Air Pollution as an Underappreciated Cause of Asthma Symptoms

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FOR NEARLY 100 YEARS IT HAS BEEN KNOWN THAT asthma is a condition in which an acute respiratory response may follow inhalation of some material to which a person is sensitized. The list of such materials grew slowly over 50 years (it started with horse dandruff), continued with ragweed and grasses, and on the basis of skin responses, was believed to include a wide variety of foodstuffs (including nuts).[1] Domestic pets, and later, pests such as cockroaches and house dust mites came to the fore, and as occupational asthma came to be recognized, the list expanded still further. However, the focus of such awareness has been on agents that directly cause allergic reaction, and therefore can be diagnosed via skin tests, rather than on agents that cause nonspecific generalized inflammation, such as air pollution.

Recognition that exacerbations of asthma commonly involve inflammation has led to awareness that agents capable of inducing an inflammatory reaction in the lungs can worsen the condition. Early on, air pollution was suspected as one such important inflammatory factor since individuals with asthma were shown to be more sensitive than those without asthma to the gaseous air pollutant sulfur dioxide,[1] and because this type of air pollution was common with uncontrolled coal burning. During the latter part of the 20th century, sulfur dioxide levels were reduced substantially, but nitrogen oxides from power plants have not been as well controlled, while public exposure to motor vehicle emissions, with their complex mixture of particles and gases, has increased. Much of today's pollution problem is due to "secondary" pollutants, such as gaseous ozone and sulfate particles, from pollutants emitted by power plants, industries, and motor vehicles. Despite the best efforts to date, such secondary air pollution, in the form of ozone and fine particles in the air, has remained at stubbornly high levels in many parts of the United States, in violation of the US Environmental Protection Agency air quality standards.[2]

Ozone is a highly reactive gas that results primarily from the action of sunlight on hydrocarbons and nitrogen oxides emitted in fuel combustion. It reacts chemically and "oxidizes" lung tissues on contact, acting as a powerful respiratory irritant at the levels frequently found in most of the nation's urban areas during the summer months.[2] Epidemiological and clinical studies have shown that ozone exposure is associated with worsening of athletic performance, reductions in lung function, shortness of breath, chest pain with deep inhalation, wheezing and coughing, and asthma exacerbations among those with asthma.[3] Despite this evidence, air pollution remains one of the most underappreciated contributors to asthma exacerbations.

In this issue of THE JOURNAL, Gent and colleagues[4] report on their cohort study of asthmatic children from the New Haven, Conn, and Springfield, Mass, areas, including 130 children who used maintenance medications for asthma and 141 children who did not; the former group was considered to have more severe asthma. In the group using maintenance medication, the level of ozone exposure was significantly associated with worsening of symptoms and an increase in the use of rescue medication. Each 50-ppb increase in 1-hour average ozone level was associated with an increased likelihood of wheezing (by 35%) and chest tightness (by 47%). The findings suggest that asthmatic children who use maintenance medication were particularly vulnerable to ozone, even after controlling for coexposure to fine particles, and even at air pollution levels below current Environmental Protection Agency air quality standards.

In the northeastern United States, ozone levels are closely associated with levels of sulfate particles, both of which are components of "summertime haze." These pollutants might account in part for the associations reported by Gent et al. However, the authors directly addressed the issue of the possibly confounding effects of other air pollutants. In their copollutant models, ozone levels, but not fine particles, were significantly associated with respiratory symptoms and rescue medication use among children using maintenance medication. This finding is supported by a major study of 13 246 hospital admissions for asthma in Brisbane, Australia,[5] which showed a strong association between hospital admissions

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for asthma and ozone in the absence of aerosolized sulfate, so there is no reason to doubt that ozone exposure is a cause of asthma exacerbations.

The study by Gent et al expands on prior reports implicating ozone as a factor in asthma exacerbations. In a more limited cohort study conducted among children at an "asthma camp" in rural Connecticut in the early 1990s, the number of asthma exacerbations requiring physician-prescribed rescue medication increased in direct proportion to the ambient ozone level.[6] Moreover, a recent report from Paris[7] in which 82 asthmatic children were followed up for 3 months and had every exacerbation of asthma evaluated by a physician demonstrated that ozone levels were associated with an increase in the occurrence of asthma attacks, respiratory infections, and reductions in peak flow rate. The observations of reduced hospital admissions for children with asthma in Atlanta, Ga, during the 1996 Summer Olympics[8] provided striking confirmation of the benefit that would follow a reduction in the levels of this pollutant. In the Southern California Children's study, exposure to ozone was associated with increased school absences for respiratory illness among both asthmatic and nonasthmatic children, although children with asthma may have been more at risk.[9] Controlled human exposures to ozone have shown not only diminished lung function, but also an increased reactivity to allergens after exposure to ozone.[10,11]

Recent air pollution studies also indicate that the preventive use of asthma medications may reduce these acute adverse effects of air pollution on those with asthma. In some epidemiological studies, the association between particle air pollution and respiratory symptoms appears to be stronger among nonmedicated than medicated children with asthma.[12,13] In studies using controlled chamber exposures, medication use attenuates the effects of sulfur dioxide exposure on respiratory outcomes in volunteers with asthma.[14-16]

During the past 15 years, the incidence of asthma and the prevalence of severe asthma have increased in many countries despite the availability of improved medications. A recent survey of schoolchildren in Hartford, Conn, found that 19% had asthma.[17] Some evidence suggests that air pollution may have contributed to the increasing prevalence of asthma.[18,19] But regardless of the role of air pollution as a contributing factor to the prevalence of asthma, the study by Gent et al and others like it indicate that the increasing numbers of children with asthma represent an expanding pool of children at risk for respiratory symptom aggravation caused by air pollution, and by ozone in particular.

Accumulating evidence of the relation between asthma and air pollution seems to have had little impact. For example, the "National Asthma Education and Prevention Program Task Force Report on the Cost Effectiveness, Quality of Care, and Financing of Asthma Care" failed to mention air pollution as a factor in patient admissions for asthma.[20-22] It seems that current data from epidemiological and toxicological studies have not yet been translated into a general understanding and emphasis by physicians caring for patients with asthma. Since there is no skin test for air pollution exposure, it all too often goes unrecognized as an important factor in asthma exacerbations.

While physicians no doubt recognize that they cannot do much about modern urban air pollution on an individual level, they can make recommendations to patients with asthma to help them avoid the potentially adverse effects of air pollution. Patients and parents of children with asthma should be aware of the ozone alert forecast, which is widely publicized in news reports, and listed in the United States on the Internet (available at: http://www.epa.gov/airnow). Patients with asthma should stay indoors on high-pollution days, since indoor ozone levels are much lower than outdoor levels because the ozone is reduced by contact with air conditioner filters, walls, and draperies. However, some ozone does get indoors (and children have a natural wish to exercise outdoors), and exposure to other triggers of asthma (eg, dust mites) may be increased by staying indoors. Patients with asthma also should avoid strenuous outdoor exercise on high-pollution days. Some patients may benefit by having their anti-inflammatory asthma medications increased on high-pollution days.

Of the many triggers of asthma in the environment, air pollution is one of the few that can be legislated and regulated. Therefore, policy makers and regulatory agencies governing air quality necessarily have an important responsibility in ensuring that greater efforts are made to clean the air by reducing the emissions that lead to ozone formation, thereby helping to improve the health of adults and children with asthma.

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Looking for Medical Injuries Where the Light Is Bright

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HEALTH CARE QUALITY IMPROVEMENT EXPERTS often argue that "you can't manage what you can't measure." Suitable yardsticks are essential to judge the magnitude of potential quality problems and track whether interventions improve care. However, this aphorism needs one critical addendum: "You can't measure what you can't define."

Measurement and definitional issues loom large when discussing patient safety. The bellwether 1999 Institute of Medicine report *To Err Is Human* provided compelling evidence that medical errors pose daily risks throughout the US health care system but failed to quash controversy about the magnitude of that risk.[1] The best-known estimates of the extent of medical error rely on extrapolations from medical record review studies,[2,3] although these numbers have generated heated debate.[4-6]

Delineating definitions, though, should precede measurement. Another Institute of Medicine report defined safety as "avoiding injuries to patients from the care that is intended to help them."[7(p39)] Producing useful patient safety measures (ie, measures that can assist in managing and improving care) requires honing this definition to the subset of events that are amenable to improvement. While most observers agree that iatrogenic injuries occur in virtually all practice settings, attribution of injuries to error is complicated. Medical harm can result from myriad and sometimes intertwined factors, including the natural history of patients' diseases, coexisting medical conditions and risk factors, access to and availability of care, recognized toxic effects of appropriate therapies, clinical judgments and misjudgments, flaws in executing medical interventions, and bad luck. Although injuries sometimes trace back clearly to actions of individual practitioners, experts believe that multiple deficiencies latent in complex care delivery systems contribute importantly to most preventable iatrogenic injuries.[8]

To be maximally useful, patient safety measurement tools should therefore focus on preventable injuries. Preventable injuries, in contrast with complications resulting from recognized risky therapies administered correctly, offer actionable targets for quality improvement. Unfortunately, preventable injuries are technically difficult and expensive to capture. Chart reviews, although rich in clinical detail, are expensive, fail to identify undocumented events and causes, and often produce unreliable judgments about preventabil-

See also p 1868.

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