E-cigarette, or Vaping, Product Use-Associated Lung Injury—Lessons Learned: A Case Series

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E-cigarette, or vaping, product use has been declared an epidemic, and a new disease has emerged from their use. We describe 4 patients with significant acute lung injury related to e-cigarette use who underwent bronchoscopy and bronchoalveolar lavage. All cases posed anesthetic challenges, including increased airway reactivity, hypoxia, increasing oxygen requirements, and, in 2 severe cases, the need for continued postprocedural mechanical ventilatory support. It is imperative that all members of the treating team are aware of the disproportionate risk of respiratory complications to anticipate the possible need for increased postprocedural respiratory support. (A&A Practice. 2020;14:e01242.)

GLOSSARY

BAL = bronchoalveolar lavage; **CDC** = Centers for Disease Control and Prevention; **CPAP** = continuous positive airway pressure; **CT** = computed tomography; **EQUATOR** = Enhancing the Quality and Transparency of Health Research Network; **EVALI** = e-cigarette, or vaping, product use-associated lung injury; **Fio₂** = fractional inspired oxygen; **HD** = hospital day; **HFNC** = high-flow nasal cannula; **HIPAA** = Health Insurance Portability and Accountability Act; **ICU** = intensive care unit; **LMA** = laryngeal mask airway; **NC** = nasal cannula; **PACU** = postanesthesia care unit; **PCV** = pressure control ventilation; **PEEP** = positive end-expiratory pressure; **P_{IP}** = peak inspiratory pressure; **RA** = room air; **Spo₂** = oxygen saturation; **TB** = tuberculosis; **THC** = tetrahydrocannabinol

In 2006, e-cigarettes were introduced as a smoking cessation tool in the United States. Twelve years later, the Surgeon General declared adolescent use of e-cigarettes (vaping) an epidemic.¹ In 2019, the *Morbidity and Mortality Weekly Report* stated that the increased use of e-cigarettes among adolescents negated any progress in reducing tobacco use in this population.² While cigarette smoking continues to be a significant risk factor for peri-interventional complications, insufficient evidence exists for the use of e-cigarettes as a successful peri-interventional smoking cessation tool.³

In the summer of 2019, the Children's Hospital of Wisconsin encountered a cluster of adolescent patients with significant acute lung injury caused by e-cigarette use. Twenty-eight cases were initially reported in Wisconsin, and the numbers continued to rise.⁴ According to the Centers for Disease Control and Prevention (CDC) as of January 2020, 2711 cases of e-cigarette, or vaping, product use-associated lung injury (EVALI) had been reported.⁵ The CDC further stated that the risk of EVALI was increased by use of tetrahydrocannabinol (THC) products, especially when vaped more than 5 times per day.^{6,7}

We describe 4 patients with EVALI who presented for flexible bronchoscopy and bronchoalveolar lavage (BAL). In contrast to other acute lung injury patients, EVALI patients often present with a variety of nonrespiratory symptoms including fever, fatigue, weight loss, and gastrointestinal or neurologic symptoms, in addition to respiratory symptoms.⁸ We will highlight the periprocedural challenges in this population because some of our patients required significant respiratory support during and after their procedures.

Institutional review board's review and approval were obtained from the Children's Wisconsin Human Research Protection Program. Consent to publish and Health Insurance Portability and Accountability Act (HIPAA) authorization were obtained from the patients' families. This article adheres to the applicable Enhancing the Quality and Transparency of Health Research Network (EQUATOR) guidelines.

CASE DESCRIPTIONS

Patient 1

Presentation

A 16-year-old boy presented with a history of 5 days of dyspnea, chest pain, and fever and a 20-pound weight loss over 8 months. He reported vaping nicotine once per week and THC up to several times daily for 6–12 months (Table; Figure 1).

Procedural Course

Anesthesia was induced with propofol, lidocaine, and rocuronium, and the trachea was intubated uneventfully. Anesthesia was maintained with sevoflurane and dexmedetomidine. Pressure control ventilation (PCV) was chosen with peak inspiratory pressure (P_{IP}) of 14 cm H₂O and

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Table. EVALI Patient Data Including Symptoms, Oxygen Requirement, Anesthesia Management, and Postprocedural Disposition

Patient	Age/Sex	Vaping Products	Presenting Symptoms	Presenting Oxygen Saturation on Room Air	Preprocedure Oxygen Saturation/Delivery Device	Anesthesia Airway Management	Anesthesia Induction and Maintenance Agents	Reactive Airway Adjuncts	Postprocedure Disposition	Postprocedure O ₂ Saturation/O ₂ Delivery Device
1	16 y/male	Tobacco/THC	Dyspnea, fever, weight loss, chest pain, cough, nausea	96%	94% on 1 L NC	Intubation/7.5 mm	Propofol, sevoflurane, dexmedetomidine, rocuronium	Lidocaine	PACU	95% on 6 L Oxy mask
2	17 y/male	Tobacco/THC	Dyspnea, weight loss, anorexia, nausea, malaise	83%	95% on 3 L NC	LMA/3.5	Sevoflurane, propofol, midazolam	Propofol	PACU	97% on 4 L Oxy mask
3	17 y/female	Tobacco/THC	Weight loss, chest pain, dyspnea	75%	97% on CPAP with Fio ₂ 0.45	Intubation/7.0 and 6.5 mm	Sevoflurane, propofol	Albuterol, 4% topical lidocaine	ICU-failed extubation trial (extubated 2.5 h later)	99% on Fio ₂ 1.00; postextubation 93% on 30 L HFNC with Fio ₂ 0.40
4	17 y/male	Tobacco/THC	Dyspnea, fever, nausea, emesis, fatigue, abdominal pain, generalized weakness, cough	85%	91% on 45 L HFNC with Fio ₂ 0.85	Intubation/7.0 mm	Propofol, sevoflurane, dexmedetomidine, rocuronium	Fentanyl, lidocaine	ICU (extubated 48 h later)	90% on Fio ₂ 1.00

Abbreviations: CPAP continuous positive airway pressure; EVALI, e-cigarette, or vaping, product use-associated lung injury; Fio₂, fractional inspired oxygen; HFNC, high-flow nasal cannula; ICU, intensive care unit; LMA, laryngeal mask airway; NC, nasal cannula; PACU, postanesthesia care unit; THC, tetrahydrocannabinol.

positive end-expiratory pressure (PEEP) of 4 cm H₂O. The patient's oxygen saturation (SpO₂) was >90% with fractional inspired oxygen (Fio₂) 0.52–0.93. After extubation, he required 6 L supplemental oxygen via facemask to maintain an SpO₂ of 95% in the postanesthesia care unit (PACU). Oxygen was decreased to 4 L via facemask before discharge from the PACU and further decreased to 2 L via nasal cannula (NC) in the inpatient unit.

Postprocedural Course

Bronchoscopy demonstrated a hypervascular mucosa. Prednisone was started on hospital day (HD) 2 for assumed inhalation injury. BAL workup was negative for infectious etiologies. The patient's oxygen requirement improved rapidly over the subsequent days. Drug and smoking cessation counseling was provided. He was discharged on HD 6.

Patient 2

Presentation

A 17-year-old boy presented with increasing dyspnea, 40-pound weight loss, anorexia, nausea, and subjectively decreased energy over a period of 2 months. The patient reported smoking THC for 7 months and vaping tobacco products for 5 months before admission (Table; Figure 1).

Procedural Course

General anesthesia was induced with midazolam and propofol. A laryngeal mask airway (LMA) was placed by request of the proceduralist for increased airway device diameter. Anesthesia was maintained with sevoflurane. An Fio₂ of 100% was used with spontaneous ventilation to keep SpO₂ >90%. Repeated boluses of 1.5 mg/kg of propofol were used to mitigate increased airway reactivity. The LMA was removed at the end of the procedure. The patient required 4 L of oxygen by facemask and 1 hour in the PACU before meeting criteria to return to the inpatient unit.

Postprocedural Course

The patient underwent a diagnostic open lung biopsy 5 days after bronchoscopy. Workup for infection and sarcoidosis was negative, and he was presumed to have inhalation injury from vaping. He was treated with high-dose intravenous methylprednisolone and transitioned from supplemental oxygen to room air (RA). He was discharged on HD 14. Despite vaping cessation counseling before discharge, the patient was readmitted 2 months later with recurrent EVALI.

Patient 3

Presentation

A 17-year-old girl with a history of latent tuberculosis (TB) on isoniazid presented with persistent cough, pleuritic chest pain, and an SpO₂ of 75% when breathing ambient air. The patient reported vaping tobacco and THC persistently for months before admission (Table; Figure 2).

Procedural Course

General anesthesia was induced with propofol. Topical lidocaine 4% was applied to the airway before intubation. Anesthesia was maintained with sevoflurane, and Fio₂ of

Figure 1. EVALI manifesting as mild-to-moderate lung disease. A, Sixteen-year-old boy with history of vaping presented with dyspnea, chest pain, fever, and 20-pound weight loss. Axial CT image of the chest in lung window (A) demonstrates ground-glass and wispy linear airspace opacities with a dependent gradient and subpleural sparing (arrowheads). The opacities are more pronounced on the right. B, C, and D, Seventeen-year-old boy with history of vaping presented with increasing dyspnea, 40-pound weight loss, anorexia, nausea, and decreased energy. Posteroanterior chest radiograph (B) demonstrates faint upper lung predominant reticular interstitial opacities (thin arrows). Axial CT image of the chest in lung window (C) demonstrates scattered patchy bilateral ground-glass opacities (arrowheads). Axial CT image of the chest in soft tissue window (D) demonstrates bilateral hilar lymphadenopathy (arrows). CT indicates computed tomography; EVALI, e-cigarette, or vaping, product use-associated lung injury.

Figure 2. EVALI manifesting as severe lung disease. A, B, and C, Seventeen-year-old girl with history of vaping presented with chest pain, cough, fever, weight loss, and severe respiratory distress. Anteroposterior chest radiograph (A) demonstrates patchy and hazy bilateral airspace opacities in a lower lobe predominant distribution (arrows). Axial and coronal CT images of the chest in lung windows (B and C) demonstrate ground-glass and confluent airspace opacities with a dependent gradient and subpleural sparing (arrowheads). D, E, and F, Seventeen-year-old boy with history of vaping presented with fever, nausea, vomiting left lower quadrant abdominal pain, and diarrhea. Anteroposterior chest radiograph (D) demonstrates diffuse, patchy bilateral airspace opacities (arrows). Axial and coronal CT images of the chest in lung windows (E and F) demonstrate ground-glass and confluent airspace opacities with a dependent gradient and subpleural sparing (arrowheads). CT indicates computed tomography; EVALI, e-cigarette, or vaping, product use-associated lung injury.

100% was administered. PCV was utilized with P_{IP} of 20 cm H_2O and PEEP of 6 cm H_2O . Intermittent manual ventilation was used to keep $SpO_2 >90\%$. The patient required albuterol

via metered dose inhaler delivered through the endotracheal tube during the procedure to mitigate increased airway reactivity. She was extubated postprocedure but, due

to increased respiratory rate and work of breathing, was reintubated and transferred to the intensive care unit (ICU).

Postprocedural Course

The patient was successfully extubated 2.5 hours postintervention to 30 L oxygen by high-flow nasal cannula (HFNC). Her bronchoscopy revealed pale mucosa with multiple scattered, round, black lesions. Sputum culture and BAL were negative for active TB. After clearance from the infectious disease service, she was started on high-dose intravenous methylprednisolone on postprocedure day 2 and successfully transitioned from supplemental oxygen to RA. Following a discussion of vaping risks, she agreed to cease further use and was discharged home on HD 9.

Patient 4

Presentation

A 17-year-old boy presented with fever, nausea, vomiting, abdominal pain, diarrhea, dyspnea on exertion, cough, and generalized weakness for 1 week. He reported vaping nicotine products daily for 4 months and THC approximately once every 2 months (Table; Figure 2).

He presented with SpO₂ of 85% on RA and required 3 L oxygen via NC. Six hours after admission, he was transferred to the ICU due to an oxygen requirement of 15 L by facemask which subsequently increased to 45 L HFNC.

Procedural Course

General anesthesia was induced with propofol, fentanyl, and rocuronium. The trachea was intubated, but the patient began to desaturate immediately after intubation. Oxygen was increased to Fio₂ of 100%, and anesthesia was maintained with sevoflurane and dexmedetomidine. He received PCV (P_{IP} up to 29 cm H₂O and PEEP up to 12 cm H₂O) with intermittent manual ventilation but had SpO₂ <90% for 18 minutes despite 100% Fio₂. Topical 4% lidocaine and fentanyl were used to treat significant airway reactivity.

Postprocedural Course

Bronchoscopy showed normal trachea, carina, and bronchi with no evidence of hemorrhage or inflammation.

He was transferred to the ICU intubated, and high-dose intravenous methylprednisolone therapy was started immediately. PEEP and Fio₂ were decreased over the subsequent days, but he continued to experience periodic desaturations with coughing. He was extubated on postprocedure day 3 to 2 L oxygen by NC and was transitioned to RA the following day. He was discharged home on HD 7. At his follow-up visit, the need for complete abstinence from inhalational agents was discussed, and the patient endorsed vaping cessation.

DISCUSSION

We have treated a series of teenage patients with vaping-associated lung injury, now defined by the CDC as EVALI.⁹ Because the workup for this disease frequently includes diagnostic flexible bronchoscopy and BAL, many of these patients undergo general anesthesia. Providing anesthesia for these patients can prove challenging as a result of significant airway reactivity, persistent desaturations, and

worsening respiratory status following the diagnostic procedures. Airway reactivity can be especially problematic, causing recurrent desaturations disproportionate to those seen in other patients undergoing flexible bronchoscopy with BAL. Multiple strategies have been used to attenuate the effects of EVALI, including deepening the anesthetic or using paralytics, albuterol, topical or nebulized lidocaine, postprocedural dexmedetomidine, or narcotics.¹⁰ Most EVALI patients show rapid improvement following initiation of steroids.

Flexible bronchoscopy is generally considered to be a safe procedure with a mortality rate of <0.04% and a major complication rate of <1%.¹¹ Though flexible bronchoscopy and BAL are known to stimulate the airway, they are usually well-tolerated with little or no supplemental oxygen required in the PACU. However, varying degrees of preprocedural hypoxia and airway disease in our EVALI patients (Table) led to challenges in providing anesthesia. Our patients presented with minor respiratory symptoms, moderate supplemental oxygen requirements, pronounced hypoxia, and severe respiratory distress requiring HFNC. Airway manipulation during anesthesia and bronchoscopy worsened respiratory status in every patient, which manifested as cough, wheezing, hypoxia, and in 2 cases, the need for prolonged mechanical ventilation. By January 2020, the CDC had reported 60 deaths associated with EVALI⁵ (Supplemental Digital Content, <http://links.lww.com/AACR/A319>). Though we have included only 4 patients, given the increased incidence of EVALI, we believe it is important to report that bronchoscopy/BAL in tenuous EVALI patients may result in significantly increased oxygen requirements, prolonged intubation, or extended ICU stay.¹²

CONCLUSIONS

Patients with EVALI can present with varying degrees of lung injury and may display pronounced airway hyperreactivity and hypoxia requiring significant respiratory support in the peri-interventional period. Because of the potential for remarkable worsening of respiratory status after flexible bronchoscopy with BAL, a high degree of vigilance and preparedness, including the ability to escalate care postprocedurally, is necessary to ensure optimal patient outcomes. ■

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DISCLOSURES

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