

E-cigarette or Vaping Product Use-Associated Lung Injury (EVALI)

Brandon D. Timmerman, BS; Richard B. Towbin, MD; Carrie M. Schaefer, MD; Alexander J. Towbin, MD

Abstract

E-cigarette or vaping product use-associated lung injury is a serious and potentially life-threatening respiratory condition characterized by diffuse lung injury following recent use of vaping or e-cigarette products. Patients commonly present with nonspecific respiratory symptoms such as cough, chest pain, and dyspnea, along with constitutional symptoms, including fever, chills, fatigue, weakness, and malaise. A small number of pediatric patients may present with isolated gastrointestinal symptoms. Noncontrast chest CT is the preferred imaging modality and may show a range of findings consistent with diffuse lung injury. Treatment is primarily supportive and may include supplemental oxygen, empiric antibiotics, and systemic glucocorticoids based on clinical presentation.

Keywords: thorax, lungs, congenital, chemical injury

Case Summary

An adolescent presented with a 3-day history of cough and hemoptysis. Symptoms began approximately 45 minutes after using a vape pen when the patient developed acute shortness of breath and a persistent cough. These symptoms progressed over the following days and culminated in 2 episodes of bright red hemoptysis on the morning of presentation. The patient reported a history of daily cigarette use (1-2 cigarettes/day) and marijuana use (2-3 times per week).

Imaging Findings

Chest radiograph (Figure 1) showed central ground-glass opacities. Chest CT

(Figure 2) showed central ground-glass opacities with peripheral sparing.

Diagnosis

E-cigarette or vaping product use-associated lung injury (EVALI).

The differential diagnosis includes hypersensitivity pneumonitis, bronchiolitis, acute eosinophilic pneumonia, organizing pneumonia, lipoid pneumonia, COVID-19, and diffuse alveolar hemorrhage.

Discussion

EVALI is an acute or subacute respiratory illness characterized by diverse patterns of lung injury in the

context of recent e-cigarette or vaping product use. It is a diagnosis of exclusion that requires a thorough history of vaping exposure, characteristic pulmonary imaging findings, and the elimination of other potential causes of lung injury. The Centers for Disease Control and Prevention (CDC) have established 4 criteria for the diagnosis of EVALI: (1) use of e-cigarettes or “dabbing” (inhaling vapors from heated cannabis concentrates) within the 90 days prior to symptom onset; (2) imaging showing pulmonary opacities; (3) a negative infectious workup; and (4) no alternative diagnosis that better explains the clinical presentation.¹ The exact cause of EVALI remains unclear but is thought to result from oxidative stress induced by various chemical constituents in electronic nicotine delivery systems. Among these, vitamin E acetate and tetrahydrocannabinol are the most commonly implicated additives, although other substances may contribute to the pathogenesis.¹ It is thought that EVALI may act as a thickening agent. When heated and inhaled, this oil coats the lungs,

Affiliations: University of Arizona College of Medicine—Phoenix, Phoenix, Arizona (Timmerman); Department of Radiology, Phoenix Children's Hospital, Phoenix, Arizona (RB Towbin, Schaefer); Department of Radiology, Cincinnati Children's Hospital and University of Cincinnati College of Medicine, Cincinnati, Ohio (AJ Towbin).

Disclosures: The authors have no conflicts of interest to disclose. None of the authors received outside funding for the production of this original manuscript and no part of this article has been previously published elsewhere.

Figure 1. (A) Posteroanterior and (B) lateral chest radiographs showing bilateral central ground-glass opacities.

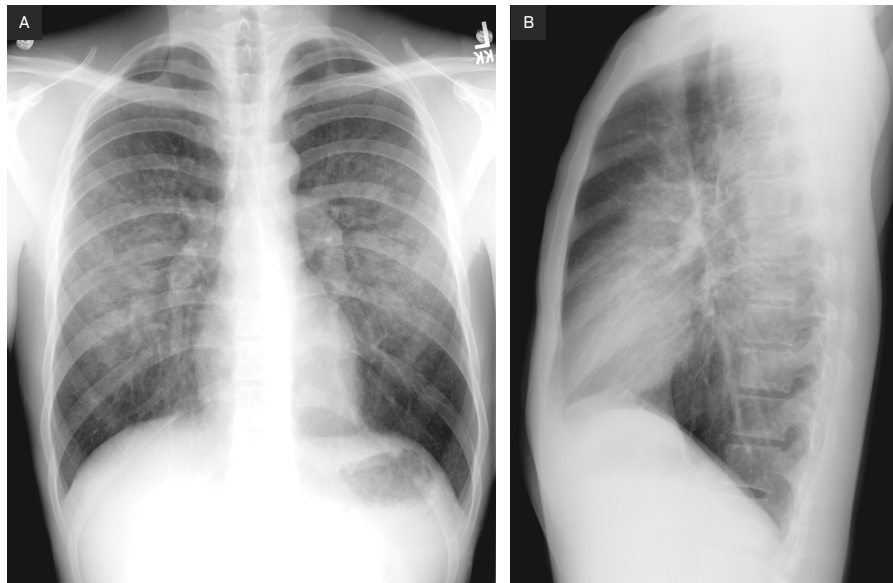
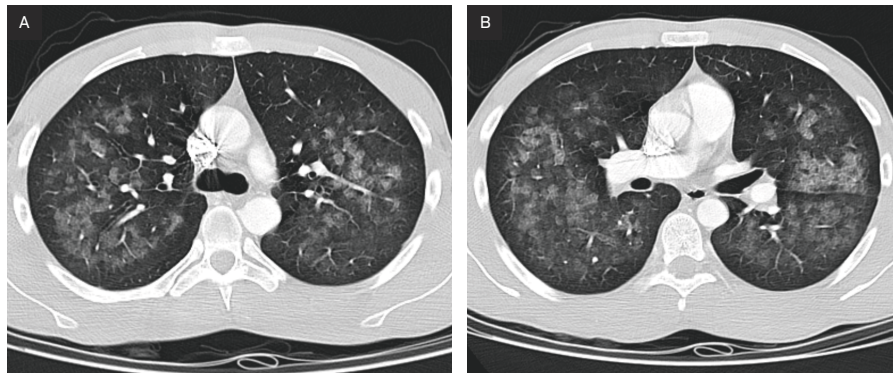


Figure 2. Axial chest CT images at the level of (A) the carina and (B) the main pulmonary artery demonstrating central ground-glass opacities with relative subpleural and lobular sparing.



disrupting the surfactant layer and leads to inflammation and potentially becoming a toxic ketene gas that injures the alveoli.²

Epidemiologic data on EVALI are limited to cases reported to the CDC. As of February 2020, 2807 cases had been reported, with approximately 15% occurring in children.³ Reported cases peaked in mid-2019 before declining; however, incidence has not returned to pre-2019 baseline levels.³ National data collection was discontinued in 2020. Now, without a centralized reporting system,

the true burden of EVALI in recent years remains unclear.

Clinically, EVALI mimics a viral respiratory illness during its acute phase. Patients typically report nonspecific symptoms such as cough, chest pain, and dyspnea, along with constitutional symptoms, including fever, chills, night sweats, fatigue, weight loss, myalgia, and malaise.^{4,5} Lung auscultation may be normal or reveal wheezing, crackles, or rhonchi.⁵ Notably, several pediatric patients diagnosed with

EVALI have presented with gastrointestinal complaints rather than respiratory symptoms. These patients have reported abdominal pain, nausea, and vomiting.⁶

Laboratory findings, though nonspecific, can assist in the diagnosis of EVALI. Most patients present with leukocytosis, often with a neutrophilic predominance, as well as eosinophilia, elevated lactate dehydrogenase, and increased C-reactive protein levels.⁷

Most patients with EVALI have diffuse hazy or consolidative opacities on chest radiography.⁸ In some patients, the opacities may appear more nodular, patchy, or demonstrate a mix of interstitial and alveolar patterns.⁵ Chest radiographs may also be normal in a subset of patients.^{5,6} Chest CT most commonly shows bilateral ground-glass opacities in the lower lobes with subpleural sparing and enlarged hilar or mediastinal lymph nodes.^{7,9} Additional findings may include a “crazy-paving” pattern, reversed halo sign, and interlobular septal thickening.⁶ Less frequently observed findings include small pleural or pericardial effusions and pneumomediastinum.⁹

The overall pattern of lung injury may resemble several entities, including diffuse alveolar damage, acute eosinophilic pneumonia, organizing pneumonia, or lipid pneumonia, suggesting that EVALI may result from multiple mechanisms of injury.^{5,6,9} The mechanism of injury is mainly a result of alveolar epithelial and pulmonary vascular endothelial cell damage from direct cytotoxicity from the inhaled agents.¹⁰ Bronchoscopy is typically reserved for patients with severe or progressive disease and can be helpful in ruling out alternative diagnoses. Bronchoalveolar lavage fluid often shows increased neutrophils and lipid-laden macrophages.³

The treatment of EVALI varies depending on the severity of presentation but generally centers on supportive care and immediate cessation of vaping or

e-cigarette use.² Most patients are treated with systemic glucocorticoids, often in combination with broad-spectrum antibiotics to cover potential community-acquired pathogens. Supplemental oxygen is provided as needed based on the patient's respiratory status. In cases of worsening hypoxemia, escalation to mechanical ventilation may be required.

Information on patient outcomes with EVALI remains limited, but most individuals recover and return to baseline following vaping cessation and supportive care.¹¹ However, some patients experience progressive lung injury, leading to persistent symptoms, chronic respiratory dysfunction, respiratory failure, or even death. In case series focused on pediatric patients, follow-up data have shown particularly decreased diffusion capacity of the lungs, with variable residual effects on overall pulmonary function.⁷

Conclusion

EVALI is a serious and potentially life-threatening respiratory condition characterized by diffuse lung injury following recent use of vaping or e-cigarette products. Patients commonly present with nonspecific respiratory symptoms such as cough, chest pain,

and dyspnea, along with constitutional symptoms, including fever, chills, fatigue, weakness, and malaise. A small number of pediatric patients may present with isolated gastrointestinal symptoms. Noncontrast chest CT is the preferred imaging modality and may show a range of findings consistent with diffuse lung injury. Treatment is primarily supportive and may include supplemental oxygen, empiric antibiotics, and systemic glucocorticoids based on clinical presentation.

References

- 1) Siegel DA, Jatlaoui TC, Koumans EH, et al. Update: interim guidance for health care providers evaluating and caring for patients with suspected e-cigarette, or vaping, product use associated lung injury - United States, October 2019. *MMWR Morb Mortal Wkly Rep*. 2019;68(41):919-927. doi:10.15585/mmwr.mm6841e3
- 2) Bhat TA, Kalathil SG, Bogner PN, et al. An animal model of inhaled vitamin e acetate and EVALI-like lung injury. *N Engl J Med*. 2020;382(12):1175-1177. doi:10.1056/NEJMc2000231
- 3) Barker CK, Ghera P, Hsu B. The evolution of a pediatric public health crisis: e-cigarette or vaping-associated lung injury. *Pediatrics*. 2024;153(5):e2023063484. doi:10.1542/peds.2023-063484
- 4) Kaslow JA, Rosas-Salazar C, Moore PE. E-cigarette and vaping product use-associated lung injury in the pediatric population: a critical review of the current literature. *Pediatr Pulmonol*. 2021;56(7):1857-1867. doi:10.1002/ppul.25384
- 5) Thakrar PD, Boyd KP, Swanson CP, Wideburg E, Kumbhar SS. E-cigarette, or vaping, product use-associated lung injury in adolescents: a review of imaging features. *Pediatr Radiol*. 2020;50(3):338-344. doi:10.1007/s00247-019-04572-5
- 6) Wang KY, Jadhav SP, Yenduri NJS, et al. E-cigarette or vaping product use-associated lung injury in the pediatric population: imaging features at presentation and short-term follow-up. *Pediatr Radiol*. 2020;50(9):1231-1239. doi:10.1007/s00247-020-04698-x
- 7) Gonsalves CL, Zhu JW, Kam AJ. Diagnosis and acute management of e-cigarette or vaping product use-associated lung injury in the pediatric population: a systematic review. *J Pediatr*. 2021;228:260-270. doi:10.1016/j.jpeds.2020.09.040
- 8) Kligerman S, Raptis C, Larsen B, et al. Radiologic, pathologic, clinical, and physiologic findings of electronic cigarette or vaping product use-associated lung injury (EVALI): evolving knowledge and remaining questions. *Radiology*. 2020;294(3):491-505. doi:10.1148/radiol.2020192585
- 9) Artunduaga M, Rao D, Friedman J, et al. Pediatric chest radiographic and CT findings of electronic cigarette or vaping product use-associated lung injury (EVALI). *Radiology*. 2020;295(2):430-438. doi:10.1148/radiol.2020192778
- 10) Alexander LEC, Bellinghausen AL, Eakin MN. What are the mechanisms underlying vaping-induced lung injury? *J Clin Invest*. 2020;130(6):2754-2756. doi:10.1172/JCI138644
- 11) Layden JE, Ghinai I, Pray I, et al. Pulmonary illness related to e-cigarette use in Illinois and Wisconsin - final report. *N Engl J Med*. 2020;382(10):903-916. doi:10.1056/NEJMoa1911614