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Pediatric Emergency Medicine Simulation Curriculum: Electrical Injury

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Abstract

Introduction: Electrical injuries are rare but potentially life-threatening medical emergencies that require providers to manage a critically ill patient while recognizing and treating the unique sequelae associated with the diagnosis. This simulation case is designed to give pediatric and emergency medicine residents, fellows, attendings, and nurses the opportunity to practice these skills in a realistic setting. **Methods:** This simulation-based curriculum was designed for a high-fidelity mannequin in an emergency department resuscitation room but can be adapted to fit a variety of learning environments. The case featured a 16-year-old boy presenting to the emergency department after arresting in the field after sustaining an electrical injury. He developed ventricular tachycardia during the simulation and had significant hyperkalemia, requiring emergent management. The included debriefing tools assisted instructors in providing formative feedback to learners. **Results:** A total of 40 residents, medical students, and fellows participated in this scenario and provided overwhelmingly positive feedback about the learning experience. Mean Likert scores for participant confidence related to learning objectives after the simulation were 4 or greater on a 5-point scale. **Discussion:** This case was developed to help learners at various levels of training recognize and manage a low-frequency, high-acuity scenario in a standardized environment. Participants specifically had the opportunity to perform airway management, cardiopulmonary resuscitation, defibrillation, and management of hyperkalemia, which may present in real life from a multitude of etiologies. The included materials helped prepare and assist facilitators with debriefing, supplemental education, and bidirectional feedback.

Keywords

Simulation, Arrhythmia, Pediatrics, Pediatric Emergency Medicine, Electrolyte Abnormality, Electrical Injury, Electric Injuries

Appendices

- A. Electrical Injury Simulation Case.docx
- B. Electrical Injury Environmental Preparation .docx
- C. Electrical Injury Moulage Instructions.docx
- D. Electrical Injury Simulation Images.pptx
- E. TeamSTEPPS Glossary .docx
- F. Electrical Injury Debriefing Guide.docx
- G. Electrical Injury Simulation Evaluation Form.docx
- H. Electrical Injury Slides.ppt

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

Educational Objectives

By the end of this session, learners will be able to:

1. Demonstrate the ability to assess and emergently manage airway, breathing, and circulation.
2. Operate a defibrillator and deliver the appropriate therapy.
3. Formulate a list of possible diagnoses and prioritize elements of evaluation.
4. Manage hyperkalemia in an acutely ill patient.
5. Construct a disposition plan after stabilization in the emergency department.

Introduction

Electrical injuries can be life-threatening medical emergencies whose consequences may be difficult to recognize and manage appropriately. Severe cases can involve patients who are found unresponsive in the field and may require providers to resuscitate a critically ill patient while simultaneously working through a broad differential to determine appropriate management.

Although the majority of electrical injuries in adults occur from high-voltage exposures in the workplace,¹ pediatric patients can present with a mix of low-voltage and high-voltage injuries that range from benign to life-threatening in their severity. Low-voltage injuries (< 1000 volts) tend to come from alternating

current (AC) sources such as household outlets and electrical cords. Injuries from these are more common in younger children (< 6 years old).²⁻⁴ High-voltage injuries can be the result of AC contact but more often are the result of direct current sources such as batteries, train tracks, or a lightning strike. Teenage patients are at higher risk for severe, adult-pattern injuries.^{2,3} Males are more often affected in all age groups.²

This simulation scenario allows the learner to practice recognizing and managing injuries and cardiac/electrolyte abnormalities that may result from exposure to high-voltage electricity. While rare in the pediatric population, they can present with a variety of complications, including deep burns, indirect trauma, secondary electrolyte abnormalities, cardiac arrhythmia, respiratory failure, and death. It is critical for providers at all levels to have an appropriate index of suspicion for electrical injury in order to promptly provide necessary interventions. The target audiences are the groups most likely to encounter this type of emergency: pediatric and emergency medicine residents, pediatric emergency medicine fellows and attendings, pediatric nurses, and medical students.

The assessment of a patient found down in the field begins with a comprehensive primary survey. If patients are unable to protect their airway or maintain breathing and circulation, interventions such as repositioning, adjunct airways, bag-mask ventilation, or intubation may be required. If circulation is impaired due to cardiac arrest or rhythm disturbance, high-quality CPR should be performed along with additional interventions such as epinephrine or electrical defibrillation as appropriate. After initial stabilization, a secondary survey and further workup for underlying causes should be performed. In the case of electrical injury, hyperkalemia from rhabdomyolysis is of particular importance to recognize due to its significant complications and its reversibility.

This simulation offers learners the opportunity to complete a comprehensive primary and secondary survey, review the differential diagnosis for a pediatric patient found down, and manage the sequelae of pediatric electrical injury. The simulation provides structured education in the management of a critically ill pediatric patient and the development of a differential in real time, while challenging learners to effectively manage an airway and support ventilation and oxygenation, provide high-quality CPR, defibrillate pulseless ventricular tachycardia, and manage fluids and hyperkalemia, skills that are relevant in other circumstances outside of electrical injury. The case can be used to supplement other simulation-based curricula from the Pediatric Emergency Medicine Simulation Curriculum⁵⁻¹⁸ or as a stand-alone unit. While there are published peer-reviewed cases pertaining to arrhythmias including ventricular tachycardia in pediatric patients, there are no other published cases that specifically address the presentation and sequelae of electrical injury.

Methods

This simulation case was designed to help learners build a framework for recognizing, managing, and treating the sequelae of electrical injury in the pediatric population. It encouraged active learning by providing the opportunity to practice resuscitation, teamwork, and communication skills. Because of the large number of diagnoses that can present as a patient found down, it is critical to have a structured approach to identifying possible underlying causes in order to deliver appropriate treatments while resuscitating and stabilizing the child. Simulation forces learners to engage in both processes, similar to real life. In the case of electrical injury, the extent of the injuries is not always evident from an external exam, a fact that heightens the need to consider the diagnosis when appropriate. We incorporated this case into our monthly mock code curriculum for pediatric residents and medical students as well as our simulation curriculums for pediatric emergency medicine fellows and emergency medicine residents. Trainees did not have specific preparation for the case, but a basic understanding of pediatric assessment and resuscitation was helpful.¹⁹ This publication includes all necessary materials to prepare facilitators for implementation.

Equipment

The scenario was set in an emergency department resuscitation room but was also run in a general patient room. It could also be modified to be run in a simulation lab. See Appendix A for the simulation case scenario and Appendix B for a full list of suggested equipment to have available. We used a high-fidelity adult mannequin with burn injuries applied to the right hand and left foot. See Appendix C for moulage details. We provided common code references such as Pediatric Advanced Life Support (PALS) cards, Broselow tape, and medication dosing for participants. In addition, common medications including those needed for PALS resuscitation and those used to treat hyperkalemia were available and labeled. Bedside equipment including monitors, stethoscopes, IV/IO supplies, gauze, syringes, and code equipment such as a crash cart, backboard, and defibrillator was provided. Finally, a comprehensive set of respiratory supplies was at the bedside, including nasal cannulas, oxygen hook-up, oral/nasal airways, bag-mask system, suction devices, endotracheal tubes, laryngoscope with Miller/Mac blades, and end-tidal CO₂ colorimeter. Chest X-rays (pre- and postintubation) and EKGs showing normal sinus rhythm with peaked T waves and ventricular tachycardia were provided on request (see the simulation images in Appendix D).

Personnel

We accommodated between four and 10 trainees in a single session, but the ideal number is the number of team members who would normally form the response team at a given institution. Due to scheduling constraints, only pediatric residents and pediatric emergency medicine fellows participated in the simulations at our institution. Ideally, other frontline providers, such as nurses, pediatric and emergency medicine residents, fellows, and attendings, would be included, and we recommend that all participants function in their normal roles (i.e., nurses perform nursing roles, physicians perform physician roles). The team leader position was filled by whichever team member would potentially fill that role in an emergency setting. Learners or confederates filled any open roles. Simulation personnel played the role of the emergency medical technician in addition to running the simulation.

Implementation

The resuscitation room was prepared prior to the learners arriving. The mannequin was placed in a hospital bed, and moulage was applied as demonstrated in Appendix C (see that appendix's Figures 1-2). Two large-bore IVs (one in each arm) were inserted into the mannequin, and equipment was arrayed at the bedside as detailed above. Monitors were available but not attached to the mannequin, and their screens were blank at the outset of the case. The EKGs and chest radiographs in Appendix D were printed and available. When the learners were ready, they were told that the patient had just been brought to the resuscitation room by emergency medical services and that the team had been called into the room. The patient was unresponsive and being manually ventilated with a bag-mask by the emergency medical technician when the participants arrived. The individual filling the role of the bedside nurse attached the mannequin to the monitors, with vital signs as described in the simulation scenario. Vital sign changes were demonstrated on the monitors. Other clinical changes and laboratory findings were verbally provided throughout the simulation case. If a low-fidelity mannequin is used, instructors can provide vital signs verbally or using a simulator application for phone/tablet and can verbalize physical exam findings concurrently with the team's examination of the patient. The teamwork and communication (TeamSTEPPS) glossary (Appendix E)²⁰ was used to orient the facilitator to communication and teamwork skills and to help guide discussion. It could also be used as a reference by participants before or after the session. After the simulation, the facilitators used the debriefing guide (Appendix F) to lead a debriefing session (further details provided below). Finally, learners were each asked to fill out the evaluation form (Appendix G) to provide feedback on the structure and content of the simulation. The PowerPoint presentation

(Appendix H) was used to lead a didactic review after the debrief session. Depending on individual needs, additional resources may be provided to learners before beginning the case.

Assessment

Assessment was formative and was provided verbally during the debrief session. Learners were primarily assessed on whether they completed the critical actions, which included completing primary and secondary surveys, identifying ventricular tachycardia and treating with defibrillation, managing the airway of an acutely ill patient including administering bag-mask ventilation and intubating the patient, identifying hyperkalemia, and administering calcium chloride or gluconate in addition to albuterol, insulin/glucose, or both. These critical actions were chosen to mimic the components of a real electrical injury resuscitation that are time sensitive and have a significant impact on patient outcomes. The debrief session, outlined below, was framed around formative feedback provided to the learners as a group based on their individual performances. The session evaluation form (Appendix G) was used to collect feedback from the learners that could be used to improve future iterations as well as to obtain their assessment of whether they had achieved the objectives.

Debriefing

Debriefing was a critical component of the simulation session that allowed for identification and exploration of lessons learned during the scenario. Ideally, we would allot twice the amount of time for debriefing as required to complete the simulation case, but in practice, the ratio was often one to one. When possible, trainees and facilitators transitioned to a debriefing room or area separate from the mannequin after the scenario was complete in order to review the case without the learners being distracted by the equipment. The TeamSTEPPS glossary (Appendix E) was used to focus on a common vocabulary. The debriefing guide (Appendix F), which focuses on medical management evaluation and teamwork and communication evaluation, was used to provide formative feedback to the learners, as introduced above. We then distributed the simulation session evaluation form (Appendix G) to obtain learner evaluations and feedback on the session itself. PowerPoint slides (Appendix H) were used to assist the instructor in delivering information about electrical injury and management of the various sequelae that could be encountered.

Results

We have utilized this curriculum over 3 years with various learners. A total of 11 pediatric emergency medicine fellows have participated as part of their fellowship curriculum. An additional 29 medical students, pediatric residents, and emergency medicine residents have also participated. We collected feedback from six pediatric emergency medicine fellows, six pediatric residents, and five emergency medicine residents during the evaluation process. Participants were asked to rate their agreement with several statements concerning the content and delivery of the curriculum on a 5-point Likert scale (1 = *strongly disagree*, 3 = *neutral*, 5 = *strongly agree*). See [Table 1](#) for results. Participants were also asked to assess their confidence with the stated learning objectives. See [Table 2](#) for results.

Table 1. Mean Scores for Evaluation of Content and Delivery

Statement	Mean Score ^a
This case presented during the simulation is relevant to my work.	4.9
The simulation case was realistic.	4.7
This simulation case was effective in teaching basic resuscitation skills.	4.9
The debrief promoted reflection and team discussion.	5.0
The group discussion helped me develop and prioritize evaluation and management options for a child with injury from electricity.	4.8
The facilitators created a safe environment for discussion and exploration.	5.0

^aRated on a 5-point Likert scale (1 = *strongly disagree*, 5 = *strongly agree*).

Table 2. Mean Scores for Confidence With Learning Objectives After Participating in the Curriculum

Objective	Mean Score ^a
Demonstrate the ability to assess and emergently manage airway, breathing, and circulation	4.3
Operate a defibrillator and deliver the appropriate therapy	4.4
Formulate a list of possible diagnoses and prioritize elements of evaluation	4.2
Manage hyperkalemia in an acutely ill patient	4.3
Construct a disposition plan after stabilization in the emergency department	4.0

^aRated on a 5-point Likert scale (1 = *strongly disagree*, 5 = *strongly agree*).

When asked to describe how their clinical practice would change or be affected, participants' comments included that they would "ask for secondary assessment sooner," "be aware of the pathway of energy," and "be better prepared and quickly establish roles." Participants also remarked that they had a better understanding of the PALS algorithms afterwards. Finally, several residents noted that they would be more likely to include electrical injury on their differential and would deliver shocks earlier in pulseless patients with ventricular arrhythmias.

Of note, when we used this curriculum with pediatric residents and medical students, we tailored the learning objects to focus on high-quality CPR, rapid role assignment, defibrillation, and identification of hyperkalemia. In this setting, we informed the participants that the patient had suffered an electrocution, whereas, with more advanced participants, the pediatric emergency medicine fellows, we provided less history so that they could consider and explore a larger differential diagnosis while performing rapid assessment and stabilization. We also challenged the pediatric emergency medicine fellows to manage hyperkalemia as well as establish a disposition plan for the patient.

Discussion

This simulation-based curriculum was designed to provide learners the opportunity to practice recognition and management of a critically ill pediatric electrical injury patient in a realistic setting. By participating in the scenario, learners are able to identify their own knowledge gaps in a safe environment. The case represents a low-frequency but high-risk disease process that any provider managing pediatric emergencies should be comfortable recognizing in order to manage such patients appropriately.

One limitation, as with many simulation cases, was an inability to fill each role with an appropriate learner. Specifically, most simulation sessions at our institution are not run with our nursing colleagues, so these roles often need to be filled by residents, medical students, or fellows. This diminishes the realism of the scenario and could impact learning. Running the case multiple times in different settings was important to guide revisions to the scenario. An early version of the case did not include moulage on the hand and foot, which led to a delay in learners bringing electrical injury into their differential. We also found it helpful to tailor the case to the needs of individual learners (e.g., providing less information to more advanced learners in order to provide a greater diagnostic challenge). The feedback received throughout this process was overwhelmingly positive at all levels of learners, and this case will continue to be used as part of our simulation curriculum moving forward.

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Ethical Approval

Reported as not applicable.

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