JPPT | Training Program Evaluation

Optimization of Pediatric Medical Emergency Training (PedMET) Program for Pharmacists in the Inpatient Setting

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OBJECTIVE It is perceived by many pharmacists that inadequate training and the resulting lack of confidence hinder participation in medical emergencies. There is insufficient information detailing training programs for pharmacists responding to pediatric medical emergencies. The primary objective of this study was to compare competency scores pre and post participation in the pediatric medical emergency training (PedMET) program. The secondary objectives included comparing confidence and knowledge for participation in pediatric medical emergencies, knowledge of resources and error prevention tools, description of the median time to prepare medications, and the most common errors that occurred during simulation.

METHODS A comprehensive didactic lecture and simulation-based training were designed and contained pre- and post-competencies to assess pharmacists' knowledge related to pediatric medical emergencies. Self-assessments were included to determine pharmacists' confidence levels in knowledge and preparation of medications. Feedback was solicited from participants to identify areas of improvement for the program. Standards for QUality Improvement Reporting Excellence (SQUIRE) 2.0 was used to report findings.

RESULTS Twenty-nine pharmacists of diverse training (e.g., residency vs nonresidency) and experience levels completed the program between July 2021 and March 2023. Competency scores improved from a median of 86% to 97% (p value < 0.001). Significant improvement was detected in pharmacists' confidence in their ability to prepare complex medications during medical emergencies (p value = 0.001).

CONCLUSIONS Following the implementation of didactic and simulation-based training, pharmacists' knowledge and confidence increased. Departments of pharmacy should consider implementing pharmacist-specific training programs for all pharmacists who respond to pediatric medical emergencies.

ABBREVIATIONS CPR, cardiopulmonary resuscitation; ICU, intensive care unit; IV, intravenous; JHACH, Johns Hopkins All Children's Hospital; MET, medical emergency training; NRP, Neonatal Resuscitation Program; PALS, Pediatric Advanced Life Support; PedMET, pediatric medical emergency training; PGY, postgraduate year; PICU, pediatric intensive care unit; PPA, Pediatric Pharmacy Association; RSI, rapid sequence intubation

KEYWORDS cardiac arrest; medication safety; pediatric advanced life support; pediatrics; pharmacists; quality improvement

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Introduction

Approximately 20,000 pediatric patients experience cardiac arrest in the United States per year, and 15,000 require cardiopulmonary resuscitation (CPR) during their hospital admission.[1] Regardless of age or precipitating cardiac rhythm, half of these children will not survive until discharge.[2–4] Pediatric cardiac arrest survival rates have improved significantly in the last 3 decades since the implementation of Pediatric Advanced Life Support (PALS).[2,3,5] Improved survival rates are possibly attributed to the availability of trained staff, early recognition of signs of cardiac arrest, and high-quality CPR. Multidisciplinary collaboration of appropriately trained staff is crucial during medical emergencies as simultaneous interventions are performed requiring diverse expertise.[6]

Pharmacist participation in resuscitation events has been previously described in adult patients. Integration of pharmacists in resuscitation teams allows for the provision of medication recommendations, preparation, and drug information. The presence of a pharmacist on the resuscitation team has been shown to result in increased compliance with national and institutional guidelines.[6–7] Although there is limited information regarding patient outcomes based on pharmacist participation in pediatric medical emergencies, there are sufficient data regarding pediatric intensive care unit (PICU) pharmacists' impact on patient care, including the prevention of medication errors. A study reviewing the implementation of full-time, unit-based, clinical pharmacists in a PICU revealed a decrease in serious medication errors from 29 to 6 per 1000 patient days and the rate of intercepted near misses increased from 32 to 57 per 1000 patients.[8] Extrapolation of data regarding PICU pharmacists' impact on patient care and prevention of medication errors supports the utility of appropriately trained pharmacists in the care of critically ill pediatric patients experiencing cardiac arrest.

While pharmacists believe their expertise is needed, they often cite a perceived lack of training as a barrier to participating in medical emergencies.[6] PALS courses and institution-specific medical emergency training (MET) programs often lack explicit medication training (e.g., preparation, indications, operational pearls, prevention of medication errors) and focus on early recognition of signs of cardiac arrest, multidisciplinary team dynamics, and high-quality CPR. When surveyed, it was noted that pharmacists would feel comfortable if adequate training in pharmacist-specific tasks were provided.[6] The purpose of this study is to describe the outcomes observed during the implementation of a pediatric medical emergency training program (PedMET).

Methods

This quality improvement project was conducted at Johns Hopkins All Children's Hospital (JHACH), a 259-bed tertiary pediatric academic medical center. JHACH is composed of 163 intensive care unit (ICU) beds and became a certified pediatric trauma center in 2019. In anticipation of becoming a pediatric trauma center, requiring 24/7 medical emergency response by pharmacists, a needs assessment was conducted to evaluate pharmacists' familiarity with pediatric medical emergencies and the frequency of their attendance. The purpose of the program was to improve the confidence and preparedness of pharmacists responding to pediatric medical emergencies through the PedMET program.

Based on the results of the previously conducted needs assessment and recommendations from a position paper on requirements for PedMET programs from the *Journal of Pediatric Pharmacology and Therapeutics*,[2] a comprehensive lecture and simulation-based training programs were created with the expectation that all inpatient pharmacists were required to participate. The contents of the lecture are displayed in Table 1. Simulation-based training was designed to assess the pharmacists' competency in preparing simple intravenous (IV) medications (e.g., epinephrine, sodium bicarbonate, amiodarone, adenosine, endotracheal epinephrine for a Neonatal Resuscitation Program [NRP] patient) and complex medications, which include the preparation of a continuous epinephrine infusion and an epinephrine 10-mcg/mL dilution and are described in detail in Supplemental Figure. Simulations occurred in small groups, ranging from 1 to 4 participants, with 2 instructors. During the simulation, preparations were timed to ensure pharmacist preparation met institutional standards that dictate that the first dose of epinephrine be administered within 5 minutes of the onset of cardiac arrest. This expectation is extrapolated across all simple preparations. Additional competencies contained in the simulation training are listed in Table 1. Preprinted evaluation forms (Supplemental Figure) were used to assess participants on the various simulation competencies. If errors occurred during the simulation, the investigators provided immediate constructive feedback to all participating pharmacists, and the simulation was then repeated by the entire group regardless of which participant made an error. This approach was chosen to reinforce key concepts with all participants and allow extra practice with medication preparation.

Prior to and after the didactic lecture and simulation session, pharmacists completed a 15-item competency of clinical knowledge in operational and medication-related topics (Table 1). A clinical competency score of 80% or higher is required on the post-intervention competency for the pharmacist to participate in medical emergencies. Pharmacists achieving less than 80% on the post-intervention competency must re-attend the didactic lecture and reattempt the competency. The pharmacists also completed a pre- and post-training self-assessment to rate their confidence in preparing simple and complex medications during a medical emergency and their knowledge of resources, medication indications, and error-prevention tools. Confidence was rated on a 4-point Likert scale (1 = *strongly disagree*, 2 = *disagree*, 3 = *agree*, 4 = *strongly agree*) to avoid central-tendency bias. Each participant served as their own control. After the completion of the program, anonymous feedback was solicited from participants to identify areas of improvement for the program.

The primary objective of this study was to compare competency scores pre and post participation in the PedMET program. Secondary objectives included comparison of the percentage of participants who agreed or strongly agreed with statements related to confidence in preparing medications, knowledge of resources, and knowledge of error prevention tools pre and post participation in the PedMET program. An additional secondary objective was to describe the median time for preparation of medications and the most common errors that occurred during simulation.

All statistical analyses were performed with R version 4.1.2.[9] Categorical variables were summarized as counts with percentages and continuous variables were summarized as medians with IQRs (Q1–Q3). Given the paired nature of the data, statistical comparisons

Table 1. Pediatric Pharmacy Medical Emergency Training Program Contents

Comprehensive Lecture (2.5 hours)

- PALS algorithms
  - *Pediatric Bradycardia With a Pulse and Poor Perfusion Algorithm*
  - *Pediatric Cardiac Arrest Algorithm* including review of reversible causes ("H's & T's")
  - *Pediatric Tachycardia With a Pulse and Poor Perfusion Algorithm*
- Non-PALS emergencies including associated order sets and institution-specific pathways
  - Anaphylaxis
  - Hyperkalemia
  - MTP*
  - RSI
  - Status epilepticus
  - TBI*
  - Trauma*
- Medication information*
  - Dosing (pediatric and maximum doses)
  - Frequency of administration
  - Available concentration(s)
  - Administration including infusion times
  - Indication(s)
  - Labeling
  - Operational considerations including dispense locations
  - Preparation including aseptic technique
  - Preparation of dilutions
  - Preparation of continuous infusions
- Code medication tray
- Code cart*
- Institution's *Medical Emergency Response* policy including definitions (e.g., code blue, rapid response), team roles, and code cart locations
- Pharmacist expectations*
- Pharmacist responsibilities on arrival, during, and after medical emergency*
- Code sheet*
- PPE requirements*
- Incompatibility information
- NRP
- Electronic and institution-specific resources*
- Documentation requirements*
- Institution's *Pharmacy Department Disaster Response Plan*
  - Hazardous Materials/bioterrorism
  - Mass casualty incident
- Additional medication kits
  - Cardiac Transport Kit
  - Disaster Response Bag
  - ECMO kit
  - RSI kit*
  - Trauma box*
- Medication safety tools including closed-loop communication*
- Tour of ED including trauma bays, medication preparation stations, identification of ADCs, and supply stations
- Tour of OR including OR Pharmacy and identification of ADCs

Simulation (2 hours)

- Demonstrates an understanding of the code cart or kit and available contents*
- Identifies available electronic and institution-specific resources*
- Locates medications in code tray
- Identifies neonatal-, pediatric-, and adult-specific elements of the code sheet
- Understands the importance of error-prevention tools including closed-loop communication
- Understands medical emergency documentation requirements*
- Describes pharmacy post-code medication and equipment responsibilities*
- Demonstrates the preparation (including aseptic technique), appropriately labels, and provides indication(s) for the following medications:
  - Simple:
    - Epinephrine IV
    - Sodium bicarbonate IV
    - Amiodarone IV
    - Adenosine IV
    - ETT epinephrine for NRP patient
  - Complex:
    - Diluted epinephrine 10 mcg/mL for hypotension in a post-ROSC patient
    - Epinephrine drip for hypotension in a post-ROSC patient

Pre- and Post-Competency (15 minutes)

- Pharmacist requirements for emergency response*
- Pharmacist responsibilities*
- Error prevention tools
- PALS algorithms
- Non-PALS medical emergencies*
- Medication*
  - Dosing
  - Preparation
  - Indications
  - Administration
  - Labeling

ADC, automated dispensing cabinet; ECMO, extracorporeal membrane oxygenation; ED, emergency department; ETT, endotracheal; IV, intravenous; MTP, massive transfusion protocol; NRP, Neonatal Resuscitation Program; OR, operating room; PALS, Pediatric Advanced Life Support; PPE, personal protective equipment; ROSC, return of spontaneous circulation; RSI, rapid sequence intubation; TBI, traumatic brain injury

* Incorporated into Trauma Training Program.

between pre- and post-training assessments were evaluated with McNemar chi-square tests or exact tests for categorical variables and Wilcoxon signed rank test for continuous variables, with an alpha level of 0.05. Standards for QUality Improvement Reporting Excellence (SQUIRE) 2.0 was used to report findings.[10]

Results

Twenty-nine pharmacists participated in the PedMET program. Pharmacists' training levels varied and included 4 current postgraduate year (PGY)-2 pharmacy residents, 9 PGY-1 trained pharmacists, 6 PGY-2 trained pharmacists, and 10 pharmacists without residency training. Pharmacist years of experience, excluding 4 current residents, ranged from 1 to 40 years (>10 years: 12/25 [48%]; 5–10 years: 5/25 [20%]; <5 years: 8/25 [32%]). Only 6 pharmacists who participated in the program had ICU experience or considered ICU their primary practice. All pharmacists had previously received PALS training and most pharmacists had previously participated in the institution's multidisciplinary PedMET program and/or mock codes.

Clinical competency scores improved from a median (range) of 86% (67–100) to 97% (83–100) following the didactic lecture and simulation training (p value < 0.001). Pharmacists who agreed or strongly agreed in their confidence to prepare complex medications increased from 62 to 100% (p value = 0.001) following the intervention. Pharmacists who agreed or strongly agreed in their confidence to prepare simple medications, knowledge of resources, and knowledge of medication indications all improved following intervention but did not reach statistical significance. All pharmacists agreed or strongly agreed they were confident in their use of error-prevention tools pre and post intervention. Results from the competency and self-assessment can be found in Table 2.

For the simulation, all participants prepared simple medications in less than 5 minutes, which is within the institution's standard time for the preparation and administration of epinephrine. Complex preparations had a median preparation time of 4.75 and 5.55 minutes for diluted epinephrine 10 mcg/mL and continuous epinephrine infusion, respectively. Simulation preparation times are depicted in Figure 1. The most frequent errors during simulation were incorrect volumes (31% of pharmacists), inappropriate labeling of the final product (28% of pharmacists), and inappropriate preparation (24% of pharmacists). Inappropriate preparation errors were often the omission of aseptic technique (e.g., swabbing vial tops prior to needle insertion). Excluding aseptic technique and labeling errors, 10 pharmacists (34%) made 1 error, 2 pharmacists (~7%) made 2 errors, and 1 pharmacist (~3%) made 3 errors

Table 2. Competency and Self-Assessment, Pre- vs Post-Training Program

	Pre/Post		
Variable	**Pre, N = 29***	**Post, N = 29***	**p value†**
Competency score (out of 100%)			<0.001
Median (IQR)	86 (80–94)	97 (94–100)	
Range	67–100	83–100	
Confidence in their ability to prepare simple medications during medical emergencies			0.13
Strongly agree/Agree	25 (86%)	29 (100%)	
Strongly disagree/Disagree	4 (14%)	0 (0%)	
Confidence in their ability to prepare complex medications during medical emergencies			0.001
Strongly agree/Agree	18 (62%)	29 (100%)	
Strongly disagree/Disagree	11 (38%)	0 (0%)	
Confidence in their knowledge of available resources and how to use resources during medical emergencies			0.13
Strongly agree/Agree	25 (86%)	29 (100%)	
Strongly disagree/Disagree	4 (14%)	0 (0%)	
Knowledge of which medications will be requested for commonly seen medical emergencies			0.07
Strongly agree/Agree	22 (76%)	28 (97%)	
Strongly disagree/Disagree	7 (24%)	1 (3.4%)	
Knowledge and confidence in using error-prevention tools			–
Strongly agree/Agree	29 (100%)	29 (100%)	

* n (%).
† Wilcoxon signed rank test; McNemar exact test.

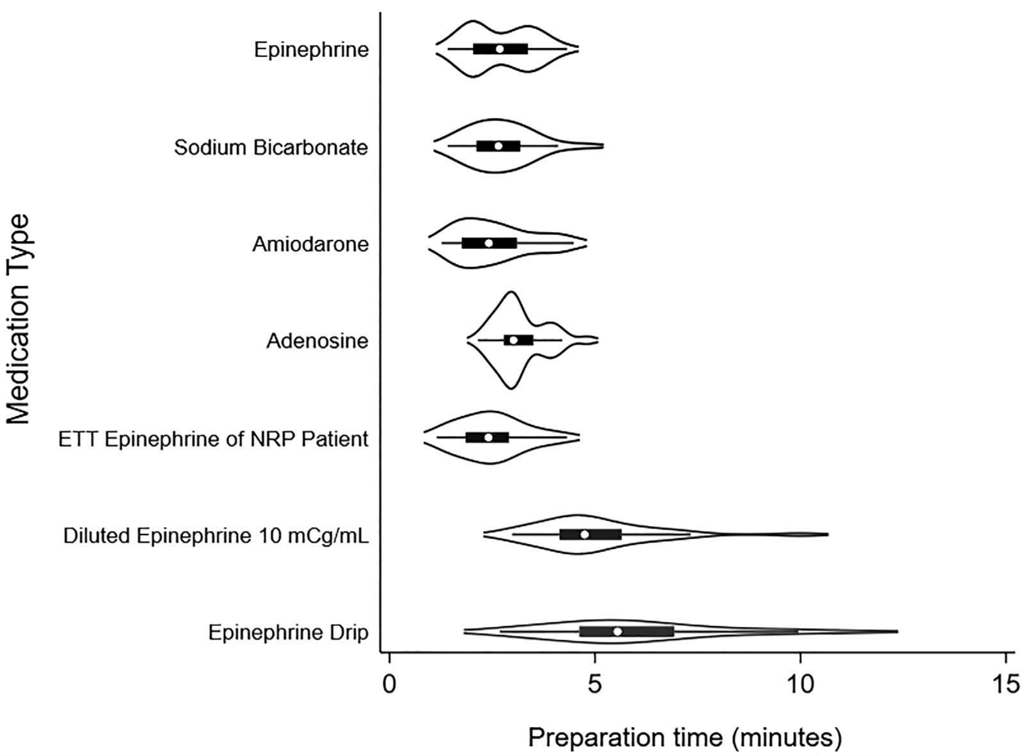
that would have resulted in an incorrect dose given to the patient. Figure 2 shows the percentage of pharmacists who made each error. The medications that had the most frequent errors during preparation were amiodarone, diluted epinephrine, and endotracheal epinephrine for an NRP patient. Amiodarone errors were primarily associated with the omission of aseptic technique during preparation. Diluted epinephrine errors were secondary to pharmacists choosing the wrong concentration of epinephrine to make the dilution, making the incorrect dilution concentration, or preparing an incorrect final dose for the patient (1 mcg/kg/dose). Lastly, endotracheal epinephrine errors were frequently associated with incorrect labeling of the final product (e.g., using preprinted labels) or using the wrong epinephrine concentration than required in NRP, 1 mg/mL instead of 0.1 mg/mL. All errors were immediately addressed by the investigators with the provision of constructive feedback and the simulation was then repeated by all participants.

Each participant was required to submit an anonymous evaluation after the completion of the PedMET program. Investigators reviewed participant feedback to improve the program following each session. Most of the feedback was positive including "it was very helpful and made me more comfortable to attend codes at our facility" and "both the lecture and hands-on experience were very helpful and improved my confidence." The remaining constructive feedback was used to improve the PedMET program (see Discussion).

Discussion

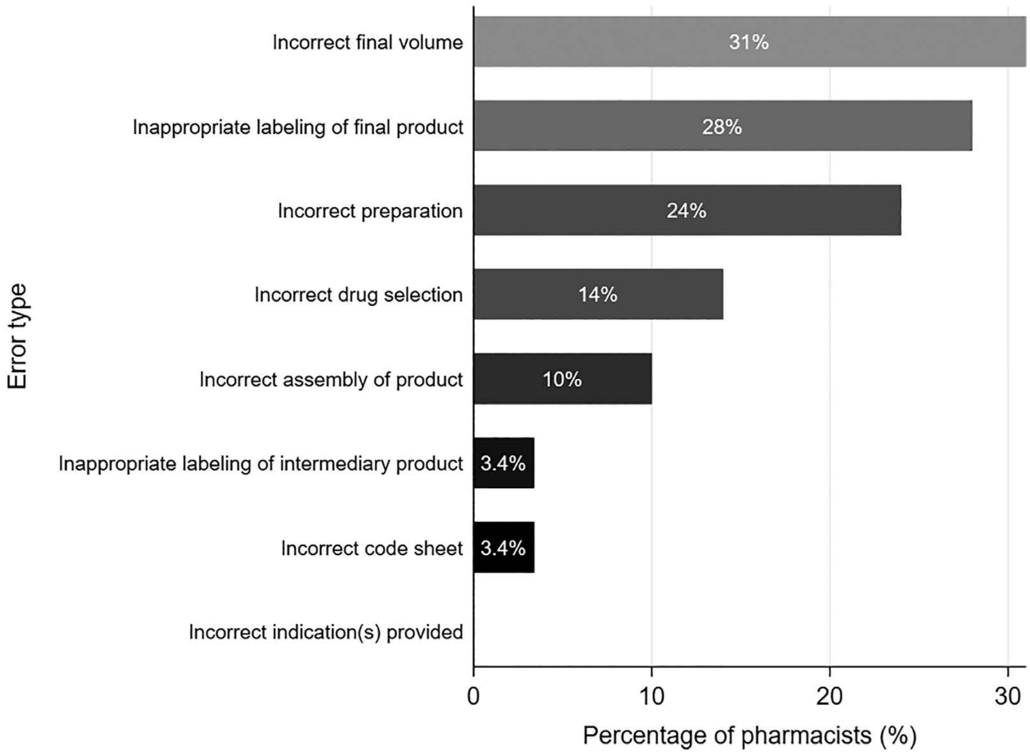
It is perceived by many pharmacists that inadequate training and the resulting lack of confidence hinder participation in medical emergencies. As previously mentioned, PALS courses and institution-specific MET programs often lack explicit medication training or pharmacist-specific training. This sentiment was also expressed by pharmacists in our needs assessment and post-training feedback. Pharmacist training programs exist that focus on medical emergency response for adult patients. However, there is limited information detailing training programs for pharmacists responding to pediatric medical emergencies. Marlowe and Woods[11] conducted a trial at a 235-bed, tertiary-care pediatric hospital, examining pharmacists' knowledge and comfort level in participating in pediatric medical emergencies. After an education session, competency increased on average by 13.8% and comfort levels improved in 8 of 20 items examined. Small et al[12] conducted a similar, voluntary program with 19 pharmacists at a pediatric teaching hospital. Following a computer-based

Figure 1. Simulated medication preparation times.



ETT, endotracheal; NRP, Neonatal Resuscitation Program.

Figure 2. Error types during simulation (N = 29).



education session and simulated resuscitation events, pharmacists' confidence levels increased on average by 14.5% and competency increased on average by 11%. Similar to the aforementioned studies, pharmacists' confidence and knowledge increased after the implementation of the pharmacist PedMET program at JHACH. This was displayed not only in the improvement of self-assessments and clinical competency scores but also in direct feedback from the pharmacists.

Resuscitation events are high-stress environments where timeliness and efficiency are crucial. This potentiates the risk of medication errors that are more likely to result in patient harm or death.[6,13] The most common medication errors that occur during resuscitation events include administration, dosing, omission, preparation, and selection errors. Commonly reported contributing medication factors include look-alike product packaging or drug names, drug shortages, confusing or missing information about medications, dispensing device problems, and multiple concentrations.[13] Environmental factors that contribute to medication errors include code carts lacking standardization or organization, excessive stock in code carts, distractions, poor communication, reliance on human calculations, guideline deviations, and inexperienced staff.[13] In a retrospective analysis conducted from registry data including pediatric and adult facilities, 842 medication errors were documented during resuscitation events.[14] Medication errors were 39 times more likely to result in harm and 51 times more likely to result in death than non–code-related medication errors.[14]

Ludwig and Abramowitz[15] reported that multidisciplinary team members value the pharmacist's mechanical and organizational contributions during an emergency event, as well as provision of drug information and overall contributions to the team. In a multidisciplinary survey assessing the addition of pharmacists to an emergency response team, most respondents agreed or strongly agreed that pharmacists improved teamwork, decreased medication turnaround time, and may have prevented a poor outcome.[16] Additionally, 66.7% of survey respondents agreed or strongly agreed that pharmacists decreased medication errors during emergency events.[16] Similar to other health care providers, most pharmacists agree that participation in medical emergencies is an appropriate use of their time and that their participation in the multidisciplinary team may prevent poor outcomes.[15]

By providing a comprehensive PedMET program at JHACH, it is believed that pharmacists are more knowledgeable and confident in their participation in medical emergencies. This results in more experienced staff participation in medical emergencies and therefore the potential reduction in medication errors and improved patient outcomes. Overall, pharmacists' feedback on the program was positive, and pharmacists' confidence increased based on the post-intervention self-assessment and program evaluation. Based on the constructive feedback from the evaluation, slides within the comprehensive lecture were updated to include pictures of the preparation of complex medications (e.g., continuous infusions, diluted epinephrine 10 mcg/mL), and pictures of appropriate medication labeling. Another incorporated recommendation includes creating a mock code medication tray, rapid sequence intubation (RSI) kit, and trauma box.

Limitations. This PedMET program was implemented at 1 institution and therefore may not apply to all inpatient hospital settings. All JHACH pharmacists are required to have PALS certification and complete institution-required training during orientation, which may limit the external validity in non-freestanding pediatric institutions. Time since PALS and institution-specific MET varied among participants, which may influence pre-intervention clinical competency scores. There is a possibility of recall bias because the same 15-item clinical competency was used before and after the intervention. Of note, the correct responses were not revealed to participating pharmacists until after the completion of the program.

Barriers exist surrounding the implementation of an in-depth, pharmacist-specific PedMET program including staffing models, inadequate staffing, apprehension of pharmacy staff, and the multidisciplinary team's perception of the utility of pharmacists during medical emergencies.[2] Implementation of the training program is time-consuming and requires dedicated staff, which may limit the application. Two investigators were required to adequately assess 1 to 4 participants during the simulation sessions. The didactic lecture and simulation totaled approximately 5 hours of instruction, which occurred on 2 consecutive days. Additionally, simulated products were used and occasionally malfunctioned, which potentially prolonged the preparation times of medications although all simple preparations met time constraints per institutional standards.

Future Directions and Considerations. Since the implementation of the pharmacist PedMET program at JHACH, additional competencies and educational services were created to provide pharmacists with ongoing education and hands-on experiences with medical emergencies. This includes the creation of a computer-based annual competency that contains the original PedMET program's content and addresses changes regarding medical emergencies that occurred in the last year such as changes to guidelines, institutional policies, and the availability of medications (e.g., removal or addition to kits, shortages). Accompanying the annual competency is an assessment of clinical knowledge and medication preparation simulations using non-PALS emergency scenarios.

An unexpected addition to the pharmacist PedMET program was the need for a remediation program for pharmacists who do not achieve all simulated medication preparation competencies. The remediation program uses 4 PALS scenarios (asystole/pulseless electrical activity, ventricular fibrillation, bradycardia with cardiorespiratory compromise, supraventricular tachycardia) to assess the pharmacist's knowledge of algorithms, medication indications, and appropriate medication preparation. Pharmacists were additionally evaluated on the appropriate preparation of diluted epinephrine 10 mcg/mL and a continuous epinephrine infusion. Failure to pass the remediation program results in the pharmacist's inability to attend medical emergencies.

To decrease the amount of information discussed during PedMET, a separate trauma training program was created following the same format as PedMET. The trauma training program lecture and simulation equates to 1.5 hours of instruction. The didactic lecture reiterates many of the topics discussed during the PedMET lecture (annotated in Table 1) and includes a review of trauma clinical pathways and order sets, massive transfusion protocols, traumatic brain injury, burns, fluid resuscitation, pain management, and antimicrobial prophylaxis for open fractures. The trauma simulations include preparing calcium chloride, cefazolin, mannitol, and continuous phenylephrine infusion.

The Pediatric Pharmacy Association (PPA) recommends that pediatric pharmacists who participate in medical emergencies, including residents, maintain appropriate credentials based on their practice area (e.g., PALS, Advanced Cardiac Life Support, NRP).[2] Additional training recommendations by PPA include quarterly mock code participation for residents and annual mock code participation for pharmacists, and all residents and new pharmacists should respond to emergencies alongside experienced pharmacists.[2] It remains uncertain how often a comprehensive program should be completed, particularly for pharmacists who only occasionally respond to pediatric emergencies.

The following recommendations may be beneficial prior to the implementation of an institution-specific pharmacist PedMET program. Pharmacy leadership should be included to determine the needs of the institution and can assist in scheduling training sessions as this is a time-intensive process. Pharmacists' participation in institutional medical emergency committees can help optimize and standardize emergency algorithms and guidelines, weight-based references, code carts, and code medication trays.[2] Pharmacists should continue to participate in institutional, multidisciplinary MET and mock codes if available and participate in ongoing quality improvement in an effort to enhance current practices.[2] Additional recommendations include simplifying content in the program to prevent the inundation of complex, noneffective information and conducting a needs assessment to identify strengths and deficiencies within the current practice model. To compensate participants for time dedicated to program completion, consider providing continuing education and/or an institutional certificate. Other considerations include providing employee resources for mental well-being and debriefing following pediatric medical emergencies.

Conclusion

Following the implementation of didactic and simulation-based training, pharmacist knowledge and confidence regarding pediatric medical emergencies increased. Departments of pharmacy should consider implementing pharmacist-specific training programs for all pharmacists who respond to pediatric medical emergency events.

Article Information

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Ethical Approval and Informed Consent. Given the nature of this study, it was exempt from Institutional Review Board approval and informed consent was not required.

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