Critical Procedures in Children: Skills Training for Pediatric Emergency Medicine Providers

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Abstract

Objective: Pediatric emergency medicine providers must attain competence in both rare and life-saving procedures to care for acutely ill and injured children presenting to the hospital. However, there are inadequate numbers of patients available to ensure that all trainees are exposed to, learn about, and perform these critical procedures. Cost, time and need for travel can limit attendance at regional or national workshops for these skills. Using educational frameworks, a one-day local simulation workshop focusing on rare and critical procedures was developed and evaluated.

Methods: Learners who care for acutely ill children were invited to attend. Small groups rotated through 8 stations: advanced airway, cricothyroidotomy and translaryngeal ventilation, pericardiocentesis, central venous catheterization, tube thoracostomy, vascular access, arthrocentesis, and vaginal delivery. Each station was manned by a faculty expert and participants had 20 minutes to learn and practice each procedure on task trainers. Participants received anonymous electronic surveys before and after the workshop to gauge their knowledge and experiences.

Results: Twenty-four participants including pediatric emergency medicine fellows, pediatric residents, and pediatric critical care transport staff attended the workshop. Participants had very limited experience with the selected procedures in simulated or real patients prior to workshop. After the workshop, participants had increased agreement regarding their ability to name the indications, contraindications, equipment and procedural steps necessary for almost all procedures.

Conclusion: This one-day simulated procedural workshop was able to expose relevant trainees and providers to rare and critical procedures. Use of local resources and faculty experts from a variety of specialties mitigated barriers to training for these procedures. Participants both experienced increases in knowledge and hands-on practice for these procedures. This workshop fulfilled an important gap in training and educational recommendations.

Keywords: Training; Procedures; Simulation; Pediatrics; Emergency
Introduction

The Accreditation Council for Graduate Medical Education (ACGME) states that Emergency Medicine (EM) providers (Pediatric EM fellows and EM residents) must attain competence in a variety of clinical procedures. While some of these procedures are commonly encountered and critically important, others are relatively rare occurrences among children. These include endotracheal intubation, cricothyroidotomy and translaryngeal ventilation, pericardiocentesis, central venous catheterization, tube thoracostomy, vascular access (intravenous, umbilical vessel and intraosseous), arthrocentesis, and obstetrical maneuvers and fetal manipulation for vaginal delivery (ACGME, 2019a; ACGME, 2019b).

There are several factors that vary between training programs that may influence a trainee's chance of participating in any of these procedures during their training period. These include differences in training length, volume of patients in the emergency department (ED), trauma designation, geographic area, and amount of clinical time spent in the ED. Several studies have documented that neither pediatric EM (PEM) fellows nor EM residents have an opportunity to perform any of these critical procedures on children (Al-Eissa et al., 2008; Petrosoniak, Herold and Woolfrey, 2013). Furthermore, pediatric faculty who may be in charge of teaching and supervising fellows about these procedures are likely to also have limited to no experience performing these procedures as well (Mittiga et al., 2013b; Mittiga, FitzGerald and Kerrey, 2016; Nguyen and Craig, 2016; Burns and Uspal, 2017). Thus, alternative modalities are necessary to train in these critical skills and procedural techniques.

Simulation-based medical education has steadily gained ground and meets a training need. Task trainers, in particular, specifically offer users a way to learn and practice new skills. The vast majority of PEM fellowship programs have access to simulation equipment for training purposes, and many program directors report using simulation to teach procedural skills (Eppich et al., 2013; Doughty et al., 2015). However, less than half of programs reported use of simulation to teach critical procedures such as pericardiocentesis, thoracostomy tube placement, umbilical vessel catheterization, and cricothyroidotomy (Doughty et al., 2015). The use of simulation training for specific procedures has also been correlated with improved performance and patient outcomes (Evans et al., 2010).

While procedural training has been developed for EM and pediatric residents in various procedures (Sawyer et al., 2010; Nestor-Arjun and Miano, 2014), there may still remain a gap in the training of PEM providers in these critical procedures. Although regional "boot camp" and multi-day workshops have been implemented in some geographic areas, the time, travel and cost associated with these sessions can limit attendance by trainees. Lastly, the impact of the coronavirus pandemic on the future of these large group gatherings is unclear. Our local small-group workshop targets the rare and critical procedures in children in which pediatric emergency providers are required to attain competency and which training programs may not have a formalized process to teach. Our objectives are to describe the implementation of and assess the effectiveness of a one-day simulation workshop on critical pediatric emergency medicine procedures using educational frameworks.

Materials and Methods

Development: Using Kern's approach to curriculum development, a needs assessment was undertaken to assess gaps between expected and actual procedural experience. Based on this review, a list of both high-risk, low-frequency procedures and highly valued procedures where simulation could serve a training role was created (Kern, Thomas and Hughes, 2009). The goals were to improve knowledge of the indications, contraindications, necessary equipment and steps involved in each procedure, as well as to provide hands-on practice with each procedure. A learner group to include PEM fellows, self-selected pediatric residents and chief residents, and pediatric critical care transport team nurses and paramedics was identified as the target audience. Expert subspecialty educators were recruited for
each procedural station. Free on-line medical education tools were used as primers for the workshop. That is, participants and facilitators were provided with links to the applicable New England Journal of Medicine Videos in Clinical Medicine for self-study prior to the session (Thomsen et al., 2006; Dev et al., 2007; Anderson et al., 2008; Hsiao and Pacheco-Fowler, 2008; Tsui et al., 2008; Ortega et al., 2010; Nagler and Krauss, 2011; Fitch et al., 2012; Lighthall, Harrison and Chu, 2013; Pasquier, Hugli and Carron, 2013). These videos reviewed the indications, contraindications, equipment and steps for each procedure. The faculty expert at each station reviewed the contents of the video with each group of learners during training.

A date was selected early in the academic year, with a plan to reoccur annually. The session was scheduled during protected education time such that all PEM fellows could attend. Approximately 3 hours were dedicated to the session. We partnered with our on-site simulation center to provide the task trainers, space, and disposable equipment for the procedure training. During the session, participants were evenly divided into 8 small groups (a group of 3 learners for each procedural station). After a brief orientation to the schedule and simulation equipment, the teams were assigned to a station. Procedural training and practice at each station was conducted over approximately 20 minutes and included a brief instructor-led discussion and demonstration followed by hands-on experience with the simulation equipment.

Materials: Each station had specific simulation equipment, procedural equipment and an expert instructor (Table 1). While indications and contraindications for each procedure were discussed, there were no clinical scenarios associated with each station allowing the learners to focus on the procedural skill alone. Station 1 incorporated vaginal delivery techniques, with a focus on shoulder dystocia. The instructor staff included an obstetrical safety nurse with extensive teaching experience, and a labor and delivery bedside nurse. The equipment included a childbirth skills trainer. Station 2 covered central venous catheter placement, led by a pediatric intensive care unit faculty member. Available equipment included an ultrasound machine, ultrasound-compatible central line task trainers, and central line equipment. Station 3 covered tube thoracostomy, taught by a surgical senior resident. Equipment included chest tube task trainers, chest tube kits, and a suction chest drainage system. Station 4, covering umbilical catheters, included a neonatal manikin and an umbilical line tray. A senior neonatology fellow instructed. Station 5 covered pericardiocentesis, including appropriate task trainers, a procedural tray, and ultrasound. The station was instructed by a pediatric emergency medicine attending and ultrasound fellowship director. Station 6 included difficult airway management, instructed by a pediatric emergency attending. Available equipment included task trainers, direct and video laryngoscopy equipment, and ancillary airway equipment. Station 7 covered surgical airway management, instructed by a pediatric ear nose and throat surgeon. Participants utilized task trainers and surgical airway trays. Finally, station 8 incorporated nurse and pediatric emergency medicine attending instruction of intravenous (IV) catheter placement (visual and ultrasound guided), intraosseous (IO) infusion, and knee arthrocentesis. Equipment included arthrocentesis task trainer, IV task trainers, ultrasound, IV equipment, IO equipment, and arthrocentesis equipment.

Evaluation: In order to evaluate the workshop, pre- and post-workshop surveys were developed. Using the New World Kirkpatrick model, we aimed to assess both the reaction and learning of the participants (DeSilets, 2018). The initial survey was distributed 2 weeks prior to the workshop and prior to distribution of learning materials. Our aim was to understand the learners’ prior procedural experience and comfort. This survey inquired about the number of procedures that the participants had performed on both simulated and real pediatric patients. The post-session survey was administered immediately following the experience. In both the pre and post surveys, participants were asked on a 5-point Likert scale their level of agreement in naming all of the indications, contraindications, necessary equipment and steps to complete each procedure. In the post-survey, participants were also queried about their ability to practice procedures, what they valued most about the workshop, their level of enjoyment, and suggestions for future workshops.
Descriptive statistics including frequency and percentages were used to describe categorical and ordinal variables. Medians and interquartile ranges (IQR) described continuous data that was not normally distributed. The Wilcoxon-signed rank test was used to compare paired ordinal data. This study was granted exemption from the Human Research Protection Program, our institutional review board.

Table 1. Procedural stations and set up

| Procedure                                      | Simulation Equipment                  | Additional Procedural Equipment                                                                 | Staffing                                      |
|------------------------------------------------|--------------------------------------|------------------------------------------------------------------------------------------------|-----------------------------------------------|
| 1. Obstetrical maneuvers and fetal manipulation for vaginal delivery | PROMPT birth simulator (Lims & Things) | N/A                                                                                             | Obstetrical staff (Obstetrical safety nurse, labor and delivery nurse) |
| 2. Central venous catheterization              | FemoraLine Man (SimuLab) and CentraLine Man (SimuLab) | Central line tray (includes needles, syringe, saline, guide wire, scalpel, tissue dilator, local anesthetic) | Pediatric critical care medicine staff |
| 3. Tube thoracostomy                           | Chest tube manikin (Life/Form)       | Chest tube kit (includes scalp, drapes, clamps, syringe, needles, saline, local anesthetic, suture kit, sutures) | Surgical staff |
| 4. Umbilical catheterization                   | SimNewB (Laerdal)                    | Umbilical catheter insertion tray (includes umbilical tape, scalpel, drapes, forceps, syringe, saline, umbilical catheter) | Neonatology staff |
| 5. Pericardiocentesis                          | Pericardiocentesis task trainer (Life/Form) | Needle with syringe Ultrasound machine                                                        | Pediatric Emergency Medicine staff |
| 6. Endotracheal intubation                     | Airway management trainer (Laerdal)  | Glidescope CMac Laryngoscope Curved blades Straight blades Endotracheal tubes Stylets Laryngeal mask airway devices | Pediatric Emergency Medicine staff |
7. Cricothyroidotomy and translaryngeal jet ventilation

- Cric trainer (SynDaver)
- Tissue replacement
- Surgical airway tray (includes scalpel, tracheal hook, clamp, forceps, tracheal dilator, retractor)
- Syringe
- Non-retractable needle
- Endotracheal tubes
- Tracheostomy tubes

- Otolaryngology staff

8. Peripheral venous catheterization

- Intravenous training arm (Laerdal)
- Needle with syringe
- Ultrasound machine

- Pediatric Emergency Medicine staff

8. Intraosseous (IO) needle insertion

- EZ-IO training bones
- IO drill with needles

- Pediatric Emergency Medicine staff

8. Knee arthrocentesis

- Arthrocentesis trainer (Simulab)
- Needle with syringe
- Ultrasound machine

- Pediatric Emergency Medicine staff

Results

Twenty-four learners and 11 facilitators were present at the workshop. Of the participants, 11 (46%) completed our pre-workshop survey and 8 (33%) completed our post-workshop survey. Most participants had performed the procedures in a simulated setting once prior to the workshop and few procedures had been performed on actual pediatric patients (Table 2).

The majority of participants somewhat or strongly agreed to being able to name all of the indications for all critical procedures. However, when asking about the contraindications, necessary equipment and procedural steps, this was only true for intraosseous insertion and intubation (Table 3). After the workshop, the proportion of participants that somewhat or strongly agreed to being able to name these procedural knowledge categories increased in almost all areas. Similarly, even in areas where agreement was strong in the pre-survey, participants often increased their level of agreement from "somewhat agree" to "strongly agree".

All participants (100%) who completed the survey strongly agreed that they had the ability to practice critical procedures during the workshop and all strongly agreed that they enjoyed the workshop. Some aspects that participants found most valuable about the workshop included hands-on practice (86%), small group learning (29%), working with experts (14%), ability to ask questions (14%), the fast pace of the day (14%), and multiple opportunities to practice the same procedure (14%). Suggestions for improvement included additional time at certain procedural stations.

Table 2. Reported procedural experience of participants (N=11)

| Procedure                              | Median Simulated Procedure (IQR) | Median Real Procedure (IQR) |
|----------------------------------------|----------------------------------|-----------------------------|
| Chest tube placement                   | 1 (0-4)                          | 0 (0-2)                     |
| Pericardiocentesis                     | 1 (0-4)                          | 0 (0-0)                     |
| Cricothyroidotomy                      | 1 (0-4)                          | 0 (0-0)                     |
| Central line insertion                 | 2 (0-4)                          | 1 (0-3)                     |
| Intraosseous needle insertion          | 6 (4-8)                          | 1 (0-1)                     |
| Vaginal delivery                       | 1 (0-4)                          | 0 (0-2)                     |
| Intubation with CMac                   | 2 (1-5)                          | 2 (0-11)                    |
| Intubation with Glidescope            | 1 (0-5)                          | 1 (0-3)                     |
| Intubation with direct laryngoscopy    | 8 (4-12)                         | 0 (0-2)                     |

Abbreviation: IQR, interquartile range.
Table 3. Proportion of participants who somewhat or strongly agreed about their ability to name each aspect of the procedure.

| Procedure               | Agreement Before Workshop | Agreement After Workshop | P value* |
|-------------------------|---------------------------|--------------------------|----------|
| **Tube thoracostomy**   |                           |                          |          |
| Indications             | 100%                      | 100%                     | .083     |
| Contraindications       | 46%                       | 88%                      | .096     |
| Equipment               | 36%                       | 100%                     | .041     |
| Steps                   | 46%                       | 100%                     | .039     |
| **Pericardiocentesis**  |                           |                          |          |
| Indications             | 81%                       | 100%                     | .063     |
| Contraindications       | 36%                       | 88%                      | .023     |
| Equipment               | 18%                       | 100%                     | .017     |
| Steps                   | 27%                       | 100%                     | .011     |
| **Cricothyroidotomy**   |                           |                          |          |
| Indications             | 73%                       | 100%                     | .059     |
| Contraindications       | 36%                       | 100%                     | .023     |
| Equipment               | 0%                        | 100%                     | .011     |
| Steps                   | 9%                        | 100%                     | .011     |
| **Central venous catheterization** |             |                          |          |
| Indications             | 91%                       | 100%                     | .180     |
| Contraindications       | 55%                       | 88%                      | .096     |
| Equipment               | 27%                       | 100%                     | .030     |
| Steps                   | 27%                       | 88%                      | .015     |
| **Intraosseous needle insertion** |             |                          |          |
| Indications             | 100%                      | 100%                     | .317     |
| Contraindications       | 73%                       | 100%                     | .059     |
| Equipment               | 100%                      | 100%                     | .317     |
| Steps                   | 100%                      | 100%                     | .317     |
| **Intubation**          |                           |                          |          |
| Indications             | 91%                       | 100%                     | .008     |
| Contraindications       | 73%                       | 100%                     | .102     |
| Equipment               | 91%                       | 100%                     | .414     |
| Steps                   | 100%                      | 100%                     | .221     |

*Represents significance of paired testing among participants with both pre-and post-survey results using Wilcoxon signed rank test

**Discussion**

Pediatric emergency medicine (PEM) providers may be required to perform emergency procedures, yet have infrequent and variable opportunities to perform in real-time or receive training in these procedures (Burns and Uspal, 2017). To our knowledge, this is the first study to describe the implementation of and to examine the effectiveness of a one-day simulation workshop for critical procedures in PEM. Our study revealed an improvement in knowledge of key areas such as indications, contraindications, equipment and steps in almost all of the critical procedures taught during the simulation workshop.

Many physicians in PEM report infrequently performing critical procedures in the ED, while some report not having performed an emergency procedure like an intubation since graduation from residency (Paul and King, 1996; Al-Eissa et al., 2008; Petrosoniak, Herold and Woolfrey, 2013; Burns and Uspal, 2017; Petrosoniak et al., 2017). Our
results similarly revealed that most of our participants had not had an opportunity to previously practice many critical procedures in real-time and even though many had the opportunity to practice most of the procedures via simulation, most had only done so once prior to our workshop. Participants enjoyed the workshop and reported knowledge gains in almost all procedures, especially those in which they had little prior real-life or simulation practice such as pericardiocentesis, cricothyroidotomy, and chest tube placement.

Given the local location, lack of registration or travel costs, and limited time needed for this workshop, we were able to include a variety of participants including members of the transport team and pediatric residents interested in procedural specialties. Additionally, unlike workshops targeted to new trainees only, all of the PEM fellows were able to participate and will have the benefit of a repetitive annual learning opportunity to practice these rare procedural skills. A workshop like this could similarly benefit academic faculty who supervise critical procedures in the ED but may not have been able to perform procedures since training (Mittiga et al., 2013a; Burns and Uspal, 2017) and emergency providers working in community emergency departments who individually see few pediatric patients, but provide the vast majority of emergency care in the U.S. (Gausche-Hill, Schmitz and Lewis, 2007; Gausche-Hill et al., 2015). The small group set up should continue to be feasible given restrictions around gathering in indoor spaces.

We invited sub-specialty faculty including an obstetrical nurse, pediatric intensive care faculty, senior surgery trainees and a neonatal intensive care unit fellow to facilitate the teaching of each simulation-based procedure. Though PEM faculty may have been able to teach these procedures, the use of instructors experienced in performing each procedure may have further increased the fidelity of the procedural training and enabled improved question-answering for the participants, which may have led to a more enjoyable experience. The use of sub-specialty faculty may also allow recruitment of participants such as community ED emergency providers and experienced PEM providers.

There are at several limitations to this work. We described and evaluated an experience in which learning occurred during a one-time simulation-based workshop. First, though simulation-based training can augment deficits in training and experience for rare but critical pediatric emergency procedures, distributed training that takes place over time or just-in-time training that takes place immediately before the clinical procedure being trained for may lead to a greater impact on retention of procedural knowledge or clinical success of a procedure than a solitary training experience (Kessler et al., 2015; Cepeda et al., 2006). Second, though we report significant improvements in self-reported areas of procedural knowledge, we did not confirm these findings through simulation-based assessments. Third, we did not examine changes in improvements in clinical procedural performance. Lastly, this was evaluated at a single center with an incomplete survey response rate, which limits the generalizability of these results.

Implementation of simulation-based workshops to train emergency providers to perform rare and critical procedures may augment and standardize procedural curricula for programs that report decreasing opportunities for real-time performance of critical procedures but have a continued need to train competent providers who can perform these life-saving procedures. Local workshops such as ours can also be combined with opportunities for distributed practice throughout fellowship or other training programs. Finally, such workshops may be used for formative and summative assessments of trainee competence prior to graduation to independent performance of critical procedures.

Take Home Messages
Life-saving and critically important procedures are rare events in children. Alternative strategies are needed in order to fulfill training requirements for pediatric emergency providers. A novel half-day simulation workshop with task trainers and expert faculty was developed, which led to improved medical knowledge and hands-on training for a wide variety of these critical procedures. Small group learning in a local environment is a feasible strategy for attaining educational goals in pediatric emergency medicine.

Notes On Contributors

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Appendices

None.

Declarations

The author has declared that there are no conflicts of interest.

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