“Thunderstorm Asthma”:
Respiratory Emergencies during Thunderstorm Events

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“Thunderstorm asthma”

- Epidemic outbreaks of acute asthma exacerbations temporally associated with a thunderstorm
  - 1983, Birmingham, England: 106 patients with asthma patients within 2 days after a thunderstorm
  - 2016, Victoria, Australia: 8,000 asthmatics, 8 asthma deaths
  - Similar epidemics in North America, UK, Europe, Australia, Kuwait, etc.
The working hypothesis

- The “perfect storm” theory
  - High pollen/spore stock before the event
  - Updraft winds bring up pollen spores from the ground
  - Precipitation causes pollen to rupture and release small allergenic particles
  - Downdraft winds help release smaller particles to ground level
  - Large number of susceptible people in the storm area
What is thunderstorm asthma?

1. Whole pollen grains get swept up into clouds as the storm matures.
2. Moisture in the clouds breaks up the pollen into smaller particles.
3. Dry, cold outflows carry pollen particles to ground level, where people breathe them into their lungs.

Source: abc.net.au
**Figure 1**

*Parietaria* pollen bursting under osmotic shock with release of cytoplasmic fragments carrying allergens.

*Source:* D'Amato et al. (2007)
Primary contributions

- First national-scale study of tstorm-related respiratory complication
  - Event studies of 2.6 million thunderstorms at county×day level, 1992-2012
  - Track elderly’s emergency room (ER) visits for respiratory complaints

Main finding: thunderstorm asthma needs no “perfect storm”

- Can observe spike in respiratory ER visits around the average thunderstorm
- Larger effect for patients with a history of asthma or COPD

Mechanism: “calm before the storm”

- Thunderstorms are preceded by a week of significant slow air motion
- Meanwhile, significant build-up of particulates pollution
- Correspondingly, gradual increase of respiratory ER in the week leading to the storm
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Data

- Thunderstorms
  - U.S. National Lightning Detection Network (NOAA & Viasala)
  - Near-universal coverage: 98% of cloud-to-ground lightning flashes
  - High accuracy in time (0.5 microseconds) and space (200 meters)
  - We define a “thunderstorm” = any county×day with lightning flashes

- Atmospheric conditions

- Emergency room visits among the elderly
Annual Number of Thunderstorm Days

Notes: Days with cloud-to-ground lightning flashes and positive precipitation.
Notes: Mean daily precipitation = 2.90 millimeter.
Data

- Thunderstorms
- Atmospheric conditions
  - Weather: NOAA Global Historical Climatology Network
  - Air pollution: U.S. EPA Air Quality System
  - Pollen counts (61 cities): American Academy of Allergy Asthma & Immunology
- Emergency room visits among the elderly
Data

- Thunderstorms
- Atmospheric conditions
- **Emergency room (ER) visits among the elderly**
  - Medicare inpatient and outpatient records (100% claims)
  - Covers 98% of U.S. population aged 65+
  - Observe all ER visits, whether or not ended up hospitalization
  - For each visit: patient’s county of residence, date of visit, primary diagnosis, preexisting medical conditions
Weather and health around thunderstorms

- Event study of thunderstorm

\[ Y_{ct} = \sum_{d=[-20,20]} \beta_d \cdot \text{Thunderstorm}_{c(t+d)} + \text{Covariates}_{ct} + \epsilon_{ct} \]

- Covariates\(_{ct}\) include FEs indicators
  - County FEs
  - Year, month, day-of-week FEs

- Cluster standard errors at the county level
Wind speed around thunderstorms

Re-analysis

Airport monitor

Notes: Average daily wind speed = 3.51 m/s (near-airport measure).
Wind speed around thunderstorms (L) vs. rainstorm (R)

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**Particulate matter around thunderstorms**

![Graph showing particulate matter concentration around thunderstorms](image)

**Notes:** Average PM$_{2.5}$ (PM$_{10}$) = 12.1 (24.8) µg/m$^3$. 

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**Graph Description:**
- The graph plots the concentration (log scale) of particulate matter (PM$_{2.5}$ and PM$_{10}$) against days since a thunderstorm.
- There is a notable spike in concentration around day 0, indicating a significant increase shortly after a thunderstorm.
- The data shows a decrease in concentration after the initial spike, approaching baseline levels by day 10.

**Analysis:**
- The concentration of both PM$_{2.5}$ and PM$_{10}$ increases dramatically around the time of the thunderstorm, possibly due to increased aerosol generation.
- The rapid decrease suggests that these aerosols are quickly dispersed or removed from the atmosphere.

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**Technical Details:**
- Log scale for concentration to better visualize the range of values.
- Days since thunderstorm range from -20 to 19 to capture pre- and post-event data.
- The concentration is plotted on a linear scale to accurately represent the magnitude of changes.
Other (gaseous) pollutants around thunderstorms

Notes: Average NO$_2$ = 15.0 ppm.
Pollen counts around thunderstorms (61 cities)

Notes: Average pollen count = 170 grains/m³.
Respiratory ER visits around thunderstorms

Notes: Mean = 152.7 visits per million. Range bars show 95% CIs constructed using SEs clustered at the county level.
Respiratory ER visits around thunderstorms: COPD patients

Notes: Mean = 562.9 visits per million. Range bars show 95% CIs constructed using SEs clustered at the county level.
Respiratory ER visits around thunderstorms: Storm intensity

Notes: Mean = 562.9 visits per million. Range bars show 95% CIs constructed using SEs clustered at the county level.
Robustness and falsification checks

- No “build-up” effect for rainstorm (precipitation without lightning)
- Placebo tests using broad diagnoses unrelated to pollution
“Placebo” ER visits around thunderstorms: Sepsis

Notes: Mean = 0.18 visits per million. Range bars show 95% CIs constructed using SEs clustered at the county level.
“Placebo” ER visits around thunderstorms: PE

Notes: Mean = 3.92 visits per million. Range bars show 95% CIs constructed using SEs clustered at the county level.
“Placebo” ER visits around thunderstorms: DVT

Notes: Mean = 2.56 visits per million. Range bars show 95% CIs constructed using SEs clustered at the county level.
Conclusion

- Emergency visits for respiratory problems among Medicare beneficiaries were increased in the days surrounding thunderstorms in the U.S., particularly among patients with a history of COPD.

- Older patients with reactive airway disease are less sensitive to airway hyperreactivity compared to younger patients.
  - The amount of additional acute respiratory illness related to lightning and thunderstorms requiring emergency care is likely higher among children and younger adults.