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Hypovolemic Shock in a Child: A Pediatric Simulation Case

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Abstract

Introduction: Volume depletion is a common problem in pediatrics. Interns need to be able to recognize critical illness such as hypovolemic shock, obtain access, and manage complications. This simulation case involves a child with hypovolemic shock who requires intraosseous (IO) needle placement. While designed for subinterns in pediatrics, it is relevant for clerkship students and interns in family medicine and emergency medicine. **Methods:** In this case, a 3-year-old child presents with vomiting, diarrhea, and lethargy, and is in hypovolemic shock. As IV access cannot be obtained, he requires IO access. Laboratory results reveal hypoglycemia, hypernatremia, and acute kidney injury. Required equipment includes an IV arm task trainer and a child mannequin with IO capacity (or a child mannequin plus a separate IO task trainer). Learning objectives include recognizing and managing hypovolemic shock, hypoglycemia, and electrolyte disturbances; obtaining IO access; and communicating with a distraught parent. Critical actions include attempting IO access, requesting labs, and administering fluids. Students complete a selfassessment survey following the case. **Results:** A pilot study was conducted in 2017 with all subinterns (N = 16) on the pediatric service. Students' perceived competence in assessment and management of volume depletion and procedural skills such as IO placement were high following the session, and students rated the case as a highly beneficial learning experience. **Discussion:** This clinical simulation case allows students to demonstrate clinical reasoning skills, procedural skills, and management skills regarding hypovolemic shock. It may be used as part of a curriculum for fourth-year students entering pediatric residency.

Keywords

Hypoglycemia, Shock, Hypovolemia, Dehydration, Team, Acute Kidney Injury, Intraosseous, Access, Fluid Deficit, Hypernatremia

Educational Objectives

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

1. Recognize a child with hypovolemic shock based on vital signs, physical exam, and a limited history.
2. Interpret laboratory tests related to hypovolemic shock.
3. Develop management plans for volume depletion and fluid/electrolyte abnormalities.
4. Demonstrate proper technique for obtaining intraosseous access.
5. Demonstrate effective communication with a distraught parent.

Introduction

As subinterns, students have primary responsibility for patients, but during emergency clinical situations, they do not usually play a central role. As a result they may be underprepared when they encounter similar clinical situations during residency. Although residency preparatory courses (usually with simulated emergency cases) are increasing in popularity, we feel that it is important to have structured hands-on learning opportunities earlier in the fourth year so that performance gaps may be recognized and addressed. The length of this simulation case provides ample opportunity to observe students' ability to clinically solve problems, and the complexity and acuity of the case demands that every student take an active role. Through problem solving in a small group setting, learners develop teamwork skills and practice communicating with a distraught parent while making clinical decisions.

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Appendices

- A. Simulation Case Template .docx
- B. Laboratory Values.docx
- C. Critical Actions Checklist and Evaluation Tools.docx
- D. Faculty Resources.docx
- E. Standardized Patient Information.docx
- F. Flow Diagram of Case.docx
- G. One Page Case Summary .docx
- H. Intraosseous Instructions .docx
- I. Survey.docx
- J. Clinical Signs Dehydration Table.docx

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

This module provides a stand-alone resource to be used for fourth-year students in pediatrics to learn about fluid management and intraosseous (IO) needle placement. It is helpful for the learners to have an understanding of the basic concepts of volume depletion prior to starting the case. It is not designed to be an evaluated exercise but to be used in an environment where it is safe for learners to make mistakes and learn from them. It could be used effectively as an application exercise for a flipped-classroom exercise or as an isolated simulation exercise. We use it during the subinternship, but it could also be used during a residency preparatory course or intern orientation. It could be used in conjunction with our previously published case¹ and others as a curriculum for fourth-year medical students entering pediatrics. It is also suitable for third-year medical students or early first-year residents in pediatrics, family medicine, or emergency medicine.

Although assessment and management of volume depletion are essential skills in pediatrics and ones that are frequently utilized during pediatric residency, there are few published curricular tools for working with learners to develop the knowledge and procedural skills to effectively diagnose and manage hypovolemia in children. There are published cases of shock in pediatric patients, but they involve newborns,^{2,3} don't include IO needle placement,⁴ or are geared toward pediatric residents or fellows.⁵ This case adds to the growing number of simulation cases available for use in the fourth year of medical school.⁶

Methods

Development

We developed this simulation exercise as part of a series for fourth-year students administered during weekly education sessions as part of their subinternship in pediatrics. There are between two and four students completing subinternships at the same time, so we designed it as a team exercise to focus on clinical reasoning skills in a safe environment. We selected the topic as it is addressed in the Council on Medical Student Education in Pediatrics/Association of Pediatric Program Directors (COMSEP/APPD) Fourth Year Curriculum⁷ in the following areas: "Describe the diagnostic evaluation and management of hospitalized patients with fluid, electrolyte, and acid-base disturbances," "Recognize variations in common laboratory findings and vital signs," and "Describe the signs and symptoms that suggest deterioration (including signs of shock and respiratory failure) or improvement of a patient's clinical condition." Students were not expected to prepare specifically for the exercise and did not know the topic ahead of time. It was essential for facilitators to have a working knowledge of fluid/electrolyte management and IO placement skills in order to provide a robust discussion and skills session on these topics following the case (background information provided in Appendix D).

Equipment/Environment

We recommend the following equipment for successful implementation of this simulation case:

- Child mannequin with IO capability or:
 - Child mannequin and separate IO partial task trainer.
- IO kit, including driver (EZ-IO), 15g pediatric needle, stabilizer, instructions, or manual IO needle.
- Child IV arm task trainer.
- Pedi code cart including:
 - Length-based tape.
 - PICU resuscitation card.
 - Bags of normal saline, ½ normal saline, lactated Ringer's solution, Normosol.
 - Bags of dextrose solution, including D10W, D25W, D50W.
 - Antibiotic bag (Ceftriaxone).
 - Nasal cannula, venturi mask, nonrebreather mask.
 - Child bag and mask (2 sizes mask).
 - Oxygen tubing.

- Pediatric urine catheterization kit or:
 - Foley catheter, lubricating jelly, simulated swabsticks, sterile urine cup, sterile gloves.
- IV supplies:
 - Tourniquet, 22-gauge IV needle X2, microbore extension set, IV connector set, IV pole, extra IV tubing, tape, saline flushes (4), 1cc, 5cc, 10cc, 20cc syringes, alcohol swabs, 18- or 20-gauge 1.5 inch needles.
- Bedside glucose measurement tool.
- Acetaminophen suppository.

Personnel

Parent: Ideally played by a standardized patient (SP), the parent gives history and answers questions. The parent may be played as “distraught.”

Nurse: May be played by a nursing student or the facilitator. The nurse assists in carrying out orders and enlisting help from students for various tasks. If the facilitator plays this role, they can be inside the room making observations on the “nursing chart” throughout the case to use as discussion points during the debriefing.

Simulation staff member: Changes vital signs on monitors as indicated and gathers any missing equipment during case.

Facilitator: Provides physical exam findings and assists students in finding equipment. Alternatively, the facilitator could be out of room watching through one-way glass and listening with headphones. The facilitator could play the role of nurse.

Implementation

One of us met with students for weekly sessions in the Clinical Simulation Laboratory during the month-long pediatrics subinternship, and this case comprised one of the sessions. After students arrived at the lab, we met outside of the simulation space to have a brief check-in and discuss expectations and ground rules for the session (e.g., a safe space for learning free from formal evaluation; procedures beyond their scope of practice are acceptable in this setting, etc.) We described the setting (the emergency department) and our role (nurse), and we discussed the importance of staying in roles to maximize learning for the entire team. We explained that we would stay in the role of nurse except to provide physical exam findings, and that we would provide students with any needed supplies as well as lab results when available.

We found it most successful to meet with students in the mid-afternoon so that they had time following morning rounds to perform necessary tasks before signing out to the senior resident. We maintained large labeled Ziplock bags with materials for the cases, including “IV supplies,” “syringes,” and “respiratory supplies” among others, to ensure consistent restocking and easy access. We used a whiteboard in the room during the case, so students could keep track of their thoughts and plans, and for use by teams during the debriefing. A child mannequin was central to the case, and since at times the mannequin with IO capability was unavailable, we occasionally used an IO task trainer with a low fidelity child mannequin with acceptable results. We found that the case usually takes about 45 minutes for students to work through, followed by 45 minutes of debriefing and 30 minutes on procedural skills practice.

The case is fully presented in the simulation case file (Appendix A). Laboratory values (Appendix B) are formatted for easy viewing and lamination. These individual lab results were provided to students when requested, along with the reference for normal laboratory values. The critical actions checklist (CAC, Appendix C) may be adapted for evaluative use. A faculty reference document (Appendix D) with information for facilitators to review to help guide the discussion following the case is also provided and can be adapted for student use as well. An in-depth description of the case from the SP’s point of view

(Appendix E) is the template used at our institution to provide SPs with in-depth information about their character. The case is longer than many simulation cases, designed to last approximately 90-120 minutes, so it is essential that the SP knows the case well. A one-page flow diagram (Appendix F) may be used with a two-sided summary of the case (Appendix G) for easy quick reference during the case for both the facilitator and the simulation center technician. A concise description of the IO technique is provided (Appendix H) for easy lamination to be used by students during the case. Additional information about IO access is also provided in the faculty reference document, including a reference for an instructional video, and this information could be reviewed prior to the session by participants or following the case as part of debriefing and/or skills-station practice. The survey used for student self-assessment following the case is included (Appendix I), Finally, the clinical signs of dehydration table is included, formatted for lamination and easy use during the case (Appendix J).

Assessment

Participants received formative feedback following the case during the 45-minute debriefing. Facilitators reviewed each learning objective in detail with students and completed a critical actions checklist. The items included on the CAC were agreed on by the authors as the minimum essential actions learners should be able to perform in order to say they successfully worked through the case.

Following the case, students completed a survey reporting perceived competence and improvement in related skills. We made an intentional decision to not provide summative evaluation for this learning exercise, based on informal student surveys, as they uniformly opposed formal evaluation and highly valued the fact that the case was a safe learning environment free from formal evaluation. However, a summative evaluation could easily be designed for the exercise, and published checklist for IO placement that may be used for this purpose.⁸ SPs could also complete a checklist following the case regarding communication skills.

Debriefing

We use a student-centered “plus-delta” approach for debriefing. As described in our previous publication¹, in this technique, the facilitator focuses first on what participants felt they did successfully and then focuses on what they would want to do differently. SPs and any members of the interprofessional team are part of the initial debriefing, including discussion about team skills and roles. Then the facilitator asks students to present a summary of the clinical scenario in order to develop a shared mental model. Facilitators review learning objectives, critical actions, and any questions students have as they arise. Procedural practice takes place following the debriefing. A list of questions and discussion points used during the debriefing are included below:

General questions for all participants:

1. What went well?
2. What could have been done differently?
3. How did you work as a team?
4. What was the clinical scenario? What happened?

Specific questions/discussion points related to educational content:

1. Describe how to estimate fluid deficit and calculate fluid replacement.
2. Review the different types of shock and vital signs characteristic of shock.
3. Compare fluid management at the initial presentation of shock versus the stabilization/deficit replacement stage.
4. Compare types of fluid, including crystalloid and colloid, with indications for use of each.
5. Discuss indications for administering a dextrose bolus as well as dextrose-containing isotonic fluid.
6. Review the basic principles of management of hypernatremia.
7. Review the basic principles for management of acute kidney injury.

8. Review the differential diagnosis and management of metabolic acidosis.
9. Discuss the options and challenges of access, including the risks/benefits of IO access.
10. Discuss the issues involved when caregivers question, challenge, or refuse treatment.

Results

We have run this case approximately 35 times with over 80 fourth-year students during their subinternship rotation in pediatrics from 2013-2017. There are usually 2-3 students participating, and we have found that this is an ideal size. It is possible to run the case with four students, but it has not run as smoothly. All students participating in the module during 2017 ($N=16$) completed a survey following the session (Table). Survey results showed that students' perceived competence in assessment and management of volume depletion and IO placement was high (average scores of 4.38 and 4.50, respectively, on a 5-point Likert scale), and that they felt the session improved clinical decision-making, procedural skills, and team skills (4.38, 4.25, and 4.56 respectively). Overall, they rated it as a highly beneficial learning experience (4.88).

Table. Postmodule Survey Results ($N=16$)

Question	M (SD)
After completing this session, I feel competent in the following areas ^a :	
Assessment and management of volume depletion.	4.38 (.62)
Diagnosing and managing fluid/electrolyte abnormalities.	4.06 (.68)
Intraosseous placement.	4.5 (.52)
This session improved my ^b :	
Clinical decision making skills.	4.38 (.62)
Procedural Skills.	4.25 (.45)
Ability to manage difficult patients or parents.	4.00 (.73)
Ability to work in a team setting making clinical decisions.	4.56 (.63)
This session was a beneficial learning experience. ^b	4.88 (.34)

^aFive-point Likert scale (1 = *much less competent*, 5 = *much more competent*).

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

Starting in 2016, four other pediatric hospitalists received training in and routinely facilitate the scenarios. Minor changes in the scenarios have been made based on their feedback. Preparation time for facilitators was minimal and included reviewing the case, reading any of the background resource material that they felt would be helpful for teaching, and reviewing the debriefing methods. We generally arrive 15-30 minutes early to confirm room set-up and clarify expectations and plan with Simulation Center staff and the SP.

Discussion

This simulation case has been successful in helping students to recognize hypovolemic shock and associated abnormalities through history, clinical signs and symptoms, and interpretation of lab values. The case also helped develop appropriate management plans. Students work through the case as a team, similar to a true patient presentation in the emergency room. They place an IO needle and provide dextrose and fluid boluses, witnessing normalization of vital signs and lab values. Throughout the case, they engage with a distraught parent, sharing thoughts about a differential diagnosis and management plans.

The case has become a successful tool for simulation-based learning based on surveys and informal feedback, and it contains all necessary instructions and supplements to provide a rich educational experience. It may be used in isolation or in combination with our previously published case¹ or other cases targeting the fourth year.⁵ It adds to the growing number of published resources for use in pediatric fourth year rotations or early internship. Students who have completed the exercise have asked for more frequent sessions, stating that the sessions are practical and relevant.

We encountered several challenges inherent to the format of the cases:

1. IO needle placement is outside of the scope of practice for subinterns, and they are sometimes hesitant to attempt this procedure without help. We provide specific instruction prior to the case that

it is appropriate in this simulation setting to attempt the procedure they would not otherwise do without supervision. Likewise, we discuss this with the SP so they are aware. Alternatively, the facilitator could provide instruction either by breaking roles or by playing the role of “chief resident” to instruct the students.

2. Students must be unsuccessful in obtaining intravenous access in order to necessitate IO needle placement. We routinely provide students with a malfunctioning child IV task trainer to attempt intravenous access and when they are unsuccessful, the nurse tries and fails as well, hopefully prompting the students to consider the IO route. Following the case, we provide direct instruction with a functioning child IV task trainer arm so students experience success.
3. When students perform a procedure improperly, it is important to review following the case so they learn from the mistakes. We have chosen to not interrupt the case to provide procedural instruction in an effort to make the case as realistic as possible without breaking roles. Following the case, all learners receive specific instruction and practice on each procedure using skill stations or at the bedside.
4. It is challenging to provide physical exam findings without breaking roles. Even with high fidelity manikins, many subtle exam findings are impossible to portray. We have chosen to have the facilitator break their role to provide physical exam findings. Other options are to provide a printed record of the physical exam or to have the findings relayed over audio.

There were a few limitations to the case. Although the response rate was high (100%) for the surveys following the case, the absolute number is small ($N = 16$) and thus limited in statistical significance. Our results successfully addressed the learning objectives but were limited to student self-assessment (Kirkpatrick's pyramid level 1).⁹ For a more robust assessment, we could incorporate assessment of a student's clinical abilities as reported by either residents or attendings during their subinternship. At this time, we have not provided summative evaluations for the students participating in the modules, however this may not be an option at other institutions. There is a CAC that may be used for scoring, and a more detailed evaluation tool could be easily developed for this resource if desired, including a procedure checklist for IO placement and/or communications skills checklist. We prefer to rely on in-person formative comments during the debriefing, maintaining a safe learning environment where learners feel comfortable making mistakes in order to learn from them.

As a learning tool, this case is rich with opportunity for clinical reasoning, problem solving, and teamwork. The opportunity to practice decision-making and procedural skills in a safe learning environment before encountering similar clinical situations in early residency is invaluable. This case adds to a growing number of simulation-based scenarios that may be instrumental in preparing students for early residency.

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Disclosures

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Ethical Approval

The University of Vermont Committees on Human Subjects approved this study.

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