPA have been associated with increased asthma prevalence or morbidity.^{61–63} Studies have also found that the closer a child lives to a source of outdoor pollutants such as a major highway or bus route, the more problems with asthma symptoms and exacerbations he/she experiences.^{64,65} A Rochester, MN study found that after using matching for other asthma risk factors using propensity scores to equalize asthma risk, children living in census tracts with proximity to a major highway or railroad had a higher risk of asthma.⁶⁶ Pollutant, interaction with allergens may play a role in the increased sensitization seen in inner-city communities: among 5 to 7 year-olds in New York City, higher levels of polycyclic aromatic hydrocarbons (PAH) were associated with increased levels of cockroach sensitization. This increased risk was highest in the children with a null genotype for GSTM1.⁶⁷

Lower income, minority communities have higher exposures to environmental pollutants due to the disproportionately higher numbers of toxic waste dumps, major highways, bus terminals, industry, etc. being located in close proximity.^{68,69} The CDC reported that in 2010 approximately 4% of the U.S. population is living within 150 meters of a major highway. Being a member of a racial/ethnic minority group (non-Hispanic black 4.4%, Hispanic 5%, non-Hispanic white: 3.1%), being foreign born (5.1% vs 3.5% native born), and speaking a language other than English at home (Spanish 5.1% vs English 3.3%) increases the probability of living close to a major highway.⁷⁰

Studies which focus on immigrants give us a better understanding of the influence of the local environment on asthma. Data from the National Health Interview 2001–9 found higher prevalence of asthma among all ages in individuals born in the United States as compared to foreign-born individuals. These differences were present in all racial/ethnic groups. Among the foreign-born, time living in the U.S. appears to be important. After 10 years or more living in the U.S., foreign-born individuals had higher rates of asthma compared to more recent arrivals.⁷¹

Obesity

Obesity is a major problem in poor and minority communities. Among children and adolescents in the US during 2009–2010, 39.4% of Mexican Americans, 39.1% of non-Hispanic blacks and 27.9% of non-Hispanic whites were overweight (BMI \geq 85%). Greater differences existed when obesity (BMI \geq 95%) is considered: 21.2% in Mexican Americans, 24.3% in non-Hispanic blacks and 14% in non-Hispanic whites. Overweight/obesity has been shown to be associated with increased asthma prevalence, symptoms and exacerbations. This difference was not related to differences in allergic sensitization.^{72,73} A randomized control trial reported that weight loss among obese asthmatics resulted in improvement in static lung function and asthma control without changes in inflammation.⁷⁴

Prematurity

Higher rates of asthma among children and adolescents have been found to be associated with certain birth characteristics such as low birth weight or premature birth.^{75,76} In a study of middle class, racially diverse children, 6 to 8 years of age, living in the suburbs of Detroit MI, approximately 1/3 of the black-white differences in physician diagnosed asthma was

accounted for by the difference in low birth weight.⁷⁷ Extreme prematurity (gestation 23–27 weeks) appears to be the period where the highest risk for developing asthma exists.⁷⁸ Natality data from the U.S. in 2012 show that non-Hispanic African-American mothers experience up to twice the rate of premature or low birth weight births. This is true for births of <37 weeks and <32 weeks gestation and for birth weights <2,500 grams or <1,500 grams. The prematurity and low birth rates for Hispanics are either equal or slightly higher than non-Hispanic whites.⁷⁹

Psychosocial Factors

Psychological factors play an important role in inner city asthma. Maternal mental health problems are associated with increased hospitalizations for childhood asthma,⁸⁰ maternal depression is associated with increased asthma ED visits,⁸¹ and maternal stress levels with increased infant wheezing.⁸² The child's psychological status is also important as childhood behavioral problems are associated with wheezing and poorer functioning.⁸⁰

Interventions

Interventions in the inner city are challenging given the many factors contributing to the high burden of asthma among poor and minority children. A number of interventions have been focused on the quality care received. One aspect of the problem of obtaining quality care in the inner city is the family's ability to successfully deal with the medical care system because of lack of knowledge\skills and other, competing major socioeconomic problems. The NIAID-funded NCICAS found that a tailored family-based intervention performed by an asthma counselor (an asthma-trained social worker) was effective in helping the families obtain better care and reduce the morbidity of their child's illness.⁸³ Other successful interventions to improve medical care usage have focused on the children or adolescents with asthma and have been school-based either by providing asthma education to the students during school day⁸⁴ or by direct observation of the use of asthma controller medications.⁸⁵ Lack of family participation limits the effectiveness of a program, as reported in an intervention using a trained parent mentor to help families with asthma.⁸⁶

As discussed earlier, environmental triggers of asthma are found are highly prevalent in the living environment of poor and minority children. Concern has been raised as to the ability to decrease allergen levels and the actual impact on disease. For example, using an exterminator service will only temporarily reduce the level of cockroach allergen.⁸⁷ The NIAID-funded Inner City Asthma Study (ICAS) completed a clinical trial evaluating the effect of a comprehensive environmental cleanup focused on home allergens and exposure to tobacco smoke. The intervention resulted in a decrease in the level of home allergens and a concomitant decrease in asthma symptoms, thus demonstrating the feasibility of lower allergen levels but also the large effort required to accomplish this goal.⁸⁸ Importantly, the effect of this approach appeared to be long-lasting, as it remained present for at least one year after the intervention of the ICAS was completed.

Other interventions have focused on improving housing conditions. A program to weatherize homes resulted in decreased mold and moisture exposure and improvement in asthma control compared to a historic control group.⁸⁹ Taking advantage of a Seattle, WA

public-housing redevelopment project, investigators found that moving families of children and adolescents with asthma into asthma-friendly homes improved symptoms and asthma-related quality of life and reduced ED visits, compared to controls who received asthma education from a nurse at a primary care setting.⁹⁰

A number of factors influence whether or not an intervention will be successful in the inner city. Interventions which are too narrowly focused, such as emphasizing nebulizer use⁹¹ or use a HEPA filter alone⁹² tend to have limited to no effect. While the targets of these interventions are important, the effects are overwhelmed by other factors that are left untreated. Lack of active participation and interest by the subjects of an asthma intervention is of importance and can lie in the design of the program itself or in the attitude and beliefs of the participants or their families. An evaluation of non-responders in the PUFF City intervention (a computer-tailored intervention designed to aid urban African American adolescents gain better control of their asthma) found a number of factors such as the Asthma Self-Regulation Interview (which measures acceptability of the chronic nature of the disease, perceived vulnerability and ability to control it), rebelliousness, religiosity, and perceived emotional support from family and friends having varying impact on adherence to controller medication, availability of rescue medication, and smoking cessation.⁹³

It has now been clearly shown that with the proper treatment inner city asthma can be well controlled. With the provision of guidelines driven care and assured access to the appropriate controller medication, the NIAID-funded ACE study reduced asthma symptoms to a low level.¹⁰ The NIAID-funded ICATA study demonstrated that asthma exacerbations could be dropped significantly with similar high quality care. In addition, ICATA found that the addition of a biologic (omalizumab) could further reduce symptoms and exacerbations.⁹⁴ While biologics are too expensive to be used widely they demonstrate that future advances in therapies will allow inner city asthma to be even better controlled

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KEY POINTS

- Inner cities are areas of high asthma morbidity and mortality
- Many asthma risk factors present, no single one predominates
- Structure and function of medical care contributes to the problem
- Social inequities contribute to the problem
- Successful interventions exist

Summary

Inner-asthma is a complex problem. Improving the efficacy of drugs to treat asthma or identifying a new environmental or genetic risk factor contributing to morbidity will add to our existing armamentarium but will have limited impact on reducing disparities. A multifaceted approach must be used that will target a broader spectrum of risk factors. Environmental interventions should not be limited to home allergens or indoor pollution, but must be expanded to include housing quality and even outdoor sources of pollution such as highways or dump sites in the neighborhood. Although guidelines-based management and new therapies targeting phenotype-specific pathways need to be implemented, it may not be sufficient for the inner-city child and adolescent with asthma to simply receive the right drugs. The structure of the medical care system must change to allow the needed access to the required follow-ups and to education and the education of physicians taking care of these patients needs to improve. In addition, other factors such as instability of housing, access to transportation or family function should be addressed to ensure that pediatric patients and their families are not otherwise overburdened to manage asthma. Only with expanded creative solutions can we decrease the disparities found in the inner city.