



Allergens as trigger factors for allergic respiratory diseases and severe asthma during thunderstorms in pollen season

Gennaro D'Amato · Emma Tedeschini · Giuseppe Frenguelli · Maria D'Amato

Received: 10 October 2018 / Accepted: 9 January 2019
© Springer Nature B.V. 2019

There are observations that thunderstorms occurring during pollen season can induce severe asthma attacks in pollinosis patients (Andrew et al. 2017; Bellomo et al. 1992; D'Amato et al. 2007, 2016a, 2017, 2018b).

According to current climate change scenarios, there will be an increase in intensity and frequency of heavy rainfall episodes, including thunderstorms, which can be expected to be associated with an increase in the number and severity of asthma attacks

both in adults and in children (Andrew et al. 2017; D'Amato et al. 2005, 2007, 2016a, 2017, 2018b).

Associations between thunderstorms and asthma attacks have been identified in multiple locations around the world and especially during the pollen season when the concentrations of allergenic pollen grains was higher (Table 1). So, was called “thunderstorm asthma,” due by dispersion of more respirable allergenic particles derived from pollen and spores outbreaks (Andrew et al. 2017; D'Amato et al. 2007, 2016a, 2017, 2018b). The emergency episodes occurred at the beginning of thunderstorms, with an increase in signaling for asthma attack by chronic patients and also by subjects affected only by seasonal rhinitis. Recently, a dramatic event in Melbourne occurred on November 21, 2016, with 10 deaths and 9000 patients who needed medical treatments in Emergency Department of Melbourne Hospital for asthma attacks (Andrew et al. 2017; Lindstrom et al. 2017). This in Melbourne has been the worst event of thunderstorm asthma with an extraordinary association of environmental factors, a very unusual weather occurrence with wind and torrential rain combined with a high pollen amount (the grass pollen was more than 100/m³) sending, an high quantity of pollens and microparticles derived from pollens over the city. In Melbourne, ambulance and hospitals experienced high scale of involvement in such a reduced time period of a few hours on 21 November with grass allergens dispersed over a very large geographical area of

G. D'Amato (✉)
Division of Respiratory and Allergic Diseases,
Department of Chest Diseases, High specialty Hospital A.
Cardarelli Naples, Naples, Italy
e-mail: gdamatomail@gmail.com

G. D'Amato
Medical School of Specialization in Respiratory Diseases,
University on Naples Federico II, Rione Sirignano,
10-80121 Naples, Italy

E. Tedeschini (✉) · G. Frenguelli
University of Perugia, Via Borgo XX Giugno,
74 06121 Perugia, Italy
e-mail: emma.tedeschini@unipg.it

M. D'Amato
First Division of Pneumology, High specialty Hospital 'V.
Monaldi', Naples, Italy

M. D'Amato
University 'Federico II' Medical School Naples, Naples,
Italy

Table 1 Examples of thunderstorm-associated asthma outbreaks (D'Amato et al. 2016b, 2018a)

Year	Country	Observations
1983	UK	26 sudden cases of asthma attacks in relation to thunderstorms
1992	Australia	Late spring thunderstorms in Melbourne can trigger epidemics of asthma attacks (five to tenfold rise)
1994	UK	Asthma or other airways disease hospital visits. 640 cases who attended during a 30-h period on June 1994, nearly 10 times expected number
1992–2000	Canada	18 970 hospital ED asthma visits among children 2–15 years of age. Summer thunderstorm activity was associated with an OR of 1.35 (95% CI 1.02–1.77) relative to summer periods with no activity
1993–2004	USA	215 832 asthma ED visits, 24 350 of these visits occurred on days following thunderstorms. Significant association between daily counts of asthma ED visits and thunderstorm occurrence. Asthma visits were 3% higher on days following thunderstorms
2000	Australia	Asthma visits during thunderstorms. History of hayfever and allergy to ryegrass are strong predictors for asthma exacerbation during thunderstorms in spring
2001	Australia	The incidence of excess hospital attendances for asthma during late spring and summer was strongly linked to the occurrence of thunderstorm outflows
2002	UK	A case–control study of 26 patients presenting to Cambridge University Hospital with asthma after the thunderstorm <i>Alternaria alternata</i> sensitivity is a compelling predictor of epidemic asthma in patients with seasonal asthma and grass pollen allergy and is likely to be the important factor in thunderstorm-related asthma
2004	Italy	In Napoli six cases of adults and one adolescent with thunderstorm-related asthma because of pollen (<i>Parietaria</i>)
2010	Italy	20 cases of thunderstorm-related asthma because of pollen (olive tree)
2010	Australia	Epidemics of 'thunderstorm asthma' that occurred in Melbourne during spring 2010. The approach of spring, together with high winter rainfall in and around Melbourne that heralds another severe pollen season, raises the risk of allergic rhinitis and asthma in pollen-sensitive individuals
2016	Australia	Epidemics of thunderstorm asthma in Melbourne with 10 deaths and 9000 in emergency department

Victoria. The rapid onset of the medical emergency and its consequences were unprecedented in the scale of the intensity in comparison with previous events and it tested the capacity of Melbourne health system to be ready for this type of medical emergency. However, demand management strategies were insufficient to manage such a widespread and rapid onset event, with ambulance resources quickly depleted and using police officers to conduct welfare check (Andrew et al. 2017; Lindstrom et al. 2017). The event of Melbourne greatly surpassed the previous epidemic of London of June 1994 that was the largest documented outbreak before the Victoria epidemic.

One of the first observations regarding thunderstorms and asthma outbreaks was provided by Packe and Ayres (1985) at the East Birmingham Hospital (Birmingham, UK) on July 6 and 7, 1983. These authors described a remarkable increase in emergency department admissions during a thunderstorm. In a 36-h period, 26 asthma cases were treated in the emergency department, compared with a daily average

of two or three cases in the days preceding the outbreak.

Another asthma outbreak occurred in London, UK, coinciding with a heavy thunderstorm on June 24, 1994, (Venables et al. 1997; Levy and Bryden 2007). In Melbourne, other two large asthma outbreaks coincided with thunderstorms (Andrew et al. 2017; Lindstrom et al. 2017). In south eastern Australia, Marks et al. (2001) and Marks and Bush (2007) observed that the incidence of excess hospital attendances for asthma during late spring and summer was strongly linked to the occurrence of thunderstorm outflows and demonstrated also that, the arrival of a thunderstorm outflow was accompanied by a large increase in the concentration of ruptured pollen grains in ambient air.

Thunderstorm-related asthma was observed also in Naples (South Italy), on June 3, 2004, (D'Amato et al. 2007, 2016a, 2017, 2018b) for six adults and one adolescent treated in emergency departments. One of these patients was admitted to an intensive care unit for a very severe bronchial obstruction and acute

respiratory insufficiency. All individuals were outdoors when the thunderstorm struck. All six subjects were sensitized to *Parietaria* pollen, but were not sensitized to grasses. *Parietaria* is a ruderal species, grows spontaneously on the urban wall so is widely diffused into the cities. The pollen is small (12–15 μm) with a very thin exine, often seem crashed in the airborne pollens. Its pollen season begins in Spring until the Autumn and partly overlapping with grasses. In Naples during the thunderstorm recorded, the concentration of airborne pollen of *Parietaria* was particularly high, with a peak of 144 grains/ m^3 (June 3, 2004). Subjects with sensitization to *Parietaria* who were indoors, with the windows closed during the night between June 3 and 4, did not experience asthma attacks. No molds or viruses were involved in the Naples epidemics but it is important underline that *Parietaria* pollen is very fragile, so the violent rains should be involved with the breaking of pollen and consequent release of respirable microbodies. Other outbreaks and/or case reports have been described in Barletta (Italy), Cartagena (Spain), Atlanta (USA) and in Canada. 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 suffering from pollen allergy. The most prominent hypotheses for thunderstorm-related asthma are linked with bioaerosols and involve the role of rainwater in promoting the release of respirable particulate matter (D'Amato et al. 2016a). Pollen grains can be carried by thunderstorm at ground level, where pollen rupture would be increased with release of allergenic biological aerosols of paucimicronic size, derived from the cytoplasm and which can penetrate deep into lower airways. In other words, there is evidence that under wet conditions or during thunderstorms, pollen grains may, after rupture by osmotic shock, release into the atmosphere part of their content, including respirable, allergen-carrying cytoplasmic starch granules (0.5–2.5 μm) or to carry other paucimicronic components that can reach lower airways inducing asthma reactions in pollinosis patients. This occurrence is more frequent on the kind of pollen fragiles such as *Parietaria* grass or cypress; moreover, it is less probable on *Ambrosia* or *Artemisia* pollens which, having very thick exina with sculturations of sporopollenis over wall (*tectum*), are more resistant to thunderstorm breaking or osmotic shock.

These allergens can likely penetrate deeper into the lung, provoking more severe symptoms. It has been suggested that grass pollen starch granules are the most likely cause of associations between thunderstorms and asthma (D'Amato et al. 2016a) showed that ryegrass pollen grains contain a large amount of starch granules coated with allergens. By osmotic shock, each grain can release 700 starch granules able to penetrate the airways and trigger asthma attacks in previously sensitized subjects. Later, Taylor et al. (2002) hypothesized that the turbulent front of the advancing outflow releases more pollen from flowering grasses and grass pollen may release large amounts of paucimicronic allergenic particles after rupture by osmotic shock during thunderstorms.

This constitutes a major concern nowadays as the possibility of thunderstorm-associated asthma outbreaks have become of dramatic actuality due to the “highly likely” increase in frequency of heavy precipitation events, including thunderstorms, projected, by the climate change scenarios for the future decades (D'Amato et al. 2016a). There is a close temporal association between the arrival of the thunderstorm, a major rise in the concentration of pollen grains, pollen microparticles, and the onset of epidemics. As a consequence, subjects affected by pollen allergy should be alert to the danger of being outdoors during a thunderstorm during the pollen season (D'Amato et al. 2017).

In conclusion:

- There is a narrow correlation between storms and asthma epidemics in subjects with atopic sensitization to pollen allergens during pollen seasons with appearance of symptoms during the first 20–30 min of a storm.
- Thunderstorm-related epidemics are limited to late spring and summer (in Europe, USA and Canada from April to end of June and in Australia from October to December), when pollen and/or mold counts are high.
- There are no episodes during storm if the allergic subjects were indoor with closed windows.
- It is possible the role of sudden cold and/or electric charges as cofactors of asthma attack in allergic subjects.
- Individuals with allergic rhinitis only and no previous asthma can experience bronchoconstriction sometimes also severe during thunderstorms.

- Subjects with pollen allergy need be informed about a possible risk of asthma attack at the beginning of a thunderstorm during pollen season.
- Individuals who experience rhinitis and asthma during a storm are not usually taking suitable anti-inflammatory treatment, while it is important to have a correct antiasthma treatment by using bronchodilators and corticosteroids by inhalation at increasing dosage if there is a need.
- Any serious asthma attack during a thunderstorm can be life-threatening and can induce also tragic consequences of near fatal asthma and of death.
- The health consequences of thunderstorm asthma may be prevented with adequate measures by meteorological forecast and by correct use of antiasthma therapy and avoiding to be outdoor, at street level, at the start of a storm during pollen season.

References

- Andrew, E., Nehme, Z., Bernard, S., Abramson, M. J., Newbiggin, E., Piper, B., et al. (2017). Stormy weather, a retrospective analysis of demand for emergency medical services during epidemic thunderstorm asthma. *BMJ*, 359, j5636. <https://doi.org/10.1136/bmj.j5636>.
- Bellomo, R., Gigliotti, P., Treloar, A., Holmes, P., Suphioglu, C., Singh, M. B., et al. (1992). Two consecutive thunderstorm associated epidemic of asthma in Melbourne. *The Medical Journal of Australia*, 156, 834–837.
- D'Amato, G., Annesi Maesano, I., Molino, A., Vitale, C., & D'Amato, M. (2017). Thunderstorm-related asthma attacks. *The Journal of Allergy and Clinical Immunology*, 139(6), 1786–1787. <https://doi.org/10.1016/j.jaci.2017.03.003>.
- D'Amato, G., Annesi-Maesano, I., Cecchi, L., & D'Amato, M., (2018a). Latest News on relationship between thunderstorms and respiratory allergy, severe asthma, and deaths for asthma. *Allergy*. <https://doi.org/10.1111/all.13616>.
- D'Amato, M., Cecchi, L., Annesi-Maesano, I., Vitale, C., & D'Amato, G. (2018b). News on climate change, air pollution and allergic trigger factors of asthma. *Journal of Investigational Allergology and Clinical Immunology*. <https://doi.org/10.18176/jiaci.0228>.
- D'Amato, G., Liccardi, G., D'Amato, M., & Holgate, S. T. (2005). Environmental risk factors and allergic bronchial asthma. *Clinical and Experimental Allergy*, 35, 1113–1124.
- D'Amato, G., Liccardi, G., & Frenguelli, G. (2007). Thunderstorm-asthma and pollen allergy. *Allergy*, 62(1), 11–16.
- D'Amato, G., Vitale, C., D'Amato, M., Cecchi, L., Liccardi, G., Molino, A., et al. (2016a). Thunderstorm-related asthma, what happens and why. *Clinical and Experimental Allergy*, 46(3), 390–396. <https://doi.org/10.1111/cea.12709>.
- D'Amato, G., Vitale, C., Lanza, M., Molino, A., & D'Amato, M. (2016b). Climate change, air pollution, and allergic respiratory diseases: an update. *Current Opinion in Allergy and Clinical Immunology*, 16(5), 435–440. <https://doi.org/10.1097/ACI.0000000000000301>.
- Girgis, S. T., Marks, G. B., Downs, S. H., Kolbe, A., Car, G. N., & Paton, R. (2000). Thunderstorm associated asthma in an inland town in south-eastern Australia. Who is at risk?. *European Respiratory Journal*, 16, 3–8.
- Grinn-Gofroń, A., & Strzelczak, A. (2013). Changes in concentration of *Alternaria* and *Cladosporium* spores during summer storms. *International Journal of Biometeorology*, 57, 759–768. <https://doi.org/10.1007/s00484-012-0604-0>.
- Levy, M. L., & Bryden, C. (2007). Thunderstorm asthma. *The British Journal of Primary Care Nursing*, 1, 69–71.
- Lindstrom, S. J., Silver, J. D., & Sutherland, M. F. (2017). Thunderstorm asthma outbreak of November 2016: A natural disaster requiring planning. *The Medical Journal of Australia*, 207, 235–237. <https://doi.org/10.5694/mja17.00285>.
- Marks, G. B., & Bush, R. K. (2007). It's blowing in the wind: New insights into thunderstorm-related asthma. *The Journal of Allergy and Clinical Immunology*, 120(3), 530–532.
- Marks, G. B., Colquhoun, J. R., Girgis, S. T., Koski, M. H., Treloar, A. B. A., Hansen, P., et al. (2001). Thunderstorm outflows preceding epidemics of asthma during spring and summer. *Thorax*, 56, 468–471.
- Packe, G. E., & Ayres, J. G. (1985). Asthma outbreak during a thunderstorm. *Lancet*, 2, 199–204.
- Taylor, P. E., Hagan, R., Valenta, R., & Glovsky, M. M. (2002). Release of allergens in respirable aerosols, a link between grass pollen and asthma. *The Journal of Allergy and Clinical Immunology*, 109, 51–56.
- Venables, K. M., Allitt, U., Collier, C. G., Emberlin, J., Greig, J. B., Hardaker, P. J., et al. (1997). Thunderstorm-related asthma—Epidemic of 24/25 June 1994. *Clinical and Experimental Allergy*, 27, 725–736.