

Thunderstorm-related asthma attacks

Gennaro D'Amato, MD,^a Isabella Annesi Maesano, MD,^b Antonio Molino, MD,^c Carolina Vitale, MD,^d and Maria D'Amato, MD^c Naples and Salerno, Italy, and Paris, France

Key words: *Bronchial asthma, severe asthma, near-fatal asthma, thunderstorm-related asthma, meteorological factors and asthma, prevention of thunderstorm-related asthma, asthma-related deaths*

In Melbourne, Australia, on Monday, November 21, 2016, hospitals were swamped with emergency patients affected by severe asthma attacks (>8500 patients across Monday night and Tuesday, 9 of whom died) while firefighters and police were called on to help physicians and paramedics respond to thousands of calls after the conditions caused breathing problems for citizens. It caused many persons, including those with no history of asthma but only hay fever, to experience breathing difficulties and frequently also have severe and near-fatal asthma. The epidemic in Melbourne was a very unusual weather occurrence, with wind and torrential rain combined with a high pollen count sending a high quantity of grass pollen allergens across the city.

Thunderstorms have been linked to asthma epidemics, especially during pollen seasons, and there are descriptions of asthma outbreaks associated with thunderstorms that occurred in several cities, prevalently in Australia (Wagga Wagga and Melbourne, where 2 other outbreaks happened in 1989 and 2010), Europe (in Birmingham and London in the United Kingdom and in Naples in Italy), and other cities around the world. All these incidents coincided with a heavy thunderstorm during the spring, when a large increase in the number of visits for asthma at emergency departments was observed.¹⁻⁵ However, the Melbourne outbreak was the worst epidemic, with 9 deaths and more than 8500 subjects in hospital emergency departments. The deaths of allergic subjects with atopic sensitization to grasses indicate that there was a very high concentration of asthma particles carrying allergens in the atmosphere during the thunderstorm.

Thunderstorm-related asthma is a dramatic example of the allergenic potential of pollen antigens, and patients with pollen allergy who encounter the allergenic cloud of pollen are at higher risk of having an asthma attack.¹⁻⁹

Pollen grains can be carried by thunderstorms at the ground level, with release of allergenic biological aerosols of paucimicronic size derived from the cytoplasm of pollens either ruptured or not that can penetrate deep into the lower airways. In other words, there is evidence that under wet conditions or during thunderstorms, pollen grains, in part after rupture caused by osmotic shock, release their content into the atmosphere, including respirable, allergen-carrying cytoplasmic starch granules (0.5-2.5 μm) or other paucimicronic components. These particles can reach the lower airways, inducing asthmatic reactions in patients with pollinosis.^{1-5,7-9}

Outbreaks of thunderstorm-related asthma are characterized prevalently at the beginning of thunderstorms by a rapid increase in visits for asthma in general practitioner or hospital emergency departments. Patients without asthma symptoms but affected by seasonal rhinitis can experience an asthma attack. No unusual levels of air pollution were noted at the time of the epidemics, but there was a strong association with high atmospheric concentrations of pollen grains, such as those from grasses or other allergenic plant species and in some cases also *Alternaria* species.⁹ However, subjects affected by pollen allergy should be informed about a possible risk of asthma attack at the beginning of a thunderstorm during the pollen season.

In particular, during the first 20 to 30 minutes of a thunderstorm, patients with pollen allergy can inhale a high concentration of the allergenic material released by pollen and dispersed into the atmosphere, which in turn can induce asthmatic reactions that are in some cases severe.^{1,2,4,5,8}

Even though thunderstorms can induce severe asthma attacks or exacerbations, they are neither frequent nor responsible for a high amount of disease exacerbation.¹⁰ This constitutes a major concern nowadays because the possibility of thunderstorm-associated asthma outbreaks have become a dramatic actuality because of the "highly likely" increase in the frequency of heavy precipitation events, including thunderstorms, projected by climate change scenarios for future decades.²

Because of its increased prevalence, the concentration of allergenic pollen is now a public health problem² and influences the degree of symptoms. However, the relationship between allergen exposure, airway inflammation, and clinical symptoms is complex, and factors other than allergens are involved, such as cold and perhaps also electrical charges of atmosphere.^{1,4,5,8,9} Pollen grains penetrate into the upper respiratory tract, but because of their size, which is always greater than 10 μm in diameter, they rarely reach the bronchial regions, even if bronchial asthma and its equivalents are not infrequent in persons affected by pollen-induced allergy.² Although much remains to be discovered about the relationship between an increase in the number of asthma attacks and thunderstorms, reasonable evidence exists in favor of a causal link between them in patients with pollen allergy. Rainfall is usually known to remove pollen from the air. However, during a thunderstorm, dry updrafts entrain whole pollens into the

From ^athe Division of Respiratory and Allergic Diseases, Department of Chest Diseases, High Speciality A. Cardarelli Hospital, Naples; ^bthe Epidemiology of Allergic and Respiratory Diseases Department (EPAR), Pierre Louis Institute of Epidemiology and Public Health (IPLESP UMRS1136), UPMC Univ Paris 06, INSERM, Saint-Antoine Medical School, Sorbonne Universités, Paris; ^cthe First Division of Pneumology, High Speciality Hospital "V. Monaldi" and University "Federico II" Medical School Naples; and ^dthe Department of Medicine and Surgery, University of Salerno.

Disclosure of potential conflict of interest: The authors declare that they have no relevant conflicts of interest.

Received for publication December 19, 2016; revised March 8, 2017; accepted for publication March 10, 2017.

Corresponding author: Gennaro D'Amato, MD, Division of Respiratory and Allergic Diseases, High Speciality Hospital "A. Cardarelli" Naples, Medical School and School of Specialization in Respiratory Diseases of University of Naples "Federico II", Rione Sirignano, n°10-80121, Napoli, Italy. E-mail: gdamatomail@gmail.com.

J Allergy Clin Immunol 2017;■■■:■■■-■■■.
0091-6749/\$36.00

© 2017 American Academy of Allergy, Asthma & Immunology
<http://dx.doi.org/10.1016/j.jaci.2017.03.003>

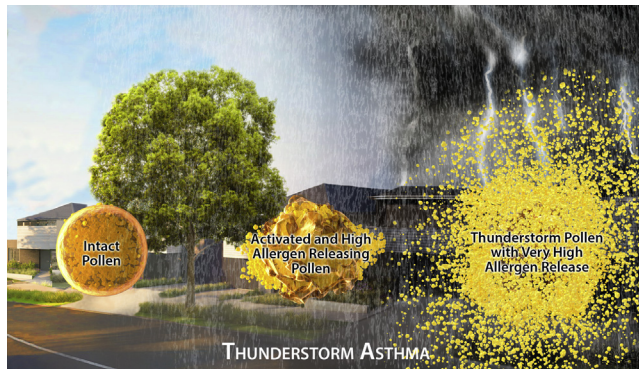


FIG 1. Hypothesis regarding release of allergens from pollen grains during a thunderstorm in the pollen season.

high humidity at the cloud base, where pollens can rupture and cold downdrafts can carry pollen fragments (pollen grains are too large to penetrate the deeper airways) to the ground level, where outflows distribute them. As a consequence, there is a high respirable allergen load in the air. Taylor et al⁴ hypothesized that the turbulent front of the advancing outflow releases more pollen from flowering grasses. Because of strong electric fields that develop during thunderstorms, positive ions are released from the ground that could attach to particles, electrical charges, or both and can enhance pollen rupture, thus enhancing bronchial hyperresponsiveness. Moreover, grass pollen can release large amounts of paucimicronic allergenic particles (ie, cytoplasmic starch granules containing grass allergens [allergen-bearing starch granules]) after imbibing and sometimes also rupture by osmotic shock during thunderstorms. Allergen-bearing starch granules obtained on contact of pollen with water have been shown to create an inhalable allergenic aerosol capable of triggering an early asthmatic response in an experimental *in vitro* study. Marks et al⁸ observed that the arrival of a thunderstorm outflow was accompanied by a large increase in the concentration of ruptured pollen grains in ambient air.

It is of interest to establish which risk factors can predict the occurrence of asthma outbreaks in such a way that early warning systems can be developed. Physicians and patients with pollen allergy should know the mechanisms involved in the release of allergens during thunderstorms in view of prevention (Fig 1 and Table I).

Information about the risk of an asthma attack is relevant in patients with pollinosis, even if affected only by seasonal allergic rhinitis, and those who can inhale a suddenly high concentration of pollen aerosol. Of course, the take-home message is that patients affected by pollen allergy should be alert to the danger of being outdoors during a thunderstorm in the pollen season. Warnings should be given during the pollen season to pollen-sensitive patients. However, regarding therapy, it is important that asthma subjects use, by inhalation, and in an emergency such as

TABLE I. Evidence-based knowledge about thunderstorm-related epidemics of rhinitis and asthma

- There is a close temporal association between the start of the thunderstorm and the onset of rhinitis and asthma epidemics.
- Rhinitis and asthma epidemics related to thunderstorms are limited to the pollen (grasses, *Parietaria* species, and olive) and outdoor mold (*Alternaria alternata*) seasons.
- There are not high levels of gaseous and particulate components of air pollution during thunderstorm-related asthma epidemics.
- Nonallergic subjects are not involved in thunderstorm-related asthma epidemics.
- Patients with pollen allergy who stay indoors with the window closed during thunderstorms are not involved.
- There is a major risk for subjects who are not receiving antiasthma treatment, but subjects with allergic rhinitis and without previous asthma can experience bronchoconstriction that is sometimes also severe.
- During thunderstorm-related epidemics, there are descriptions of near-fatal asthma with relapse in more outbreaks in different years; 9 cases of death from allergic asthma in the Melbourne epidemic of 2016 have been observed.

thunderstorm-associated bronchial obstruction, not only bronchodilators but also corticosteroids.

In cases of near-fatal asthma in intubated patients, in our experience it is useful to use not only corticosteroids, theophylline, and bronchodilator β_2 -stimulants administered by means of intravenous infusion but also magnesium sulfate.¹⁰

REFERENCES

1. D'Amato G, Vitale C, D'Amato M, Cecchi L, Liccardi G, Molino A, et al. Thunderstorm-related asthma: what happens and why. *Clin Exp Allergy* 2016;46:390-6.
2. D'Amato G, Holgate ST, Pawankar R, Ledford DK, Cecchi L, Al-Ahmad M, et al. Meteorological conditions, climate change, new emerging factors and asthma and related allergic disorders. A statement of the World Allergy Organization. *World Allergy Organ J* 2015;8:25.
3. Bellomo R, Gigliotti P, Treloar A, Holmes P, Suphioglu C, Singh MB, et al. Two consecutive thunderstorm associated epidemic of asthma in Melbourne. *Med J Aust* 1992;156:834-7.
4. Taylor PE, Hagan R, Valenta R, Glovsky MM. Release of allergens in respirable aerosols: a link between grass pollen and asthma. *J Allergy Clin Immunol* 2002;109:51-6.
5. Packe GE, Ayres JG. Asthma outbreak during a thunderstorm. *Lancet* 1985;2:199-204.
6. Pulimood TB, Corden JM, Bryden C, Sharples L, Nasser SM. Epidemic asthma and the role of the fungal mold *Alternaria alternata*. *J Allergy Clin Immunol* 2007;120:610-7.
7. D'Amato G, Cecchi L, Liccardi G. Thunderstorm-related asthma: not only grass pollen and spores. *J Allergy Clin Immunol* 2008;120:530-2.
8. Marks GB, Colquhoun JR, Girgis ST, Hjelmroos Koski M, Treloar ABA, Hansen P, et al. Thunderstorm outflows preceding epidemics of asthma during spring and summer. *Thorax* 2001;56:468-71.
9. D'Amato G, Vitale C, Lanza M, Molino A, D'Amato M. Climate change, air pollution and allergic respiratory diseases: an update. *Curr Opin Allergy Clin Immunol* 2016;16:434-40.
10. D'Amato G, Cecchi L, Annesi-Maesano I. A trans-disciplinary overview of case reports of thunderstorm-related asthma outbreaks and relapse. *Eur Respir Rev* 2012;21:82-7.