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Pediatric Toxidrome Simulation Curriculum: Liquid Nicotine Overdose

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Abstract

Introduction: Liquid nicotine exposure is becoming more common in the pediatric population. Toxicity may occur with exposure to small quantities given the high concentrations in solutions available commercially. Effects can include altered mental status, seizure, and death. **Methods:** This simulation-based case involves the identification and management of a toddler presenting with acute liquid nicotine exposure, with emphasis on the general approach to the acutely ill pediatric patient, consideration in toxic exposures, and the presentation of nicotine exposure. Providers should assess airway, breathing, and circulation while concurrently providing supportive care for an actively seizing simulated patient, necessitating appropriate selection of medications and acute airway management. Additionally, providers must maintain a broad differential diagnosis and obtain a focused history to narrow that differential and identify toxic exposure as a cause of the patient's presentation. Preparatory and didactic material is provided to help the instructor prepare the simulation environment, guide learners through the case, and debrief with learners afterward. **Results:** We implemented this curriculum with four pediatric emergency medicine fellows and 15 pediatric residents during two sessions. Feedback was overwhelmingly positive; participants who completed evaluations reported high levels of confidence with knowledge and skills directly related to the educational objectives after participation (mean Likert scores of 4.9 out of 5 in response to effectiveness of the case in teaching evaluation and management of nicotine toxicity). **Discussion:** This comprehensive resource will aid in offering continuing education for providers and specifically in educating learners with regard to acute liquid nicotine exposure in a child.

Keywords

Simulation, Nicotine, Toxicology, Pediatrics, Liquid Nicotine

Appendices

- A. Nicotine Simulation Scenario.docx
- B. Nicotine Simulation Environment Preparation .docx
- C. Nicotine Simulation Diagnostic Images.pptx
- D. Simulation Environment Teamwork and Communication TeamSTEPPS Glossary .docx
- E. Nicotine Simulation Debriefing Materials.docx
- F. Nicotine Toxicity PowerPoint Presentation .pptx
- G. Nicotine Simulation Session Evaluation Form.docx

All appendices are peer reviewed as integral parts of the Original Publication.

Educational Objectives

By the end of the session, participants will be able to:

1. Describe the presentation of a pediatric patient with nicotine exposure.
2. Demonstrate effective evaluation and management of the acutely toxin-exposed child.
3. Demonstrate effective management of seizure in a toxin-exposed child.
4. Provide focused and effective management to the undifferentiated child presenting with an emergent condition.

Introduction

Liquid nicotine use in electronic cigarettes has increased dramatically over the past decade.¹ As a result of this increased use, young children are at greater risk of unintentional exposure and overdose. The majority of calls to US poison control centers regarding liquid nicotine are in children 5 years or younger, and there has been a steep increase in the number of reports over the past several years.² Given that acute nicotine toxicity is rare in adults and that pediatric overdose is a recently increasing trend, many health care providers may not be familiar with the presentation and management in the pediatric population.

Nicotine has several effects on the human body. Exposure leads to a primarily sympathetic nervous stimulation due to its bindings at nicotinic cholinergic receptors. With higher doses, parasympathetic stimulation and neuromuscular blockade are possible. Nicotine also has excellent penetration of the blood-brain barrier, which can have direct effects on the brain, resulting in emesis, seizures, and even coma. Oral bioavailability of nicotine in its liquid form is 30%-40%, and its half-life is approximately 2 hours. The toxic dose is estimated to be approximately 1.4 mg/kg, and typical cigarettes have 10-15 mg of nicotine.^{3,4}

Electronic cigarettes pose additional problems. These electronic devices contain a heating element that vaporizes a liquid containing nicotine, along with many other chemicals. Liquid nicotine concentrations vary widely but are sold in concentrations up to 100 mg of nicotine per mL. Therefore, liquid nicotine ingestions in children can present with significant acute toxicity involving multiple branches of the central nervous system. Presenting symptoms can be variable, depending on multiple factors such as route of exposure, dose, and size of child. Presenting symptoms in acute nicotine exposure include nausea/vomiting, tachycardia, tachypnea, hypertension, tremors and fasciculation, ataxia, confusion, decreased level of consciousness, coma, seizure, and death, among others.^{5,6} Symptoms generally begin within half an hour of exposure.

Seizures specifically can present a challenge to health care providers as they are potentially life threatening, require immediate intervention, require consideration of the underlying cause despite a potentially broad differential diagnosis, and may lead to escalation of supportive measures such as intubation. Moreover, seizures in patients presenting with toxin exposures are generally treated with benzodiazepines as opposed to other antiepileptic medications.

The lungs, skin, GI tract, and mucous membranes readily absorb nicotine, especially in its liquid form, and this poses a particular challenge to providers with regard to decontamination of an exposed child. Decontamination is an important consideration in toxic exposures and is emphasized in the simulation case presented here. Decontamination of the toxin-exposed child includes removing clothing and rinsing skin. Other therapies such as activated charcoal are not generally recommended for liquid nicotine exposure due to the risk of aspiration in a vomiting child, but consultation with a toxicologist can help guide further decontamination.

Initial evaluation of an altered child, such as the one presented in this simulation, requires attention to airway, breathing, and circulation. In seizing patients, the airway must be assessed to determine whether it is protected and patent. Adjunctive therapies such as nasopharyngeal and oropharyngeal airways, bag-mask ventilation, and supplemental oxygen may be necessary. Intubation, although a last resort, is the definitive tool with which to protect the airway. Other threats to the airway, such as emesis, should be treated with appropriate therapies.

Obtaining a comprehensive yet focused history is of utmost importance, especially in the toxin-exposed child, as it is often the only way to reveal the underlying etiology of the patient's symptoms. In seizure specifically, evaluation should be performed for underlying cause, such as electrolyte disorder or anatomic abnormality. Vital sign abnormalities should be treated supportively, and there should be evaluation for other causes of tachycardia, fever, or altered mental status, such as occult infection. Useful studies include bedside glucose, basic labs such as electrolyte panel and complete blood count, blood gases and CO-oximetry, urinalysis, EKG, toxicology screens if available, plain chest and abdomen radiography, and head imaging.

Supportive care includes airway management as above. Severely poisoned patients may require further interventions such as fluid resuscitation, vasopressors, and treatments for arrhythmia. Patients should be observed in an appropriate setting until asymptomatic, generally at least 6 hours.

This case was created using simulation and debrief as the instructional methods because they allow learners to practice the clinical and communication skills required in a low-frequency, high-risk situation and to reflect upon team and individual performance as well as knowledge or skill gaps. The case was originally developed with a target audience of pediatric residents and pediatric emergency medicine fellows in mind but would also be appropriate for emergency medicine residents, pediatric emergency fellows, pediatric and emergency medicine faculty, and emergency department nursing staff. Given the target audience, it is expected that participants will have prerequisite knowledge about how to evaluate and stabilize an acutely ill pediatric patient.⁷ Although peer-reviewed simulation-based curricula regarding the evaluation and management of seizures in the pediatric population exist, there are no comprehensive curricula that specifically focus on the identification and management of the sequelae of nicotine toxicity in children.

These materials can be used independently or in conjunction with other simulations from the Pediatric Emergency Medicine Simulation Curriculum⁸⁻²¹ or the Pediatric Toxidrome Simulation Curriculum²²⁻²⁵ published on *MedEdPORTAL*.

Methods

Development

This simulation case was developed to educate pediatric providers on the topic of liquid nicotine exposure in children, with an emphasis on the general approach to the toxin-exposed pediatric patient and on seizure management in cases of toxic overdose. Our goal was to engage participants in active experiential learning. Participants had to activate prior knowledge in order to rapidly assess and stabilize a seizing child and demonstrate resuscitation skills universal to caring for the critically ill child such as taking measures to evaluate and support airway, breathing, and circulation. The unusual cause of nicotine toxicity allowed them to construct new knowledge or reinforce concepts particular to this case. Multiple resources were created to help the educator prepare for, conduct, and debrief the case.

Equipment/Environment

The setting of the case was an emergency department room. We performed the scenario in both the emergency department and a general inpatient room. The simulation could also be conducted in a simulation lab, depending on center capabilities. We used a high-fidelity pediatric mannequin dressed in age-appropriate clothes. A fruity or other sweet smell could be applied to the clothing to mimic the aroma of flavored liquid nicotine. All required medical equipment and medications had been gathered prior to the session.

Adaptation if using a low-fidelity simulator: If a high-fidelity mannequin is not available, it is important to identify a method by which learners can be updated on clinical status changes and vital sign changes during the simulation. Verbal cuing is an appropriate method to do so. Simulator apps for phones or tablets may also be used. Similarly, physical examination findings should be described by educators in a manner concurrent with learner physical examination.

Personnel

Approximately four to six trainees per session could be accommodated by this simulation scenario. Ideally, the scenario was performed with health care providers and staff playing the parts most closely resembling their normal roles. Nurses and other support staff played the roles of nursing and support staff when possible. More experienced residents, fellows, or faculty led the case given that they were likely to be leading the case in a real scenario. The remaining participants could act any unfilled roles, but having providers acting the role of other professionals may likely contribute to decreased realism of the scenario. The session also required one simulation technician to run and progress the case through its various stages. At least one facilitator, but ideally two, was present to play the role of a parent as well as provide any exam findings that were not obtainable from the simulator (e.g., capillary refill or skin warmth). The

facilitator(s) also actively observed the actions of and communications between team members in order to help guide the debrief.

Implementation

This session was conducted over the course of an hour, with approximately 20 minutes devoted to the simulation and 40 minutes to the debrief and didactic component. When feasible, the debrief was conducted in an area separate from where the simulation had occurred. The scenario began with a verbal report to participants that a 23-month-old boy, previously in his usual state of health, had been brought to the emergency department after his mother noticed that he was acting drowsy. On the way to the hospital, he became unresponsive, with stiff arms and rightward gaze deviation. He had another such episode of seizure activity while being roomed, so providers (our learners) were asked to enter the room to promptly evaluate the child. The case then progressed as described in the simulation scenario (Appendix A). Medical equipment and medications required for the case had been gathered prior to the session (see Appendix B for more information). The mannequin was shaken or verbal cues were given by educators to simulate the seizure activity. Values for laboratory tests that could be obtained emergently were provided verbally and are included in the case scenario. If participants requested emergent bedside diagnostics such as EKG or portable chest radiograph, they were provided with the relevant images from Appendix C. The teamwork and communication (TeamSTEPPS) glossary²⁶ (Appendix D) and debriefing guide (Appendix E) were used as references and guides by the facilitators during the debrief (see the Debriefing section below). We created a brief didactic (Appendix F) that was reviewed with participants after the simulation and debriefing. The simulation session evaluation form (Appendix G) was distributed immediately after the session in order to assess the curriculum and session as a whole.

Assessment

We used the simulation session evaluation form (Appendix G) to obtain assessment of the session from our participants and to collect feedback for future improvements. Our learners received formative feedback during the debrief and were asked to engage in self-reflection during the discussion.

Debriefing

After the simulation scenario was completed, the facilitators led a debrief. Educators and learners discussed the case, with particular focus on a structured review. The teamwork and communication (TeamSTEPPS) glossary²⁶ (Appendix D) was used to provide a shared language regarding teamwork and communication. Alternatively, the glossary could be distributed to participants before or after the session for additional educational support or used solely by facilitators to help identify ways in which the team performed well and opportunities for future improvement. The debriefing guide (Appendix E) offered general tips on conducting a debrief as well as a structured script to help facilitate a discussion depending on learners' performance and the overall goals of the session. A form to facilitate note taking during the simulation has also been included in Appendix E for facilitator use. The PowerPoint presentation (Appendix F) was used to provide additional education to learners after the simulation and served as a brief comprehensive review of the major learning points. It could also be given to learners before the session to provide background knowledge on nicotine toxicity and acute management of the poisoned child if the goals of the session are more focused on resuscitation and teamwork.

Results

This simulation case has been implemented with four pediatric emergency medicine fellows and 15 pediatric residents at our institution. Using the included materials, two different facilitators have led educational sessions. Nine of the 19 participants completed evaluations for the session.

Average mean Likert scores for these completed evaluations (Table 1) demonstrate that the participants felt the simulation case was relevant and realistic and that it was effective in teaching basic resuscitation and seizure management skills. In addition, Likert scores indicate that participants felt the case effectively demonstrated appropriate evaluation and management of the specific pathology, nicotine toxicity. Likert

scores also show that participants felt more prepared to identify and manage nicotine toxicity in a child after participation in the session (Table 2).

Table 1. Participant Feedback on the Simulation (*n* = 9)

Statement	M Score ^a
This simulation case provided is relevant to my work.	5.0
The simulation case was realistic.	4.9
This simulation case was effective in teaching basic resuscitation skills.	5.0
This simulation case was effective in teaching seizure management skills.	4.9
The simulation case was effective in demonstrating the evaluation for and management of nicotine toxicity.	4.9
The debrief created a safe environment.	5.0
The debrief promoted reflection and team discussion.	5.0

^aOn a 5-point Likert scale (1 = *strongly disagree*, 3 = *neutral*, 5 = *strongly agree*).

Table 2. Participants' Confidence in Their Ability to Perform Key Skills Tasks Directly Related to the Educational Objectives (*n* = 9)

Item	M Score ^a
After participating in this session, how confident are you in your ability to:	
Identify a nicotine exposure.	4.4
Effectively manage a toxin-exposed child.	4.4
Effectively manage a seizure in a pediatric patient.	4.6

^aOn a 5-point Likert scale (1 = *strongly disagree*, 3 = *neutral*, 5 = *strongly agree*).

In open-comment sections of the evaluations, participants wrote that their clinical practice would change as a result of the knowledge and skills obtained during this simulation. Learners reported that after the simulation, they would be more likely to “consider nicotine overdose” on their differential and incorporate that consideration into their history taking. They commented that the simulation had enhanced their “recognition of nicotine toxicity and appropriate management.” In addition, learners felt that they could now identify and treat nicotine exposure and had an improved understanding of the time course involved with manifestations of toxicity.

Discussion

Liquid nicotine exposure is becoming more common as the use of electronic cigarettes increases. Given the pleasant and enticing aromas that many of these concentrated formulas have, pediatric patients may become unintentionally exposed to amounts sufficient to cause serious consequences such as hemodynamic instability and seizure. This 1-hour simulation-based resource can be used with pediatric residents, pediatric emergency medicine fellows, and other frontline health professionals who care for children in the emergent setting to facilitate teaching on the identification and management of acute liquid nicotine exposure in a pediatric patient. The case also serves to emphasize the more integral components of caring for seizing pediatric patients and toxin-exposed pediatric patients. To effectively care for patients presenting with low-frequency, high-risk medical problems, providers must be familiar with their presentation, evaluation, and management and able to work effectively as a team. The scenario provided in Appendix A includes the expected course of the case, cues and timing for instructors to provide information or initiate changes in the patient's clinical status, and more detail regarding the patient presentation. Additional resources, such as the debriefing guide (Appendix E), slide set (Appendix F), and evaluation forms (Appendix G), allow instructors to implement and elicit effective feedback mechanisms that can both help to improve the case and serve to solidify components of the simulation.

With any simulation-based curriculum, limitations related to realism may occur. We found particular challenges with regard to simulating seizures, emesis, and airway status. We also found that we often needed to provide verbal cues to the participants in regard to seizurelike movements and emesis. For example, in order to prompt concern about the airway in an altered patient, we often verbally explained that the patient was not gagging with suctioning. The use of a high-fidelity mannequin combined with frequent verbal cues from educators is helpful in making the simulation case more consistent with a real one. A further limitation was that evaluations were elicited only from learners.

Limitations noted by our participants included the lack of smell that may have accompanied a liquid nicotine exposure in real life. Given that most liquid formulations are compounded to have fruity or sweet smells, the absence of an aroma took away from the reality of the case. We found that seizure activity, emesis, and poor protection of the airway could also be difficult to replicate in the simulation environment and required prompting by and verbal cues from instructors.

In future iterations of this case, we plan on applying a fruity scent to the mannequin's clothes in order to simulate contamination with a liquid nicotine-containing fluid. During implementation, we noticed that teams did not quickly remove the patient's clothing in order to minimize ongoing cutaneous exposure. While we emphasized the importance of decontamination during the debrief, we are interested to see whether participants are quicker to remove soiled clothing if olfactory cues are present.

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Ethical Approval

Reported as not applicable.

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