The Spectrum and Frequency of Critical Procedures Performed in a Pediatric Emergency Department: Implications of a Provider-Level View

Matthew R. Mittiga, MD; Gary L. Geis, MD; Benjamin T. Kerrey, MD, MS; Andrea S. Rinderknecht, MD

Study objective: We seek to provide current, comprehensive, and physician-level data for critical procedures performed in a high-volume pediatric emergency department (ED).

Methods: We conducted a retrospective study of all critical procedures performed in the ED of a tertiary care pediatric institution. Data were collected from written records of resuscitative care provided. The primary outcome measure was the cumulative frequency of each critical procedure during 12 consecutive months. Additional outcome measures included the number of critical procedures performed by pediatric emergency medicine faculty and fellows and a description of the other physician types performing each procedure.

Results: Two hundred sixty-one critical procedures were performed during 194 patient resuscitations, which represented 0.22% of all ED patient evaluations. Sixty-one percent of pediatric emergency medicine faculty did not perform a single critical procedure. Orotracheal intubation occurred 147 times and represented 56% of all critical procedures, yet 63% of pediatric emergency medicine faculty did not perform a single successful orotracheal intubation. Pediatric emergency medicine fellows performed a median of 3 critical procedures.

Conclusion: Critical procedures were rarely performed in a large, academic pediatric ED. Pediatric emergency medicine faculty are at significant risk for skill deterioration, and pediatric emergency medicine fellows are unlikely to achieve competence in the performance of critical procedures if clinical exposure is the sole basis for the attainment and maintenance of skill. [Ann Emerg Med. 2013;61:263-270.]

Please see page 264 for the Editor's Capsule Summary of this article.

A **feedback** survey is available with each research article published on the Web at www.annemergmed.com.
A **podcast** for this article is available at www.annemergmed.com.

0196-0644/$-see front matter

http://dx.doi.org/10.1016/j.annemergmed.2012.06.021

SEE EDITORIAL, P. 279

INTRODUCTION

Background

Diagnostic and therapeutic procedures are an integral part of the practice of pediatric emergency medicine, particularly for critically ill or injured children. Some, such as intubation and cardiac defibrillation, are lifesaving. The ability to obtain intraosseous or central venous access is critical when traditional peripheral intravenous catheter placement fails. Needle thoracostomy, tube thoracostomy, or pericardiocentesis may be required in the resuscitation of multisystem trauma.

A survey of physicians working in general community emergency departments (EDs) found that 25% of respondents were uncomfortable performing these potentially lifesaving procedures on children.[1] In a survey of pediatric ED medical directors, 62% judged the number of intubation opportunities to be inadequate for their providers to maintain competency.[2] In a recent study of 114 children undergoing rapid sequence intubation in the pediatric ED of our institution, we reported that 48% experienced failure of the first intubation attempt, with the first-attempt failure of trainees being particularly high.[3] As noted in the editorial published with that study, the infrequency with which intubation is performed in a pediatric ED may be a primary contributor to the higher frequency of first-attempt failure.[4]

A number of studies have reported the relative low acuity level of pediatric ED patients, with only 2.5 of every 1,000 pediatric ED patients requiring significant resuscitative efforts.[5-11] Few studies, however, have attempted to quantify the number and type of critical pediatric procedures performed in the pediatric ED setting. A nearly 20-year-old review of 183 pediatric cardiopulmonary and trauma resuscitations during a 17-month period found 106 intubations, 44 intraosseous line placements, 46 central venous line placements, 5 tube thoracostomies, and 4 instances of defibrillation or cardioversion.[5] A more recent review of 304 resuscitations in a tertiary level pediatric ED in Canada found 58 intubations, 7

Editor's Capsule Summary

What is already known on this topic

Critical illness is far less common in children than in adults.

What question this study addressed

What is the critical care procedural exposure in a pediatric emergency department (ED)?

What this study adds to our knowledge

In this retrospective analysis at a busy children's hospital ED, pediatric emergency medicine fellows performed a median of 3 critical care procedures annually, with some performing none. During the study year, most faculty performed no such procedures.

How this is relevant to clinical practice

Critical care procedural experience during direct patient care in a pediatric ED may be insufficient to ensure competency for trainees.

intraosseous line placements, 7 central venous line placements, and 2 tube thoracostomies during a 2-year period.[7] The 20-year-old review may not be an accurate reflection of the current practice of pediatric emergency medicine, and the more recent study included only patients who were admitted to the pediatric ICU or who died in the pediatric ED, possibly underestimating the number and scope of critical procedures that are performed. The more significant limitation of both studies is the absence of an individual physician-level view of procedural experience.

Importance

Emergency physicians must be competent in the performance of critical procedures associated with pediatric resuscitation. It has traditionally been assumed that the clinical practice of pediatric emergency medicine is sufficient for the acquisition and maintenance of these skills. If the relative low acuity of the pediatric emergency medicine patient population provides inadequate opportunity, there is a risk that procedural skills will not be acquired by trainees or maintained by faculty. An accurate description of the frequency with which faculty and trainees perform critical procedures in a pediatric ED would allow for more informed discussion and targeted interventions to reduce this risk.

Goals of This Investigation

We hypothesized that even in a high-volume pediatric ED, the overall frequency of critical procedures would be very low and the exposure of individual providers to critical procedures negligible. The objective of this study was to provide current, comprehensive, and provider-level data for the critical procedures performed in a pediatric ED.

MATERIALS AND METHODS

Study Design and Setting

This study was a retrospective review of existing medical records and was approved by our institutional review board before commencement. The setting was the ED of a free-standing tertiary-care children's hospital, which is the major regional provider of emergency care to children and has approximately 90,000 annual visits. In this ED, critically ill or injured patients are evaluated and managed in one of 4 resuscitation bays by a resuscitation team, which includes emergency physician and nurse team leaders, a pediatric or emergency medicine resident, several bedside nurses, and a respiratory therapist. The resuscitation team is activated through a paging system, and the pager for the physician team leader is held by board-certified pediatric emergency medicine faculty or a second- or third-year pediatric emergency medicine fellow. For critically injured patients, the team also includes a general surgery resident, a surgical fellow or faculty, and providers from anesthesiology. Because a portion of these patients require admission to an ICU, fellows from neonatology, pediatric critical care, and pediatric cardiology augment the team as indicated.

The pediatric emergency medicine fellowship at our institution consists of 3 years of training. The first 2 years are entirely clinical, with the fellows working all shifts under direct faculty supervision, except for 10 overnight shifts that each second-year fellow works independently in preparation for the third year. The third year of fellowship is devoted mainly to research, with fellows also working independently in the ED as junior faculty. Our institution is also associated with a large 3-year pediatric residency program, which trains 36 categorical and 19 noncategorical pediatric residents per year. Residents from a neighboring 4-year emergency medicine residency program, which trains 12 residents per year, also rotate through our ED. Every month, approximately 16 pediatric residents and 4 emergency medicine residents rotate through the ED.

Selection of Participants

Our study sample was obtained from all patients, medical and trauma, who were evaluated in one of the ED resuscitation bays during 12 consecutive months. Any of these patients who had a critical procedure performed while in a resuscitation bay was eligible for inclusion. Few, if any, critical procedures are performed outside of the resuscitation bays in our ED.

Methods of Measurement

Using electronic tracking resources, we identified all patients evaluated in the resuscitation bays during the study period, and a database was prepopulated from our institution's electronic medical record with patient demographics, ED disposition (admission, discharge, transfer, or death), and diagnosis. A study investigator (M.R.M., B.T.K., or A.S.R.) then reviewed the medical records of these patients to gather further data, including resuscitation type (medical or trauma), the pediatric emergency medicine faculty provider responsible for each case,

and all critical procedures performed. A standardized electronic form was used for all data abstraction. The primary data source was the handwritten record completed by the nurse team leader in real time during the resuscitation. Additional sources for data collection included physician procedure notes and other physician documentation. Our methods conformed to all aspects of a published guideline for studies based on chart review, except that the primary data abstractors (M.R.M., B.T.K., and A.S.R.) were not blinded to the study objective.[12]

We defined critical procedures according to the pediatric emergency medicine Fellowship Curriculum Statement on lifesaving procedural skills and the Core Content for Emergency Medicine.[13,14] Critical procedures included pharmacologic cardioversion, electrocardioversion, defibrillation, external cardiac pacing, nasotracheal intubation, orotracheal intubation, needle cricothyroidotomy, needle thoracostomy, tube thoracostomy, pericardiocentesis, diagnostic peritoneal lavage, thoracentesis, arterial line placement, venous cutdown line placement, intraosseous line placement, and central venous line placement. Pharmacologic cardioversion was defined as the administration of an intravenous antiarrhythmic medication in an attempt to terminate an arrhythmia. It was included as a critical procedure because of the potential associated complications of antiarrhythmic medication administration, including prolonged asystole, deterioration to ventricular fibrillation, or severe hypotension, and because treatment of pediatric arrhythmias and proper administration of antiarrhythmic medications are points of emphasis in the American Heart Association pediatric advanced life support guidelines.

After all critical procedures were identified by the initial review of each patient's medical record, one investigator (M.R.M.) collected additional data, including the specialty and level of training of the provider who successfully performed each procedure, the pediatric emergency medicine faculty responsible for the care of that patient, and involvement of a pediatric emergency medicine fellow. In rare cases in which the nursing documentation of who performed a procedure differed from physician documentation, the data point was abstracted from the physician documentation (physician procedure note or other physician documentation).

Outcome Measures

Our primary outcome measure was the cumulative frequency of each critical procedure during 12 consecutive months. Additional outcome measures included the performance of each procedure by pediatric emergency medicine faculty, pediatric emergency medicine faculty supervision of each critical procedure, pediatric emergency medicine fellow performance and exposure to each critical procedure, and a description of the physician types performing each critical procedure. We defined performance of a critical procedure as successful completion; we did not include unsuccessful attempts. The number performed by each provider type during 12 months is reported as a median along with a range. We defined supervision as being the pediatric emergency medicine faculty of record for a patient on whom the critical procedure was performed. If the pediatric emergency medicine faculty performed the procedure on the patient for whom they were the attending physician of record, credit was given for performance only and not supervision. Third-year pediatric emergency medicine fellows work independently as junior faculty and were counted as such. The rate of opportunity for performance or supervision of a procedure was calculated by dividing the number of hours pediatric emergency medicine faculty carry the team leader pager each year (8,760 hours) by the number of each procedure type, yielding a projected number of hours that faculty would have to carry the pager to perform or supervise each procedure once. For pediatric emergency medicine fellows, exposure to a critical procedure was defined as having performed the procedure or having direct involvement in the care of the patient undergoing the procedure, whether as the supervisor or while working under a pediatric emergency medicine faculty supervisor. In our setting, cardioversion and defibrillation require the coordinated effort of multiple members of the resuscitation team, with the physician team leader's primary role focusing on the cognitive aspects of care. Therefore, credit was not assigned to an individual provider for performance of these procedures. Rather, we report only pediatric emergency medicine faculty supervision and pediatric emergency medicine fellow exposure for cardioversion and defibrillation.

Primary Data Analysis

We tabulated all data and generated descriptive statistics for all outcomes and data elements of interest. To assess the reliability of primary data abstraction, a trained research assistant, blind to the study objective, repeated data collection, focusing on the identification of critical procedures for 10% of eligible patient charts.

RESULTS

From April 1, 2009, through March 31, 2010, 3,067 evaluations were performed on medical and trauma patients in the resuscitation bays. Two hundred sixty-one critical procedures were performed during 194 evaluations, representing 6.3% of all resuscitation bay evaluations and 0.22% (2.2/1,000) of all ED patient evaluations during the study period. Table 1 summarizes our primary outcome, the critical procedures performed during the 12-month study period, stratified by resuscitation type. During 17 resuscitations, 3 or more critical procedures were performed. The maximum number of critical procedures performed during a single resuscitation was 7. Resuscitative thoracotomy, although not a priori defined as a critical procedure, was performed once by a surgeon during a trauma resuscitation. The single episode of pericardiocentesis was performed during this same trauma resuscitation before the resuscitative thoracotomy. The following procedures were not documented for any subject during the study period: external cardiac pacing, nasotracheal intubation, needle

Table 1. Critical procedures performed during 194 pediatric ED patient resuscitations during 12 months.

	Resuscitation Type		
Procedure	**Medical (n=147)**	**Trauma (n=47)**	**Total (n=194)**
Orotracheal intubation	114	33	147
Intraosseous line placement	32	9	41
Pharmacologic cardioversion	23	0	23
Tube thoracostomy	6	12	18
Central venous line placement	9	6	15
Needle thoracostomy	2	7	9
Electrocardioversion	6	0	6
Defibrillation	1	0	1
Pericardiocentesis	0	1	1
Total	193	68	261

cricothyroidotomy, diagnostic peritoneal lavage, thoracentesis, arterial line placement, and venous cutdown line placement.

During the study period, 41 pediatric emergency medicine faculty were on staff. Faculty performance and supervision of critical procedures are summarized in Table 2. Sixty-one percent of pediatric emergency medicine faculty did not perform a single critical procedure; no faculty provider performed more than 6 total critical procedures. Twenty-six faculty (63%) did not perform a single successful orotracheal intubation, the most common critical procedure; 10 (24%) performed it 1 to 2 times and 4 (10%) performed it 3 to 4 times; 1 faculty member performed 5 orotracheal intubations. Table 3 displays an estimation of the amount of time the physician team leader pager would need to be carried for a physician to perform or supervise each critical procedure once. If the 194 patient resuscitations during which a critical procedure was performed were spaced evenly during the course of 12 months, a pediatric emergency medicine faculty physician would require nearly 6 eight-hour shifts to supervise 1 resuscitation during which at least 1 critical procedure was performed.

During the study period, 10 physicians were enrolled in the clinical portion of the pediatric emergency medicine fellowship. Table 4 shows both pediatric emergency medicine fellow performance of and exposure to critical procedures. Of the 42 critical procedures performed by pediatric emergency medicine fellows, 28 (67%) were performed during the first year of fellowship.

Other physician types who performed critical procedures in the ED are listed in Table 5. Seventy-one critical procedures (27% of all critical procedures) were performed by non–emergency medicine specialties (surgery, anesthesiology, pediatric critical care, neonatology, and otolaryngology), the most common being orotracheal intubation (42/147, or 29% of all ED intubations). Eleven of 15 central venous line placements that occurred in the ED were performed by non-ED-based specialists.

Among the 305 charts reviewed by the trained research assistant to assess reliability in data abstraction, only 1 critical procedure (intraosseous line placement) was identified that was not found during primary data collection.

LIMITATIONS

Our study has several limitations. First, beyond extensive chart review, we used no additional method to ensure that all relevant cases were included. However, in a published study of rapid sequence intubation in which redundant methods of identification were used, we found that our chart review methods identified 122 of 123 intubations. If this proportion of successful identification of critical procedures from chart review is extrapolated to all procedures in our study, the likelihood of excluding a significant number of relevant cases is small. Additionally, if these missed procedures are then divided over the number of faculty and fellows in our study, the potential change in provider-level results is negligible.

Second, the validity of data collected from the written record is subject to the incompleteness and inaccuracies inherent to this source. We believe that it is unlikely that any critical procedure, if successfully completed, would be undocumented. However, we suspect that certain procedures, such as arterial line or central venous line placement, were rarely documented if attempted but not successfully completed. Given the paucity of documentation in the medical record for unsuccessful attempts, we have not included these in our study. We acknowledge that learning can occur during unsuccessful attempts, and our inability to identify or describe them may underestimate the true experience of providers. We were also unable to reliably assess bedside presence of the attending physician or fellow during the procedure from chart review. However, in our experience, unless another critically ill patient arrives simultaneously, the fellow does not leave the bedside of a patient undergoing a critical procedure, in part because of the rarity and perceived educational benefit of this type of exposure and in part because it is an expectation during the clinical rotation.

Third, the primary chart abstractors were not blinded to the purpose of the study. However, the study outcomes were straightforward, and reliability of data abstraction was high.

Fourth, we did not attempt to quantify the frequency with which bag-valve-mask ventilation or chest compressions were performed. We acknowledge that these skills are critical during resuscitation; however, they are often performed by nonphysicians in our ED and are not documented as procedures in the medical record.

Fifth, our study was conducted at a single, academic pediatric center, which may limit generalizability of our findings to other ED settings.

DISCUSSION

The ability to competently perform critical procedures for ill or injured pediatric patients is essential to delivering the highest level of care, ensuring patient safety, and providing the optimal education to trainees. We present comprehensive data

Table 2. Pediatric emergency medicine faculty (n=41) exposure to critical procedures during 12 months.

	Performance			Supervision			Exposure Faculty Performing or Supervising at Least 1, %
Procedure	Median	Range	Faculty Performing at Least 1, %	Median	Range	Faculty Supervising at Least 1, %	
Any critical procedure	0	0–6	39	4	0–17	98	98
Orotracheal intubation	0	0–5	37	2	0–12	88	90
Intraosseous line placement	0	0–2	20	0	0–4	41	43
Central venous line placement	0	0–1	5	0	0–2	27	32
Needle thoracostomy	0	0	0	0	0–2	12	12
Tube thoracostomy	0	0–1	2	0	0–2	37	39
Pharmacologic cardioversion	*	*	*	0	0–4	32	32
Electrocardioversion	*	*	*	0	0–2	12	12
Defibrillation	*	*	*	0	0–1	2	2
Pericardiocentesis	0	0	0	0	0–1	2	2

*Credit was not assigned to an individual provider for performance of the procedure because cardioversion and defibrillation in our setting are carried out by a multidisciplinary team, with the physician's primary role focusing on cognitive aspects such as timing and delivery of medications or energy. We report supervision only for these procedures.

Table 3. Projected clinical hours* for pediatric emergency medicine faculty (n=41) to perform or supervise a successful critical procedure.

	Performance		Supervision	
Procedure	Clinical Hours	8-Hour Shifts	Clinical Hours	8-Hour Shifts
Orotracheal intubation	292	36	73	9
Intraosseous line placement	876	109	258	32
Central venous line placement	4,380	547	674	84
Needle thoracostomy†	—	—	973	122
Tube thoracostomy	8,760	1,095	487	61
Pharmacologic cardioversion	‡	‡	381	48
Electrocardioversion	‡	‡	1,460	182
Defibrillation	‡	‡	8,760	1,095
Pericardiocentesis†	—	—	8,760	1,095

—, procedure was not performed by any pediatric emergency medicine faculty during the study period; therefore, a calculation of projected clinical hours was not possible.
*Represents time holding the team leader pager.
†Procedure not performed by any pediatric emergency medicine faculty during the study period.
‡Credit was not assigned to an individual provider for performance of the procedure because cardioversion and defibrillation in our setting are carried out by a multidisciplinary team, with the physician's primary role focusing on cognitive aspects such as timing and delivery of medications or energy. We report supervision only for these procedures.

Table 4. Pediatric emergency medicine fellow (n=10) performance of and exposure to critical procedures during 12 months.

Procedure	Median Number Performed	Range	Fellows Performing at Least 1, %	Fellows Exposed to at Least 1, %*
Any critical procedure	3	0–9	90	90
Orotracheal intubation	2.5	0–9	90	90
Intraosseous line placement	0.5	0–2	50	90
Central venous line placement	0	0	0	60
Needle thoracostomy	0	0	0	30
Tube thoracostomy	0	0–1	30	60
Pharmacologic cardioversion	†	†	†	50
Electrocardioversion	†	†	†	10
Defibrillation	†	†	†	10
Pericardiocentesis	0	0	0	10

*Exposure is defined as having performed the procedure or being directly involved in the care of a patient on whom the procedure was performed.
†Credit was not assigned to an individual provider for performance of the procedure because cardioversion and defibrillation in our setting are carried out by a multidisciplinary team, with the physician's primary role focusing on cognitive aspects such as timing and delivery of medications or energy. We report exposure only for these procedures.

establishing the spectrum and frequency of critical procedures performed in a high-volume, academic pediatric ED. More important, to our knowledge we present the first provider-level view about experience with these procedures in this setting. Our data reveal that in a large, academic pediatric ED, critical procedures are infrequent and pediatric emergency medicine faculty and fellows rarely perform any critical procedure. Our results raise 3 important questions: (1) can pediatric emergency

Table 5. Performance of critical procedures by physician type.*

Provider	Orotracheal Intubation	Intraosseous Line Placement	Central Venous Line Placement	Needle Thoracostomy	Tube Thoracostomy	Total
PEM faculty	30	10	2	0	1	43
PEM fellow	32	7	0	0	3	42
Pediatric resident	26	8	0	0	1	35
EM resident	16	4	1	2	2	25
Pediatric ICU fellow	19	0	7	0	0	26
Surgery†	0	4	4	3	9	20
Anesthesia	21	1	0	0	0	22
Other subspecialist‡	2	0	0	0	0	2
Unknown	1	7	1	4	2	15
Total	147	41	15	9	18	230§

PEM, Pediatric emergency medicine.
*Cardioversion and defibrillation were excluded because in our setting those procedures are carried out by the multidisciplinary team, with the physician's primary role focusing on cognitive aspects such as timing of delivery of medications or energy.
†One pericardiocentesis was performed by a pediatric surgeon.
‡One neonatology fellow and 1 otolaryngology resident.
§Excludes 23 pharmacologic cardioversions, 6 electrocardioversions, 1 defibrillation, and 1 pericardiocentesis.

medicine faculty successfully maintain critical procedural skills through clinical experience alone?; (2) can pediatric emergency medicine fellows reliably achieve competence in the performance of these procedures through clinical experience alone?; and (3) what proportion of these procedures should be attempted initially by pediatric emergency medicine faculty to maintain competence?

The frequency with which critical procedures are performed in our pediatric ED (0.22% of ED evaluations) is similar to that of previous reports.[5] However, when the data are presented from the novel perspective of the individual provider, the rarity is greatly magnified. Nearly two thirds of our faculty did not perform a single critical procedure during the 12-month study period. Although orotracheal intubation was the most common critical procedure performed, accounting for more than half of all critical procedures, 63% of pediatric emergency medicine faculty did not perform a single successful intubation in an entire year of practice.

Faculty performance was the primary focus of our study because, as junior faculty who have completed a fellowship at a large, academic institution, we are concerned about our procedural experience and that of our peers both during and after fellowship. It has long been assumed that we perform or teach about these procedures frequently enough during clinical care to be reliably successful performing them when necessary and to be adequate instructors for learners who are attempting to master these skills. The true frequency with which individual faculty perform these procedures after training has heretofore been unknown. Families expect the provision of a certain level of care when presenting to an ED with a critically ill or injured child. There may be up to a 61% chance that the critical procedure that a child may require has not been practiced clinically in the preceding 12 months by the senior physician in the room. To our knowledge, there is no peer-reviewed literature that quantifies faculty procedural performance and no information on what is actually required to maintain procedural skill.

Although the 10 pediatric emergency medicine fellows performed as many critical procedures as the 41 faculty, no fellow performed a central venous line placement, needle thoracostomy, or pericardiocentesis in the pediatric ED during the study period. Only half of the fellows performed an intraosseous line placement, and just 30% performed a tube thoracostomy. Fellows performed a median of 2.5 orotracheal intubations compared with a faculty median of zero, but 40% of the fellows performed 1 or fewer. The adult anesthesia literature suggests that approximately 50 to 60 intubations are required to achieve competence.[15-17] To our knowledge, similar estimates are not available for any pediatric critical procedures. If the number of procedures performed by pediatric emergency medicine fellows in our 12-month study were projected over a 3-year fellowship, we believe no procedure would be performed frequently enough by fellows in the pediatric ED for them to reliably achieve competence. Additionally, 67% of the procedures performed by fellows occurred during the first year of fellowship. First-year fellows spend 1 month more in the pediatric ED than do second-year fellows, partially explaining this statistic. First-year fellows also do not routinely function as the resuscitation team leader and are therefore more readily available to perform procedures.

The infrequency with which critical procedures were performed, combined with the resultant competition to practice these skills in the pediatric ED, essentially eliminates the chance that any provider, whether faculty or trainee, will have sufficient clinical opportunity to achieve or maintain competence in this setting alone. Restricting the opportunity to perform any critical procedure to those providers who need to achieve expertise in pediatric resuscitation and its associated procedures would improve the likelihood of success in this endeavor. This would mean limiting the attempts of trainees who do not realistically

expect to perform these procedures in their future medical practice. From the patient's perspective, this would have the added benefit of increasing the number of procedures that are performed by more knowledgeable and experienced providers.

Twenty-seven percent of all critical procedures in our study were performed by non–emergency medicine specialties (surgery, anesthesiology, pediatric critical care, neonatology, and otolaryngology). Because of the absence of data on unsuccessful attempts, we are unable to comment on the exact proportion that represents rescue of failed ED attempts. However, unpublished data from a video review study that we performed demonstrated that 35 of 114 (31%) rapid sequence orotracheal intubations were performed by non–emergency medicine specialties. For 23 of these 35 (66%), a non–emergency medicine specialist was the initial and only provider involved in performance of the procedure. Twelve of the 35 (34%) represented rescue performance after unsuccessful attempts by a pediatric ED resident, fellow, or faculty.

A surprising finding from our data was the infrequency of cardioversion and defibrillation. Defibrillation was performed once during the 12-month study period. According to our data (Table 3), pediatric emergency medicine faculty working 32 clinical hours per week would defibrillate a pediatric patient only once every 5.3 years. The American Heart Association, in the pediatric advanced life support 2010 guidelines, stated that ventricular fibrillation or pulseless ventricular tachycardia is the initial cardiac rhythm in approximately 5% to 15% of pediatric inhospital and out-of-hospital cardiac arrests, and it is reported in up to 27% of pediatric inhospital arrests at some point during resuscitation.[18] The rarity of defibrillation, especially in our ED, suggests that either our patients are different from those included in the pediatric advanced life support studies or, more likely, that rhythms such as ventricular fibrillation and pulseless ventricular tachycardia are underrecognized during pediatric ED resuscitations.

Patient safety and the delivery of cost-effective, high-quality care have increasingly become a public focus. An article addressing issues relating to preparation of a pediatric emergency physician workforce identified assurance of appropriate technical skills as one of the key drivers in delivering high-quality care.[19] The need for clinical leadership to monitor individual performance of technical skills and develop curricula for procedural skill maintenance was also acknowledged. Unfortunately, no evidence or recommendations exist about the optimal way for faculty to maintain competence in the performance of pediatric critical procedures. In the survey of pediatric ED medical directors about maintenance of skill in emergency intubation, qualifying activities reported by the medical directors to maintain intubation competence included attendance at a pediatric advanced life support course (69%), simulation training (48%), operating room performance of intubation under the supervision of an anesthesiologist (38%), attendance at an advanced airway course (34%), animal laboratories (8%), and delivery room intubation of newborns (2%).[2] Two percent of medical directors reported no method for maintaining competence in intubation. We strongly believe that if every ED provider who manages ill or injured children is going to be proficient with pediatric critical procedures, then ED clinical and educational leadership must commit to the development and implementation of mandatory and rigorous maintenance-of-skill programs to supplement clinical experience.

We believe that the basis of any acquisition and maintenance-of-skill program is deliberate practice.[20,21] Simulation provides an opportunity for deliberate practice with feedback immediately available to the learner and no risk of harm to patients. A systematic review and meta-analysis of simulation-based medical education showed that, compared with traditional medical education, simulation-based education with deliberate practice was superior in clinical skill acquisition.[22] Given the findings of our study, we are developing a simulation-based critical procedure course with the goal of assisting residents, fellows, and faculty in achieving and maintaining competence in critical pediatric procedures. Additionally, we are exploring novel metrics of procedural performance through the use of video review. For example, we are able to quantify the number of laryngoscopy attempts that a faculty member or fellow performs to successfully insert an endotracheal tube. This allows for assessment of whether laryngoscopy, tube insertion, or some other aspect of the intubation process might provide a focus for improvement efforts.

In summary, critical procedures were infrequently performed in a large, academic pediatric ED. Pediatric emergency medicine faculty are at significant risk for skill deterioration if other venues for practice are not actively sought and required, and pediatric emergency medicine fellows are unlikely to achieve competence if clinical exposure is the sole basis for the attainment of procedural skill. Valid and reliable methods to ensure acquisition and maintenance of critical procedural skills need to be developed, tested, and practiced. Quality assurance systems around the performance of critical pediatric procedures should be established by clinical and educational leadership within EDs to ensure the highest level of patient care, patient safety, and education for trainees.

Supervising editor: Steven M. Green, MD

Author affiliations: From the Cincinnati Children's Hospital Medical Center, Division of Emergency Medicine, Cincinnati, OH.

Author contributions: All authors conceived the study. MRM, BTK, and ASR were responsible for supervising all study procedures and collected all study data. MRM was primarily responsible for data processing and management. MRM drafted the article, and all authors contributed substantially to its revision and approved the final article. MRM takes responsibility for the paper as a whole.

Funding and support: By *Annals* policy, all authors are required to disclose any and all commercial, financial, and other relationships in any way related to the subject of this article as per ICMJE conflict of interest guidelines (see www.icmje.org). The authors have stated that no such relationships exist.

Publication dates: Received for publication April 27, 2012. Revision received June 11, 2012. Accepted for publication June 27, 2012. Available online July 27, 2012.

Presented as a poster at the Pediatric Academic Societies annual meeting, May 2011, Denver, CO.

Address for correspondence: Matthew R. Mittiga, MD, E-mail matthew.mittiga@cchmc.org.

REFERENCES

1. Simon HK, Sullivan F. Confidence in performance of pediatric emergency medicine procedures by community emergency practitioners. *Pediatr Emerg Care*. 1996;12:336-339.
2. Losek JD, Olson LR, Dobson JV, et al. Tracheal intubation practice and maintaining skill competency: survey of pediatric emergency department medical directors. *Pediatr Emerg Care*. 2008;24:294-299.
3. Kerrey BT, Rinderknecht AS, Geis GL, et al. Rapid sequence intubation for pediatric emergency patients: higher frequency of failed attempts and adverse effects found by video review. *Ann Emerg Med*. 2012 Mar 14. [Epub ahead of print].
4. Green SM. A is for airway: a pediatric emergency department challenge. *Ann Emerg Med*. 2012 Apr 18. [Epub ahead of print].
5. Schoenfeld PS, Baker MD. Management of cardiopulmonary and trauma resuscitation in the pediatric emergency department. *Pediatrics*. 1993;91:726-729.
6. Green SM, Ruben J. Emergency department children are not as sick as adults: implications for critical care skills retention in an exclusively pediatric emergency medicine practice. *J Emerg Med*. 2009;37:359-368.
7. Guilfoyle FJ, Milner R, Kissoon N. Resuscitation interventions in a tertiary level pediatric emergency department: implications for maintenance of skills. *CJEM*. 2011;13:90-95.
8. Kissoon N, Walia MS. The critically ill child in the pediatric emergency department. *Ann Emerg Med*. 1989;18:30-33.
9. Claudet I, Bounes V, Federici S, et al. Epidemiology of admissions in a pediatric resuscitation room. *Pediatr Emerg Care*. 2009;25:312-316.
10. Chen EH, Cho CS, Shofer FS, et al. Resident exposure to critical patients in a pediatric emergency department. *Pediatr Emerg Care*. 2007;23:774-778.
11. Chen EH, Shofer FS, Baren JM. Emergency medicine resident rotation in pediatric emergency medicine: what kind of experience are we providing? *Acad Emerg Med*. 2004;11:771-773.
12. Gilbert EH, Lowenstein SR, Koziol-McLain J, et al. Chart reviews in emergency medicine research: where are the methods? *Ann Emerg Med*. 1996;27:305-308.
13. Pediatric emergency medicine (PEM) fellowship curriculum statement. Curriculum Subcommittee, Section of Emergency Medicine, American Academy of Pediatrics. *Pediatr Emerg Care*. 1993;9:60-66.
14. Core content for emergency medicine. Task Force on the Core Content for Emergency Medicine Revision. *Acad Emerg Med*. 1997;4:628-642.
15. Mulcaster JT, Mills J, Hung OR, et al. Laryngoscopic intubation: learning and performance. *Anesthesiology*. 2003;98:23-27.
16. Konrad C, Schupfer G, Wietlisbach M, et al. Learning manual skills in anesthesiology: is there a recommended number of cases for anesthetic procedures? *Anesth Analg*. 1998;86:635-639.
17. Kopacz DJ, Neal JM, Pollock JE. The regional anesthesia "learning curve." What is the minimum number of epidural and spinal blocks to reach consistency? *Reg Anesth*. 1996;21:182-190.
18. Kleinman ME, Chameides L, Schexnayder SM, et al. Part 14: pediatric advanced life support: 2010 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. *Circulation*. 2010;122(18 suppl 3):S876-908.
19. Luria J, Buncher MJ, Ruddy RM. Workforce and its impact on quality. *Clin Pediatr Emerg Med*. 2011;12:151-160.
20. Ericsson KA. Deliberate practice and the acquisition and maintenance of expert performance in medicine and related domains. *Acad Med*. 2004;79(10 suppl):S70-81.
21. Ericsson KA. Deliberate practice and acquisition of expert performance: a general overview. *Acad Emerg Med*. 2008;15:988-994.
22. McGaghie WC, Issenberg SB, Cohen ER, et al. Does simulation-based medical education with deliberate practice yield better results than traditional clinical education? a meta-analytic comparative review of the evidence. *Acad Med*. 2011;86:706-711.