8. The Role of Air Pollutants and Environmental Factors in Childhood Asthma

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Dr. Pam Wood is going to present next on asthma and respiratory problems. Dr. Wood is with the Department of Pediatrics at the University of Texas Health Science Center in San Antonio.

DR. WOOD: I'll be talking today about the role of air pollutants on respiratory diseases, particularly on asthma, and I'll focus on indoor air pollutants and irritants and allergens and some potential strategies for reducing exposure to these substances.

To start out I'd like to give you a clinical definition of asthma. Asthma is a disease of airway obstruction that involves airway inflammation; the obstruction is reversible, either with medication or with time, which distinguishes it from most other respiratory disorders. There is also increased airway responsiveness. This means the airways are very sensitive and easily irritated and will clamp down on exposure to a variety of different inhaled substances. So to make the diagnosis, you must have recurrent episodes. It's difficult to make the diagnosis of asthma the first time someone has difficulty.

Asthma is the most common chronic illness of childhood and the most recent data estimate that it affects somewhere between 5 and 6 percent of children. In 1999 4 million children had an acute episode of asthma. This added up to a great deal of healthcare utilization—office visits, emergency room visits, hospitalizations, and days missed from work and school. Asthma is a very significant illness.

What about trends in asthma prevalence and severity? Between 1980 and 1996 we saw a tremendous increase in the prevalence of asthma. One of the difficulties is that in 1997 the epidemiologic definition of asthma used in the National Health Survey changed, so it’s a little bit difficult to compare the 1997 and later data with the earlier data in terms of prevalence. Beginning in 1997, we separated asthma data into life-time prevalence and symptoms within the previous year. (Figure 8-1) What we do know is that since 1995 we have had a continued increase in the number of acute care visits and clinic visits for asthma, but it does seem that the rates for hospitalization and for death from asthma have stabilized or decreased.

There are some particularly high risk groups including African-Americans, Puerto Rican-Americans living in large urban centers, and children less than four years of age.

Why do children have more difficulty? They have smaller airways which are more easily obstructed. There's not much room for mucosal swelling and bronchospasm if you have a small airway to start with. Children also breathe more rapidly, so for any given exposure they're going to be inhaling more than an adult would on the basis of their body weight.

In the indoor environment we know children are crawling around on the floor and there are a lot of different allergens and irritants that are found in carpeting and flooring, so that may also be a factor

I want to talk very briefly about some of the most common outdoor irritants and data on respiratory diseases and asthma in particular. Nitrogen dioxide has been shown in some studies to result in changes in airway responsiveness. In other words, the airways are more twitchy, more sensitive, if they have been exposed to nitrogen dioxide. Exposures to nitrogen dioxide result in increases in respiratory illness, including non-asthma illnesses and perhaps an increased susceptibility to infection.

Ground level ozone is also a very potent irritant to the airways, and children and adults with asthma and other pulmonary disease are particularly susceptible to irritation from ozone. The health effects are increased symptoms of disease, increase in lung inflammation, and problems with lung function. The high risk groups for most of these exposures are individuals with pre-existing lung disease and physically active individuals because they have a greater respiratory rate and tend to spend more time outdoors.

Particulate matter, fine particles and the larger coarse particles, are also potent airway irritants and are found in both outdoor and indoor environments. And finally sulphur dioxide has also been shown to result in reduced lung function and an increase in respiratory symptoms. So we have a whole large number of outdoor airway pollutants.

How are we doing as a country? Well, we're certainly not doing as well as we would like to do. Figure 8-2 is EPA data on the number of persons in millions living in counties where the air quality exceeds standards for given pollutants, and particularly for ground level ozone and for larger particulate matter. We're not where we would like to be.

I'd like to show you a couple of studies in patients with asthma looking at specific pollutants. (Figure 8-3) First, are two studies on individuals who are known to have asthma. If you look at individuals with asthma when exposed to both ozone and sulphur dioxide, you see an increase in bronchial reaction. So ozone and sulphur dioxide are very significant airway irritants. Individuals with asthma who are exposed to ozone during exercise have an increase in airway inflammation as compared to control subjects. So once again, ozone is a very potent irritant.

Some of you may be familiar with the National Cooperative Inner-City Asthma Study. It's a very large study of asthma in young children in a number of urban centers around the United States. (Figure 8-4) They also collected data from air quality monitors that were in close proximity to the individuals enrolled in their study, and they looked at a subgroup of 826 children between four and nine years of age for whom they had corresponding air quality data. They found some information about especially high risk groups. We already know that children with asthma are at an increased risk, and all of these children had asthma, but those who also had been premature or low birth weight had a greater decrease in peak expiratory flow and a greater increase in symptoms with ozone exposure. This was particularly the case for non-atopic children—children who don't have allergies. Maybe for the children with allergies, the allergens are overriding and masking the effects of ozone, but for whatever reason, that was a difference that was noted.

Another recent study looked at children at an asthma camp in a rural area, I believe in Connecticut. The investigators measured ambient ozone levels and simultaneous lung function, and they found a 40% increased risk of asthma exacerbations on high pollution days. They also found that other airway irritants were associated with an increased need for asthma medications.

I'd like to move to what happens in the indoor scene. There are basically two different types of indoor air exposures that are important. We have biological exposures and we have chemical exposures. (Figure 8-5) Most of the biological exposures are allergens, with the exception of the infectious agents down at the end of that list, and then we had a huge number of chemical exposures.

Figure 8-6 shows data from the PORT Study of Asthma in Children, which involved children between three and 15 years of age at three or four managed care clinics in Chicago, Seattle and Boston. The investigators looked at what percentage of children with asthma were exposed to different environmental irritants and allergens. Thirty percent had a smoker in their home; almost 20% reported household pests, cockroaches or other household pests; and 60% had furry pets; most of them had bedroom carpeting which we know is a reservoir for dust and mold, among other things; and a high number of them had forced air heat, which it means you're blowing potential allergens and irritants into the air; and very few of them had dust-mite-impenetrable covers on their pillows or mattresses—and we'll get to that in a moment.

They also looked at what factors were associated with exposures, and this gets into some of the issues of why particular groups are vulnerable. We know that smoking is more common in low education and low income families. Dog ownership was also associated with low education in this particular group of patients, but cat and dog ownership were less common among African-American families. Individuals who considered themselves to be black reported an increased rate of household pests, but they were less likely to have carpets, so some good things, some bad things.

Let's look at the big picture of what we know about indoor allergens and irritants causing asthma, or if you already have asthma, increasing symptoms. The EPA, in their study "Clearing the Air" (which you can access off the internet), did a very nice job of looking in a systematic way at the evidence for the indoor air quality and the relationship to asthma. For dust mite antigen, we really have very strong evidence for a causal relationship. (Figure 8-7) In other words, children who are exposed to high levels of dust mites are more likely to develop asthma.

There is an association between environmental tobacco smoke and the development of asthma, particularly for preschool children, who are probably exposed to higher levels because of their proximity to their parents. There is some limited and subjective evidence for cockroach and for respiratory syncytial virus (RSV) infection. RSV tends to affect young children.

What about exacerbations in children who already have asthma? (Figure 8-8) We have evidence for a relationship for pet dander, for cockroach antigens, for house dust mites, and for environmental tobacco smoke in younger children. There is an association, not quite as strong a degree of evidence, for dog, for molds, for rhinovirus, which is another very common respiratory virus, and for nitrogen dioxide.

Cigarette smoke, environmental tobacco smoke (ETS), is probably the worst indoor irritant for children, and particularly for children with asthma. Unfortunately, there's not a lot of data on how we can effectively change that particular behavior. Looking at exposure rates in 24 cities in the United States and in Canada, almost 50% reported a current exposure to cigarette smoke, and a quarter of the children had at least two smokers in their household. In the PORT study of children with asthma, 30% had a smoker in the home. So even in children who have respiratory disease, a lot are being exposed to ETS.

What happens when you expose a child in-utero to ETS? (Figure 8-9) Well, there are a number of studies that show that in utero exposure, even if there's no postnatal exposure, results in decreased lung function and increased bronchial hyperactivity in the children. There is a very interesting recent study on the interplay between environment and genetics. You've already heard something about the GSTM1 gene and the enzyme product for that gene. This group looked at children who were null, that is, they did not code for that gene product. It was these children who with in-utero exposure had an increased prevalence of asthma, wheezing and emergency room visits. So, again, there is gene and environment interaction.

Parental smoking increases a child's odds ratio for wheezing and asthma, even after adjusting for all the confounding variables: poverty, environment, other non-tobacco smoke pollutants. There is a dose effect; the symptoms increase as the level of smoke in the household increases. Maternal smoking is more powerful than paternal smoking, perhaps mothers spend more time with their children indoors.

From the NHANES-III data, we find that, particularly in young children four to six years of age, children who have a high level of cotinine have an increased prevalence of asthma, and for children who already have asthma, those with the highest cotinine levels have a huge odds ratio, 2.7 for moderate to severe asthma. They also have a decrease of 80% in their lung function as measured by FEV1, and the youngest children are the most affected.

Another study from NCICAS, the National Cooperative Inner-City Asthma Study, found that ETS exposure, yes or no, was not actually associated with the degree of asthma symptoms. However, if you look at children who are exposed, the frequency of symptoms is the highest among those with high levels of exposure.

A common indoor air pollutant in many parts of the world is sulphur dioxide, usually related to combustion, particularly oil, coal and kerosene. Nitrogen dioxide is a problem from gas appliances, particularly poorly ventilated gas stoves. We have environmental tobacco smoke that we've already talked about, and particulate matter, particularly from fires and from cooking. If you're a bad cook and do a lot of burning and have poor ventilation in the kitchen, then you're going to raise the levels of particulate matter. We also have exposure from fumes and other airway irritants.

What about exposure to nitrogen dioxide. Once again some of our best data comes from the National Cooperative Inner-City Asthma Study where they actually did indoor as well as outdoor air quality monitoring. They found that a quarter of the children had relatively high levels of nitrogen dioxide exposure and these had more symptoms and lower peak flows. And once again, those children who were not allergic were at particularly high risk from the respiratory pollutants.

Let’s get back to the issue of cooking. If you're going to make your home the best for your child with asthma, you should not smoke, and you should not cook. So that's good news for all of us that don't like to cook.

There are some very interesting 24-hour monitoring studies which found that the levels of indoor fine particulate matter were associated with nocturnal symptoms, which are a big problem in asthma and account for the use of many rescue medicines and with many ER visits.

There are a lot of indoor allergens. The big offenders are dust mites, cockroaches, and cats. Dust mite and cockroach antigens are produced in the gut of the insect and excreted in the feces. Even after you kill the dust mite or the cockroach, you've got antigens spread around so you have to kill and remove the reservoirs.

Rates of sensitization are very high but depend on where you look. Figure 8-10 shows data from a study in Atlanta, which is very humid and has high rates of dust mite and cockroach sensitization. Alternaria is a mold. Eighty percent of the children were sensitized to at least one indoor allergen.

NCICAS had similar data, (Figure 8-11) except that the studies were in drier, colder cities; dust mites do not like cold and dry environments. The most striking allergy data out of NCICAS was that if you have high levels of cockroach and you're sensitized to cockroach, that's one of the biggest predictors for emergency room visits.

How do you get rid of these irritants and allergens? If you're dealing with a biological source, you have to get rid of the source but you also have to get rid of the reservoir for the antigen. If you're dealing with a chemical or with particulate matter, you need to get rid of the source. Venting is a poor substitute for getting rid of the source, and one of my biggest frustrations is parents of children with asthma or other pulmonary disease opening a window and smoking.

The dust mite, requires high humidity and a food source, which happens to be shed human skin. That's usually a ready food source. Mite levels are highest in fall. Interestingly, if you're exposed in-utero, you may actually turn on your sensitization to dust mites.

The data on eliminating dust mites are mixed. (Figure 8-12) The best method of decreasing exposure is plastic mite-impenetrable covers for mattresses and pillows. Washing bedding in hot water will kill the dust mite and remove most of the allergen. Getting rid of dust catchers and reducing indoor humidity are other important strategies.

Not surprisingly, cockroaches have turned out to be a major problem for low income level children living in urban areas. The really bad news is that with cockroaches, even with the most aggressive program, you can get the levels down temporarily, but they usually rise back up. (Figure 8-13) And the families who need help the most, usually have the greatest difficulty complying with the cleaning strategies. I recently talked with a colleague of mine who has become famous over researching cockroaches and asthma, and he is convinced that you can decrease the levels, but it takes a huge investment. You really need professional extermination and professional cleaning.

I'm going to end here with some summary data—this is also from the "Clearing the Air" report. (Figure 8-14) We know you can eliminate or significantly reduce dust mite. For cockroach antigen, we don't have a lot of evidence either for successfully eliminating the roach or for reducing symptoms if we do eliminate it. If you're cat-allergic, and you get rid of the cat, your lungs get better. We don't have good evidence for particle air pollutants; toward the bottom of this table is the weaker evidence for reduction in symptoms.

I think my time is up, so I'm going to stop here.