CLINICAL INVESTIGATION

Characteristics of Medication Use During Pediatric Medical Emergency Team Events and the Role of a Pharmacist-Provided Medication Supply

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OBJECTIVES To determine the type and frequency of and indications for medications used during pediatric medical emergency team (PMET) events and to describe a PMET pharmacist training model, creation of a standardized “pharmacist PMET supply,” and the pharmacist’s role in implementation and ongoing improvement of a PMET.

METHODS This is a retrospective observational cohort study of 210 PMET events in 172 patients in a tertiary care, academic pediatric hospital, from September 15, 2005, to September 15, 2007. We focused on the types and sources of medications used during PMET events.

RESULTS The medications most commonly used were lorazepam (11%), neuromuscular blockers (10.5%), atropine (9.5%), epinephrine bolus (9%), and albuterol or levalbuterol (9%). However, 49 distinct medications were used in 53.8% of all PMET events. Of all medications requested during a PMET event, only 40% originated from an institutionally standardized emergency medication box, while an additional 35% were readily available at the patient’s bedside as part of the “pharmacist PMET supply.”

CONCLUSIONS A wide variety of medications are required to care for children who suffer acute in-hospital deterioration. The pharmacist’s medication supply and expertise ensured immediate availability of therapies for clinical entities ranging from seizures and anaphylaxis to rapid sequence intubation, regardless of the PMET event location.

INDEX TERMS medical emergency team, pediatric, pharmacist

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INTRODUCTION

Only 27% to 36% of children who suffer in-hospital cardiopulmonary arrest (CPA) survive to discharge.^{1,2} Most patients display signs of respiratory distress or shock prior to the event,³ which prompted numerous hospitals to introduce pediatric medical emergency teams (PMET) in an effort to identify and treat these patients before CPA occurs.⁴ The PMET represents response members that all have four competencies: advanced airway management, have established central vascular access, can prescribe therapy, and can start intensive care unit (ICU)-level care

at the bedside. PMETs are generally physician-led, as opposed to rapid response teams (RRT), which are not necessarily physician-led and are used mostly for rapid assessment and triage of patients.⁴ In contrast with traditional code teams, PMETs respond to any physiological or psychological deterioration of a hospitalized patient who requires a clinical response and not only to emergencies where the patients have already decompensated and need active resuscitation.⁴

A recent Australian pediatric study showed a significant decrease in preventable CPA events (55% reduction), CPA-related deaths (87% reduction), and hospital deaths from all causes (35%

reduction) after the introduction of a PMET compared to a historical cohort prior to the introduction of a PMET.⁵ Similar studies in the United States that compared outcomes before and after the introduction of a PMET have shown significant reductions in respiratory arrests without changes in CPA incidence⁶ and a trend toward decreased preventable CPA events and deaths⁷ after a hospital-wide PMET was instituted. Team configurations were different in each of these studies, and the optimal team composition is unknown. Teams range from 3 to 10 members, but all have a core of intensive care unit-trained individuals.^{5,7}

Pharmacists have been shown to contribute to improved patient outcomes when they act as part of resuscitation teams.^{8,9} Large nationwide hospital data studies showed that pharmacist participation in resuscitation teams was associated with a 22% decrease in the rate of adverse drug events, a decrease in patient deaths of 17.9 deaths/year/hospital, with 5047 fewer deaths per year in 282 hospitals that had pharmacists in CPA events.⁸⁻¹⁰ Their roles consist primarily of obtaining drug histories, recommending drug therapies, ensuring appropriate dosing, preparing drugs for administration, facilitating drug procurement rapidly from the hospital pharmacy, and documenting drug administration and/or adverse drug events that contribute to the patient's deterioration.¹¹⁻¹³ All of these roles are particularly important in the pediatric population, which is at higher risk for medication errors due to weight-based dosing, need for serial dilutions, and variability in dosage forms for children.^{14,15} While there is now an emerging trend of PMET models that include pharmacists, there are few data in the literature supporting the presence of the pharmacist on the PMET.

Our institution has used pharmacists on the PMET since its inception in October 2004. The present study aimed to determine the frequency and type of medications used, to present a PMET pharmacist training model, to describe the creation of a standardized "pharmacist PMET supply," and to describe the pharmacist's roles in the implementation and ongoing improvement of the PMET.

METHODS

This is a retrospective observational cohort

study of all PMET activations that occurred from September 15, 2005, to September 15, 2007, at the Johns Hopkins Children's Medical and Surgical Center, which is a tertiary care, academic pediatric hospital. The PMET at our institution is a physician-led medical emergency team that responds to the deterioration of a hospitalized pediatric patient who is at "imminent risk of serious harm."⁴ Triggers for calling the PMET are broad and include respiratory distress or compromise, abnormal or worsening respiratory symptoms, decrease in oxygen saturation, seizures with apnea, change in mental status, circulatory compromise or shock, dysrhythmias, respiratory arrest, CPA, and worried staff or family member.⁶ The PMET is activated by calling a hospital dispatcher and indicating the location. The caller is not required to provide any further information, such as diagnosis. The dispatcher sends a message with the location of the call to pagers carried by all PMET members. A similar system existed before 2004, but there were delays due to the need of giving a report on the status of the patient. The PMET responds to pediatric medical emergencies in all areas of the hospital except for the pediatric ICU (PICU), the labor and delivery suite, and the neonatal ICU (NICU). Our children's hospital does not have a separate RRT.

The PMET program at our institution started in October 2004, and a PMET event database was initiated in September 2005. The PMET event data collection form is completed immediately after the event by a senior nursing coordinator and includes patient demographic information; time, location, and duration of the event; vital signs prior to and during the event; interventions during the event; and patient disposition and any systems problems as part of an ongoing quality assurance process. The PMET has 10 members, each with a specific, preassigned role (Table 1). Pharmacists were an integral part of the PMET from its initial creation.

Medications given during a PMET event are obtained from any of the following locations (1) the emergency medication box (i.e., institutionally standardized boxes maintained on each ward and at major entrances that contain atropine, dextrose 25%, epinephrine, sodium bicarbonate, diphenhydramine, hydrocortisone acetate, and naloxone); (2) the "pharmacist PMET supply," as described below; (3) a ward-based automated dispensing cabinet; or (4) the pediatric pharmacy

Table 1. Pediatric Medical Emergency Team Members and Associated Roles

PMET Member	Role
PICU fellow*	Team leader
PICU nurse	Drug administration and assistance with complex procedures
PICU respiratory therapist	Airway support
Pediatric senior resident	Airway management
Pediatric junior resident	Defibrillation and intraosseous needle placement, as indicated
Pediatric intern	Chest compressions
Senior nursing coordinator	Assistance with code cart, medication preparation and documentation
Pharmacist	Coordination of all phases of the medication administration process, including medication preparation, drug recommendations, information on accurate dosing and route of administration, screening for allergies and drug interactions, provision of additional non-resuscitation medications and supplies
Chaplain	Family support
Security officer	Facilitation of patient transport

PICU, Pediatric Intensive Care Unit

* The PICU fellow determines which medications to use, as well as the dose required, after consultation with the pharmacist

in our institution. Pharmacists bring the “pharmacist PMET supply” consisting of three bags to each PMET call: a controlled substances bag (the “Pharmacist Controlled Bag”), a refrigerated medication bag (the “Pharmacist Refrigerated Bag”), and a code bag (the “Pharmacist Code Bag”), the contents of which are detailed in Table 2.

All data from PMET events were collected prospectively, primarily for quality improvement purposes, and were de-identified in compliance with the Health Insurance Portability and Accountability Act. This study was approved by the Johns Hopkins Institutional Review Board.

Statistical Analysis

Exploratory data analysis was conducted to examine patient and event characteristics to determine the proportion of PMET events in which medications were used and to describe the source and classes of medications used. PMET events were divided in two categories, those with and without medication use. The two groups of PMET events were compared by bivariate analysis with regard to patient and event characteristics. Differences between the two groups were analyzed with the Wilcoxon rank sum test for non-normally distributed continuous variables, the Student *t* test for normally distributed continuous variables, or the χ^2 test for binary variables, as appropriate. All statistical analysis

was conducted using Stata statistical software version 10.0 (Stata Corp, College Station, TX). Unless otherwise noted, all data are presented as mean $\pm$ SD.

RESULTS

There were 210 PMET events in 172 patients between September 15, 2005, and September 15, 2007. The median age was 3.4 years (interquartile range [IQR], 8.4 months-11.9 years) and 49% of patients were male. Most patients were under the care of a nonsurgical pediatric service (70%). PMET events had an average duration of 26 $\pm$ 13 minutes.

Of the 210 PMET events, 20 (9.5%) were CPAs, defined as any event requiring chest compressions and/or defibrillation. Of the 20 CPA events, 8 (40%) occurred on a general pediatric ward, 9 (45%) occurred in the emergency department (ED), 1 took place in the catheterization suite, 1 during a magnetic resonance imaging study, and 1 at the hospital entrance. Of the 9 PMET calls for CPA in the ED, 6 (67%) were for patients who presented with unwitnessed out-of-hospital CPA; 2 (22%) patients had pre-existing “do not resuscitate” orders, and only 1 patient (11%) suffered a witnessed CPA while in the ED. Therefore, a total of 12 of 210 (5.7%) PMET calls were made for witnessed in-hospital CPA. Overall PMET event mortality (i.e., death declared at the PMET

Table 2. Contents of Pharmacist Pediatric Medical Emergency Team (PMET) Supply

Pharmacist Controlled Substances	Pharmacist Refrigerated Bag†	Pharmacist Code Bag‡
Fentanyl	Fosphenytoin	Epi Pen (Jr)
Midazolam	Rocuronium	Lidocaine Bristojet
Ketamine	Succinylcholine	Syringes, needles, connectors
Thiopental	Regular Insulin	NS and D5W, 100 ml bags (to mix infusions)
Etomidate		Drug dosing references
Phenobarbital		Emergency weight-based drug cards
Lorazepam		Syringe labels

* Used in 38/210 (18.1%) of all PMET calls

† Used in 27/210 (12.9%) of all PMET calls

‡ Used in all calls for supplies and in 2/210 (1%) of PMET calls for medications.

location by a PMET member) was 9 of 210 (4.3%) (Table 3).

Medications were administered in 113 of 210 (53.8%) PMET events. Forty-nine distinct medications were used 248 times during 113 PMET events in our 2-year study period. The median number of drugs used per PMET event was two (range, 1-7). This count does not include multiple doses of the same medication given during a single PMET event. Patient and event characteristics were compared between PMET events with and those without medication administration (Table 3). The most commonly used medications are presented in Figure 1. Indications for PMET drug administration are presented in Figure 2. Sources for PMET drugs are presented in Figure 3. Of note, only 100 (40%) of 248 drugs ordered during PMET events were readily available at the patient's bedside through our standardized emergency medication box. The "pharmacist PMET supply" provided an additional 85 (35%) of 248 dosages.

All medications used in pediatric advanced life support (PALS) calls for CPA were available at the bedside from the emergency medication boxes or from the "pharmacist PMET supply"

(Figure 4). The proportions of medications originating from the pharmacist bags increased significantly in non-CPA scenarios compared to CPA scenarios (79 of 196 [40.4%] versus 6 of 52 [11.5%], respectively, $p=0.0002$) (Figure 4). There were only four medication doses given during CPA calls that had to be obtained from an automated dispensing cabinet or to be requested from the pharmacy, and these were used to address the suspected underlying cause of the CPA, as opposed to being part of the resuscitation algorithm (e.g., antibiotics, steroids). Overall, the proportion of medications originating from the "pharmacist PMET supply" was highest during calls for respiratory arrest and for patients who required urgent intubation (10 of 17 [58.8%] and 40 of 67 [59.7%], respectively). This was due to the fact that the controlled substances and the refrigerated medication bags contain most drugs requested by PMET physicians for rapid sequence intubation (Table 2). There were four PMET calls in "unusual locations": three in a diagnostic suite and one at the hospital entrance. These four calls were made for CPA (3 of 4) and hypoglycemia with altered mental status (1 of 4). All 11 medications used were readily available

Table 3. Patient and Event Characteristics

Variable	No. of Medications Given During PMET Event (n=97)	PMET Events with Administration of Medications (n=113)	p-value*
Age (yr), median (IQR)	3 (0.45-9.8)	5.5 (1-13.6)	0.012
Weight (kg), median (IQR)	13 (5-32)	18 (8-43)	0.015
Males, n (%)	48/96 (50)	58/112 (51.8)	0.797
Admitting service, n (%)			
Medical	70/97 (72.2)	73/113 (64.6)	0.241
Surgical	16/97 (16.5)	28/113 (24.8)	0.141
Other	8/97 (8.3)	11/113 (9.7)	0.708
Location, n (%)			
General ward	79/97 (81.4)	94/113 (83.2)	0.741
ED	5/97 (5.2)	10/113 (8.9)	0.300
Outpatient clinic	7/97 (7.2)	4/113 (3.5)	0.233
Diagnostic suite/nonclinical areas	6/97 (6.2)	5/113 (4.4)	0.568
Preliminary diagnosis of PMET event, n (%)			
Respiratory distress/hypoxia	37/97 (38.1)	40/113 (35.4)	0.681
Seizure	20/97 (20.6)	26/113 (23)	0.676
AMS/LOC	11/97 (11.3)	5/113 (4.4)	0.060
Shock	8/97 (8.3)	7/113 (6.2)	0.565
Hemorrhage	7/97 (7.2)	4/113 (3.5)	0.233
Cardiopulmonary arrest	4/97 (4.1)	16/113 (14.2)	0.014
Anaphylaxis, drug/transfusion	2/97 (2.1)	7/113 (6.2)	0.140
Reaction			
Dysrhythmia	2/97 (2.1)	6/113 (5.3)	0.220
Other	6/97 (6.2)	2/113 (1.8)	0.096
PMET event category, n (%)			
Cardiopulmonary arrest	4/97 (4.1)	16/113 (14.2)	0.014
Respiratory arrest	3/97 (3.1)	7/113 (6.2)	0.293
Intubation without arrest	0	15/113 (13.3)	<0.001
Other	90/97 (92.8)	75/113 (66.4)	<0.001
Disposition, n (%)			
No change in level of care	31/96 (32.3)	18/113 (15.9)	0.005
Transfer to intermediate care unit	6/96 (6.3)	5/113 (4.4)	0.556
Transfer to pediatric ED	13/96 (13.5)	8/113 (7.1)	0.121
Transfer to PICU	41/96 (42.7)	73/113 (64.6)	0.002
Transfer to OR	1/96 (1.0)	3/113 (2.7)	0.396
PMET event mortality, n (%)†	3/97 (3.1)	6/113 (5.3)	0.429

AMS/LOC, altered mental status/loss of consciousness; ED, emergency department; IQR: interquartile range; OR, operating room; PICU, pediatric intensive care unit; PMET, pediatric medical emergency team

* Bolded values are statistically significant

† Excludes mortality after transfer of patient to Pediatric ED, PICU or OR

Figure 1. Medication Usage.

Jr, junior; IM, intramuscular; PMET, pediatric medical emergency team; SUX, succinylcholine.

Miscellaneous medications: acetaminophen, adenosine, amiodarone, choline magnesium trisalicylate, dopamine, epinephrine infusion, furosemide, glucose, hydralazine, hypertonic saline, insulin, ipratropium bromide, ketamine, labetalol, lidocaine, magnesium, mannitol, meperidine, morphine, octreotide, pantoprazole, phenobarbital, phenylephrine, terbutaline.

from the emergency medication boxes or from the “pharmacist PMET supply.”

DISCUSSION

These data show that in our institution, medications are used in just above half of all PMET calls. The most common indications for medication administration were seizures, asthma or anaphylaxis, rapid sequence intubation, and CPA. Seventy-five percent of all medications were readily available at the patient’s bedside, either from the standardized emergency medication boxes or from the “pharmacist PMET supply,” regardless of the patient’s location, as illustrated in Figure 3. Most of the medications used for CPA originated from the emergency medication box, as expected. The proportion of medications used from the “pharmacist PMET supply” increased significantly in elective intubations and nonarrest scenarios compared to those used in CPA events. This allowed for immediate availability of therapies for seizures, rapid sequence intuba-

Figure 2. Medications Administered by Indication (n=248) ICP, intracranial pressure; RSI, rapid sequence intubation. Miscellaneous indications: hyperkalemia, pulmonary edema, hyperthermia, hematemesis.

tion, and anaphylaxis, regardless of the PMET event location.

PMET Pharmacist Training and Institutional Experience

During their orientation month, all pharmacy residents complete educational sessions on participation in the hospital PMET teams. These sessions provide hands-on experience with drug boxes, a review of the medications used in emergency situations, and practice in preparing medications for administration. Pharmacy residents also obtain basic life support and advanced cardiac life support certification during orientation and are encouraged to obtain PALS certification, which they most often do. All pediatric pharmacy clinical specialists are PALS certified, and staff pharmacists are encouraged to obtain and maintain PALS certification as well. Staff pharmacists are also oriented to the PMET drug and supply boxes, their storage location in the pediatric pharmacy, how to restock items once used, and how to document the items used. Finally, pharmacists participate in monthly in-patient ward mock codes and have recently started participating in our monthly multidisciplinary PMET training sessions in the simulation laboratory. These training sessions allow pharmacists to see patterns of medication usage, practice the difficult skill of communication in a crisis, and participate in the postsimulation debriefing exer-

Figure 3. Source of medications administered (n=248).

■ = emergency medication box; □ = pediatric pharmacy; ▒ = automatic dispensing cabinet; □ = pharmacist pediatric medical emergency team

* antibiotics, terbutaline, hypertonic saline solution, intravenous pantoprazole, octreotide, meperidine
† albuterol, steroids, racemic epinephrine, rectal diazepam, ipratropium bromide, hydralazine, acetaminophen

cises focused on addressing errors observed. Our training program is similar to others reported by combining hands-on, simulation experience, with didactic sessions.^{16,17}

Pharmacists at our institution respond to PMET calls around the clock and have been vital members of the PMET since its inception in October 2004. A series of 34 mock CPA and pediatric emergency scenarios were performed prior to the PMET formation. These simulated sessions revealed that the number of interventions requested by team members overburdened nurses. These requests and tasks interrupted key resuscitation efforts by the nurses who were supposed to act as first responders but instead were bringing equipment to the bedside and drawing up medications.⁶ The introduction of pharmacists, initially in simulated scenarios and then in clinical practice, allowed key players in the resuscitation to focus on patient interventions while the medications were being prepared and checked by pharmacists. Pharmacists played a greater than anticipated role in nonarrest scenarios, where they facilitated medication dilution, checked patient allergies prior to drug administration, calculated opiate or benzodiazepine exposure for patients who were overly sedated, and facilitated rapid medication transfer from the pharmacy to the bedside. At the conclusion of a PMET call,

Figure 4. Source of medications by main pediatric medical emergency team (PMET) event category (n=248)

■ = emergency medication box; □ = pediatric pharmacy; ▒ = automatic dispensing cabinet; □ = pharmacist pediatric medical emergency team

pharmacists kept track of the medications delivered and their timing to ensure compliance with the PALS guidelines. Pharmacists also played a crucial role in the development of computerized web-based code cards that are weight-based with adult maximum dose limits. Two staff pharmacists of the pediatric pharmacy respond to PMET calls 24 hours a day, 7 days a week. In addition to pediatric staff pharmacists, a pediatric clinical specialist and an on-call pharmacy resident respond during nights and weekends.

Special Drugs for the PMET

Involvement of pharmacists in the development and maintenance of the PMET has allowed for early identification and inclusion of additional drugs and supplies that may be useful in a PMET call. When the pharmacist notes a medication has been requested with urgency, but was not readily available, they bring this drug to the pediatric Quality Improvement Advisory Committee to consider whether it should be added to one of the emergency medication sources. The list of drugs and supplies has expanded to include medications that cannot be kept in the standard code box due to storage limitations or regulatory standards (Table 2). The "pharmacist PMET supply" is particularly useful in non-CPA calls and for locations in which a code box may not be immediately available, such as nonpatient care areas. The addition of fosphenytoin, lorazepam,

and phenobarbital to the pharmacist bag has allowed for fast treatment of status epilepticus, which represents 22% of all PMET calls (Table 3). The PMET pharmacist supply provided epinephrine (EpiPen Jr, Dey Pharma, LP, Basking Ridge, NJ) for the treatment of allergic reactions and anaphylaxis, given that larger package size and higher cost have been deterrent factors in adding the EpiPen Jr to all hospital code drug boxes. Furthermore, PMET physicians have been able to quickly and safely intubate patients using rocuronium (Zemuron, Organon USA Inc, Roseland, NJ), which is a refrigerated medication. Rocuronium is available only in the ED, PICU, and NICU medication refrigerators as a safety measure to ensure it is not mistakenly used in nonintubated patients on the general floors.

Medical Emergency Team Composition

Institutions vary in the composition of their METs. There has been recent evidence that non-physician-led METs (e.g., ICU nurse-led MET) have had success in the stabilization and timely transfer of patients.^{18–21} Respiratory therapists are particularly helpful if patients present with respiratory symptoms.^{22–24} However, there are very few data to date that describe the role of a pharmacist as a member of a MET. A review of the literature documented pharmacist involvement in a RRT at an adult community hospital where pharmacists helped optimize drug therapy in 32.6% of the calls, spending an average of 20 minutes/call.²⁵ Several other reports of pharmacist participation in adult RRT/METs exist in the literature.^{13,15,26,27}

Pharmacist participation in RRT/METs has occurred in some centers as an extension of the well-described beneficial role of pharmacists as part of CPR teams. The first documented pharmacist presence on CPR team was in 1972.²⁸ By the late 1990s, 32% to 37% of hospitals were deploying pharmacists on their adult resuscitation teams.^{12,29,30} Pharmacy residency programs also started including attendance at in-hospital resuscitation events to their curriculum, with 30% of residency programs requiring residents to respond to CPR events and 38% of programs offering the option of participating in CPR teams to their residents.³¹ Pharmacist training strategies include orientation to code carts, simulated emergency scenarios, direct observation of patient events, buddy systems as well as basic life

support with or without PALS training requirements.^{6,12,31,32}

In a series of large reviews of national hospital data, Bond et al^{8–10} showed that the presence of pharmacists on CPR teams improved hospital survival rates significantly (12,880 reduced deaths in 885 hospitals) and decreased the rate of adverse drug events during medical emergencies by 22%. Pharmacist presence improves compliance with existing resuscitation guidelines: advanced cardiac life support-compliant interventions during adult resuscitations were twice as frequent when a pharmacist was part of the code team in a single-institution study.¹¹ In nonresuscitation scenarios, adding pharmacists to an adult MET improved goal-directed therapy for septic shock, decreasing the time from prescription to administration of antibiotics from 154 minutes to 54 minutes.²⁶ Last, through consistent documentation and reporting of adverse drug events noted during MET calls, pharmacists played a vital role in the identification of the risk for methemoglobinemia with the use of benzocaine sprays, which eventually led to the elimination of this medication from Veterans Affairs hospitals at a national level.¹³

Our study evaluates the frequency and types of medications used during PMET events and describes pharmacists' roles in the implementation and continued improvement process of a PMET. Given that pharmacists were present on the PMET at the time of its inception, we were not able to determine whether their presence on the team impacted clinical decision making at the bedside, incidence of adverse drug events, or patient outcomes. Similarly, while it is our perception that the presence of the "pharmacist PMET supply" has greatly facilitated rapid sequence intubation on the wards, we started using pharmacist-brought PMET drug boxes since the PMET's creation and thus we were not able to determine whether this intervention decreased PMET event duration or improved clinical management significantly by making these drugs readily available. This study lacks a cost effectiveness component, but, at least for our institution, pharmacy staffing did not require any additions once the PMET was implemented, given that, for approximately a half of ~100 PMET events/year, medications were not administered and pharmacists could quickly leave the PMET site.

CONCLUSIONS

Medications are used in more than half of all PMET events. The main indications are seizure, anaphylaxis and rapid sequence intubation. In our institution, pharmacists have been present on the PMET from its inception. They bring key refrigerated and controlled drugs to PMET events, thus increasing the bedside availability of requested medications from 40% to 75% of all medication orders. Immediate availability of therapies for seizures, rapid sequence intubation and anaphylaxis is therefore ensured regardless of the location of a PMET event. Pharmacists play the role of coordinators of all phases of medication administration and quality assurance agents. Further studies are needed to determine the impact of the pharmacist in PMET on patient outcomes.

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ABBREVIATIONS CPA, cardiopulmonary arrest; IQR, interquartile range; MET, medical emergency teams; NICU, neonatal intensive care unit; PALS, pediatric advanced life support; PICU, pediatric intensive care unit; PMET, pediatric medical emergency team; RRT, rapid response teams

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