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Air Pollution, Reactive Oxygen Species, and Allergic Bronchial Asthma

The Therapeutic Role of Antioxidants

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1. INTRODUCTION

Bronchial asthma is characterized by airway inflammation, airway hyperresponsiveness to several specific and nonspecific stimuli, and reversible airway obstruction with the appearance of respiratory symptoms, such as dyspnea, chest tightness, wheezing, and cough. Although the pathogenesis of bronchial asthma is not completely understood, it is evident that this clinical condition has a multifactorial etiology, and a body of evidence suggests that bronchial asthma has become more common worldwide in recent years (1–2). There is a link between the increase in the prevalence of allergic airway diseases and the increase in air pollution. Several studies have shown the adverse effects of ambient air pollution on respiratory health (3–10). Moreover, exposure to components of air pollution enhances the airway response to inhaled allergens in susceptible individuals and, in most industrialized countries, people who live in urban areas are more affected by allergic respiratory diseases than those who live in rural areas (11,12). Road traffic, with its gaseous and particulate emissions, is currently, and likely to remain, the main contributor to air pollution in most urban settings (13–16).

Although the nature and concentration of outdoor pollutants vary from one area to another, the most abundant pollutants in the urban atmospheres are nitrogen dioxide, ozone, and fine particulate matter. Sulfur dioxide is an additional concern in industrial areas, whereas in rural and in urban areas aeroallergens are carried and delivered by plant-derived particles, such as pollen grains or fungal spores. The interaction between air pollution and aeroallergens can favor both the appearance and the exacerbation of allergic respiratory diseases.

Reactive oxygen species (ROS) play an important role in the pathogenesis of inflammatory airway diseases, such as bronchial asthma, and dietary antioxidants have a protective effect in bronchial asthma.
2. COMPONENTS OF AIR POLLUTION

2.1. Ozone

Ozone is the most important factor in so-called “summer smog,” because it is the main component of photochemical oxidants. Ozone probably accounts for up to 90% of total oxidant levels in cities that enjoy a mild sunny climate, such as the Mediterranean area and California, where current safety standards for ozone levels are frequently exceeded. Ozone is generated at ground level by photochemical reactions involving ultraviolet (UV) radiation of atmospheric mixtures of nitrogen dioxide and hydrocarbons, derived mainly from vehicle emissions. Consequently, ozone trends depend not only on substrate supply (nitrogen dioxide emitted by cars) but also on sunny weather that favors the transformation of nitrogen dioxide into ozone, thereby producing photochemical smog. Approximately 40–60% of inhaled ozone is absorbed in the nasal airways, and the remainder reaches the lower airways. However, ozone can affect both the upper and the lower respiratory tracts, and it induces more adverse effects in asthma sufferers than in healthy individuals.

Exposure to increased atmospheric ozone levels causes decrements in lung function and increased airway reactivity to nonspecific and specific bronchoconstrictor agents and is related to an increased risk of asthma exacerbation in susceptible patients with asthma (16–21). Atmospheric levels of ozone and nitrogen dioxide have been linked to increases in respiratory morbidity and in-hospital admissions for asthma in children and adults. Ozone can modulate the airway inflammation of diseases, such as bronchial asthma, by increasing the release of inflammatory mediators from bronchial epithelial cells (22). It has also been observed that ozone exposure has a priming effect on allergen-induced responses, as well as an intrinsic inflammatory effect in the airways of allergic asthmatics (23–25). Indeed, ozone produces an immediate dose-dependent increase in intracellular ROS, as well as in epithelial cell permeability, which could facilitate entry of inhaled allergens and toxins, causing an increase in the release of inflammatory cells and their products.

Because inhalation of ozone by healthy subjects increases airway responsiveness and airway inflammation, subjects with asthma were once expected to be more sensitive to the acute effects of ozone. Epidemiologic studies have provided evidence that high ambient ozone concentrations are associated with an increased rate of asthma attacks (17–19). Because ozone-induced airway inflammation may last several days and ozone-related asthma exacerbations often occur several days after exposure, it is feasible that ozone-induced enhancement of preexisting airway inflammation enhances susceptibility to asthma exacerbations.

Ozone decreases exercise tolerance in well-trained athletes without asthma (26–27). Repeated daily short-term exposure to ozone in healthy subjects attenuates the acute decreased lung function and inflammatory responses (28,29). It is important to establish whether the enhanced ozone-induced inflammatory responses of persons with asthma also become attenuated with repeated daily exposures, particularly because exposure to high ozone concentrations may occur for several consecutive days during smog episodes.

It has long been speculated that ozone and other pollutants may render allergic individuals more susceptible to antigens to which they are sensitized. Recently, it has been observed that the incidence of new diagnoses of asthma is associated with heavy exercise