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EDUCATION AND PRACTICE

SIMULATION-BASED ASSESSMENT OF PARAMEDIC PEDIATRIC RESUSCITATION SKILLS

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ABSTRACT

Background. Emergency medical services (EMS) providers infrequently encounter seriously ill and injured pediatric patients. Clinical simulations are useful for assessing skill level, especially for low-frequency, high-risk problems. **Objective.** To identify the most common performance deficiencies in paramedics' management of three simulated pediatric emergencies. **Methods**. Paramedics from five EMS agencies in Michigan were eligible subjects for this prospective, observational study. Three clinical assessment modules (CAMs) were designed and validated using pediatric simulators with varying technologic complexity. Scenarios included an infant cardiopulmonary arrest, sepsis/seizure, and child asthma/respiratory arrest. Each scenario required paramedics to perform an assessment and provide appropriate pediatric patient care within a 12-minute time limit. Trained instructors conducted the simulations by following strict guidelines for sequences of events and responses. Videos of CAMs were reviewed by an independent evaluator to verify scoring accuracy. Percentage of steps completed for each of the three scenarios and specific performance deficiencies were recorded. **Results.** Two hundred twelve paramedics completed the CAMs. The average percentages of steps completed were as follows: arrest CAM, 45.3%; asthma CAM, 51.6%; and sepsis CAM, 47.1%. Performance deficiencies included lack of airway support or protection; lack of support of ventilations or cardiac function; inappropriate use of length-based treatment tapes; and inaccurate calculation and administration of medications and fluids. **Conclusion.** Multiple deficiencies in paramedics' performance of pediatric resuscitation skills were objectively identified using three manikin-based simulations. EMS educators and EMS medical directors should target these specific skill deficiencies when developing continuing education in prehospital pediatric patient care. **Key words:** emergency medical services; simulation; pediatric emergencies; competency assessment

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INTRODUCTION

Emergency medical services (EMS) personnel infrequently encounter seriously ill and injured pediatric patients. Retention and knowledge of medical skills by EMS providers have been correlated with frequency of use. Skill retention may decrease precipitously within six months after completing a pediatric course.[1,2]

The Pediatric Continuous Quality Improvement Model Project[3] was initiated in 2002 to demonstrate improvement in pediatric protocol compliance in agencies receiving regular feedback from Michigan Emergency Records Management and Information Database (MERMaID), Michigan's electronic EMS information system. Data queried from MERMaID revealed that the frequency of paramedic encounters with seriously ill or injured pediatric patient is extremely low. Measured in average days between patient encounters per provider, a paramedic will manage an adult respiratory patient once every 20 days as compared with once every 625 days, 958 days, and 1,087 days for teen/preteen, child, and infant patients, respectively. This limited clinical experience is often cited as the reason most paramedics report a lack of confidence in caring for pediatric patients.[4] The low frequency of pediatric emergencies also makes direct observation by paramedic instructors impractical.

Continuing paramedic education is considered the most effective remedy for skill atrophy.[5] Training courses, such as the American Heart Association's Pediatric Advanced Life Support (PALS) course[6] and the American Academy of Pediatrics' Pediatric Education for Prehospital Professionals (PEPP) course,[7]

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have been utilized to increase knowledge and skills as well as to identify individual deficiencies.[8] Although these types of programs are vital in establishing a clinical foundation for pediatric care, briefer and more frequent continuing education "refresher" programs are still required. Current national guidelines for paramedic continuing education identify major topics and skills that should be taught to providers. However, these guidelines recommend only three or four hours of refresher training every year in the category of "special considerations," which includes not only pediatrics, but also geriatrics, abuse, assault, and patients with special needs.[9] Finite personnel and financial resources limit the amount of time EMS agencies can dedicate to continuing education, especially for specialized areas such as pediatrics.

EMS educators would benefit from additional effective, affordable, and efficient educational strategies for paramedic skill maintenance. If specific pediatric skill deficiencies could be identified, remedial education activities could be focused on the problematic aspects of high-risk pediatric cases.

Patient simulation has been used to assess the knowledge and skills of health care personnel in other fields. Initial equipment costs, curriculum development time, and instructor time make simulation an expensive method of assessment. However, this methodology represents actual clinical situations more accurately than traditional written or skills stations examinations and, therefore, has greater predictive validity. Instructors can directly observe skill performance from the beginning to the end of a resuscitation, in a controlled setting, and at the convenience of both instructors and students.

We developed a pediatric simulation-based assessment tool that can be used to measure the baseline resuscitation skills of paramedics. Identification of common deficiencies could provide guidance to EMS educators who are developing refresher courses. The objective of this study was to use this assessment tool to identify the most common errors and knowledge and skill deficiencies of Michigan paramedics during the performance of three simulated pediatric resuscitations.

METHODS

Study Setting and Population

Licensed paramedics employed by five participating Michigan EMS agencies on a full- or part-time basis were recruited for this prospective, observational study. Paramedics were drawn from three geographically separate areas in Michigan. The south region is composed of the Kalamazoo metropolitan statistical area (MSA), with a population of 242,110. The central region includes the Saginaw MSA, which has a population of 209,327, and seven additional non-MSA rural counties, with a combined population of 338,704. The northern region is exclusively rural and includes six non-MSA counties, with a combined population of 136,708. The total population for all regions is 926,849 (with an MSA population of 451,437). (Population numbers are based on 2000 census results.) These locations collectively represent diverse EMS practice areas ranging from inner-city to very rural, which is similar to the makeup of most states. The average transport times for all calls in each of the three regions were as follows: northern, 16.2 minutes; central, 13 minutes; and southern, 11.8 minutes. Five EMS agencies provide primary advanced life support (ALS) services in the three regions. The northern and southern regions both have two EMS agencies participating in the project, while the central region is served by a single EMS (ALS) agency. Crew configurations comprised one emergency medical technician–basic (EMT-B) and one paramedic in 47% of ALS ambulances in the northern region, 100% of those in the central region, and 40.8% of those in the southern region. The remaining configurations comprised two paramedics. Three of the five agencies are accredited by the Commission on the Accreditation of Ambulance Services. The five agencies differ in total call volume and number of paramedics. However, the three project regions are similar in terms of number of paramedics and percentage of pediatric patient encounters.

All paramedics employed by the participating agencies were recruited through direct contact by paramedic trainers. Participation in this project was voluntary, and paramedics were compensated for their time by their respective agencies in accordance with existing agency policies. This study was approved by the Borgess Medical Center Institutional Review Board, and written informed consent was obtained from all subjects.

Paramedics were excluded if they responded to fewer than five emergency calls per month. Paramedics who participated in the validation study were also excluded.

Study Design

Development and Validation of the Assessment Tool

Three simulated pediatric emergencies were developed for use as assessment tools. Medical problems chosen for these clinical assessment modules (CAMs) were among the most frequent types of life-threatening, prehospital, pediatric emergencies in Michigan as identified through MERMaID and the Pediatric Quality Improvement Model Project. These medical problems also required a broad range of basic and advanced decision-making and procedural skills. Each simulation required paramedics to perform an assessment, identify life-threatening problems, make critical decisions, and deliver appropriate care consistent with Michigan's State Model Pediatric Protocols, including basic bag–valve–mask ventilations, endotracheal intubation, intravenous (IV) or intraosseous (IO) access, and medication calculations and administration.[10] Michigan's State Model Pediatric Protocols, which are based on national EMS model protocols,[11] had been used by paramedics in these regions for three years prior to this study.

The scenario for module 1 (*arrest CAM*) involved an infant asystolic cardiopulmonary arrest. A low-fidelity training manikin (Laerdal ALS Baby, Laerdal Corp., Stavanger, Norway) was used to portray this case. This manikin, which is commonly used in pediatric emergency care and resuscitation training courses, can generate a variety of cardiac arrhythmias and has a bulb/tubing mechanism for creating pulses, but it does not have heart or lung sounds or spontaneous breathing. Simulations using this manikin require the instructor to provide much of the clinical information.

Module 2 (*asthma CAM*) consisted of a 7-year-old child with an asthmatic respiratory arrest using MegaCode Kid (Laerdal Corp.), an intermediate-fidelity child simulation manikin. Features of this manikin include wireless cardiac rhythm controls, a heart and lung sound generator, and a bulb/tubing mechanism for creating carotid pulses.

The scenario for module 3 (*sepsis CAM*) involved a 6-month-old infant with hypotension and seizures resulting from dehydration, hypoglycemia, and sepsis. A high-fidelity infant simulator (SimBaby, Laerdal Corp.) was used in this scenario. This computer-controlled simulation manikin has the realistic anatomic and physiologic features of a 6-month-old, including cardiac rhythms, pulses, normal and abnormal lung and heart sounds, spontaneous and variable breathing patterns, vocalizations, and clonic, seizure-like movements with either a fast or slow frequency. Changes in the clinical findings and physiology during the scenario were preprogrammed, and evaluators triggered these changes in response to paramedic actions.

A task analysis approach was used to identify steps in the optimal performance of each of the resuscitations. *Task analysis* is the description of the most basic cognitive, technical, and interpersonal components of a complex skill. Combinations of these components constitute sequences of actions, processes, or steps required for the completion of the task.

Performance deficiencies were defined as steps that were omitted, performed incorrectly, or performed out of sequence and, as a result, would have resulted in a complication, procedure failure, morbidity, or mortality. A performance scoring protocol was derived by consensus among the investigators. The scoring protocol included specific rules for determining if steps were performed correctly, including acceptable ranges of drug doses and routes of delivery, acceptable time delays in response to problems, proper technique, and flexible sequences of steps. Pilot tests of the simulations revealed that some of the steps were not reliably observable (e.g., "Checked for chest rise with ventilations"). These steps were eliminated from the protocol. Performance scoring forms consisted of checklists of steps: 72 steps for the arrest CAM, 55 steps for the asthma CAM, and 46 steps for the sepsis CAM (see Appendixes 1–3). Subjects' performance scores were reported for each scenario as the percentage of steps completed correctly within the time allowed.

The CAMs and the performance scoring protocols were validated prior to this study by comparing the performance scores of high- and low-experience prehospital health care providers not associated with the main study. The high-experience group consisted of pediatric intensive care nurses and flight nurses from a regional air medical transport service, all of whom had managed critical pediatric patients. The low-experience group consisted of paramedic students in their final trimester of a one-year community college paramedic training program. These paramedic students had completed their pediatric module (including PEPP), but they had no field EMS experience as paramedics.

Study Protocol

All paramedics participated in a uniform educational experience by successfully completing either an initial or refresher PEPP course during the six months preceding the study. The purpose of this preparatory training was to create a common baseline level of knowledge and skills in pediatric care among all participating paramedics with varying educational and experiential backgrounds. Paramedics did not undergo CAM testing until six to eight months after completing one of the courses.

Standard EMS pediatric equipment was used for all testing, including cardiac monitors, basic and advanced airway management equipment, IV and IO vascular access devices, medications (in their original vials or prefilled syringes), and typical immobilization and trauma care equipment. All of the simulators allowed paramedics to perform basic and advanced airway management, cardiopulmonary resuscitation, cardiac monitoring/defibrillation, and IV and IO cannulation of extremities.

Most prehospital pediatric resuscitations are accomplished by a minimum of two EMS personnel. Therefore, subjects completed each CAM scenario with the assistance of a partner playing the role of an EMT-intermediate (EMT-I) with limited experience. This partner, who was an actor played by an experienced paramedic or paramedic instructor, followed a script that specified all actions and communications with the subject. An evaluator ran the simulation, provided scripted information in the role of a parent or bystander during the initial 30–60 seconds of the scenario, and scored the subject's performance during and after the simulation. All evaluators were trained on the performance and scoring of the CAMs. Assessment sessions were also video recorded, which allowed one of the investigators (MB) to review and verify the performance scoring of the evaluators at a later time.

The three simulations were run sequentially during a one-hour time period for most subjects. Prior to beginning each scenario, paramedics received a brief overview of the functionality, features, and nuances of each simulator and were briefed on the manner in which they should conduct themselves during the scenario. Subjects were given 12 minutes for each resuscitation to accomplish as many steps as possible. This time frame was designed to make completion of all of the possible steps difficult in order to provide the greatest discriminatory power to each simulation. Subjects were informed that they were being timed and instructed to complete as much of the resuscitation as possible within the time limit. Before and after the CAMs, subjects completed questionnaires documenting their recent experiences with pediatric emergencies, self-confidence with pediatric intubation, and level of fatigue. They were not given feedback on their performances after the CAMs.

Measurements

Evaluators were asked to complete the performance scoring form during or immediately after the simulations in order to provide a backup document in case of video camera failure. All videotapes were reviewed by one of the investigators (MJB), who amended the evaluators' scoring forms if a discrepancy was observed between the performance scoring form and the subject's performance on the video. This investigator made final decisions on all scores.

Data Analysis

The Wilcoxon Mann-Whitney test was used to compare the scores of the high- and low-experience groups in the validation study. The strength of associations of CAM scores with years of experience for each paramedic was measured using the Pearson correlation coefficient. Descriptive statistics were used for all other data.

Interrater Reliability

Interrater reliability (IRR) was assessed by having two independent observers (not including the investigator who made the final determination of all CAM scores) watch and score a number of video-recorded performances. Reliability data were calculated for each of the three scenarios individually and combined. The IRR was calculated using an exact agreement method in which an agreement is indicated by both observers scoring either "present" or "absent" on a particular task. The total agreements were divided by the total number of agreements plus disagreements and then multiplied by 100 to arrive at a percentage agreement score. The standard for an acceptable level of agreement using this method was set at 80%.

TABLE 1. Clinical Assessment Module Validation: Comparisons of Percentage of Steps Completed by High- and Low-Experience Groups

	Arrest CAM	Asthma CAM	Sepsis CAM
High-experience group			
Average percentage of steps completed	40.4%	53.9%	54.4%
Range	27–55%	29–67%	44–75%
Interquartile range	35–50%	43–55%	46–61%
Low-experience group			
Average percentage of steps completed	30.5%	47.0%	38.3%
Range	20–46%	31–60%	23–57%
Interquartile range	26–38%	40–51%	30–45%

CAM = clinical assessment module.

RESULTS

Fourteen experienced providers and 14 paramedic students participated in CAM validation. A difference in overall performance scores (average percentage of steps completed) was found between the high- and low-experience groups for the arrest CAM ($p = 0.003$), the asthma CAM ($p = 0.01$), and the sepsis CAM ($p = 0.0003$). Percentages of steps completed by the high- and low-experience groups during the validation study are presented in Table 1.

Two hundred fourteen paramedics volunteered to participate in the CAMs; two withdrew after initially consenting to participate but before starting the CAMs. This sample of subjects represented 91% of eligible paramedics in these regions. Seven paramedics were unable to complete one of the simulations because of unexpected duty requirements (five did not complete the sepsis simulations, and two missed the asthma simulations).

The average percentages of steps completed were as follows: arrest CAM, 45.3% (95% confidence interval [CI], 43.8%–46.9%); asthma CAM, 51.6% (95% CI, 50.1%–53.1%); and sepsis CAM, 47.1% (95% CI, 45.7%–48.6%). Average time for completing the three CAMs ranged from 11.1 to 11.4 minutes. The percentages of subjects who completed the scenarios in less than the 12-minute time limit (and ranges of times for each CAM) were as follows: arrest CAM, 39% (4.0–12 minutes); asthma CAM, 48% (3.8–12 minutes); and sepsis CAM, 43% (6.6–12 minutes).

TABLE 2. Most Common or Significant Performance Deficiencies in the Arrest Clinical Assessment Module

Steps ($n = 72$)	Not Completed	95% CI
Use of basic life support assessment skills		
Check for spontaneous respirations	18%	(12.8%, 23.1%)
Begin bag–mask ventilations within 60 seconds	18%	(12.8%, 23.1%)
Auscultate lungs during bag–mask ventilations	74%	(68.2%, 80.0%)
Check pulse	10%	(6.3%, 14.5%)
Perform chest compressions	5%	(2.2%, 8.2%)
Begin chest compressions within 60 seconds	51%	(44.2%, 57.8%)
Basic airway management		
Select correct size OP airway	71%	(64.6%, 76.9%)
Prepare suction	96%	(93.0%, 98.5%)
Insert OP airway	56%	(49.5%, 62.8%)
Insert OP airway correctly	61%	(54.3%, 67.4%)
Intraosseous access		
Prep IO site	33%	(27.1%, 39.8%)
Insert in correct location	14%	(9.1%, 18.3%)
Aspirate or flush	39%	(32.6%, 45.7%)
Attach IV line to IO needle	18%	(12.8%, 23.1%)
Medication dosing (first round of drugs)		
Use Broselow tape to obtain correct weight	50%	(42.8%, 56.3%)
Give correct volume of epinephrine (either concentration)	69%	(N/A)
Advanced airway management		
Select correct endotracheal tube size	58%	(51.4%, 64.7%)

CI = confidence interval; IO = intraosseous; IV = intravenous; N/A = not applicable; OP = oropharyngeal.

TABLE 3. Most Common or Significant Performance Deficiencies in the Asthma Clinical Assessment Module

Steps ($n = 55$)	Not Completed	95% CI
Basic airway management		
Select correct size of OP airway	65%	(58.2%, 71.1%)
Insert OP airway correctly (if used)	48%	(44.2%, 57.7%)
Deliver high-flow oxygen during bag–mask ventilation	23%	(17.0%, 28.3%)
Use two-person bag–mask ventilations	93%	(89.5%, 96.4%)
Medication dosing		
Apply oxygen within 60 seconds	29%	(23.1%, 35.4%)
Give correct dose of albuteral	23%	(17.0%, 28.3%)
Use Broselow tape to obtain correct weight	51%	(44.7%, 58.1%)
Select correct concentration of epinephrine	57%	(50.4%, 63.7%)
Give correct, weight-based volume of epinephrine	75%	(69.7%, 81.3%)
Advanced airway management		
Prepare suction	91%	(87.2%, 94.9%)
Select correct ET tube	47%	(40.0%, 53.4%)
Perform ET intubation	21%	(15.3%, 26.2%)
Insert ET tube to proper depth (if intubated)	49%	(41.9%, 55.3%)
Confirm ET tube placement (other than auscultate)	84%	(79.0%, 88.9%)
Auscultate gastric area to confirm ET tube placement	53%	(46.1%, 59.6%)
Secure ET tube (before decision to transport)	45%	(38.6%, 52.0%)

CI = confidence interval; ET = endotracheal; IO = intraosseous; OP = oropharyngeal.

General performance deficiencies included lack of airway support or protection; lack of support of ventilations or cardiac function; inappropriate use of length-based treatment tapes; and inaccurate calculation and administration of medications and fluids. The most clinically important or most common specific performance deficiencies identified by each of the CAMs are listed in Tables 2–4. There was no correlation between a paramedic's years of experience and the arrest CAM score ($r = 0.018$), the asthma CAM score ($r = 0.024$), or the sepsis CAM score ($r = -0.063$).

Of the 212 subjects who completed the CAMs, 209 filled out the pre-CAM questionnaires, and 146 completed part or all of the post-CAM questionnaires. Results of the pre- and post-CAM questionnaires are presented in Tables 5 and 6. There was a positive correlation between number of years of experience and a subject's confidence in managing a pediatric asthma patient similar to the CAM simulation (Fig. 1). Video recording captured 86% of the CAM sessions. After viewing the videos, the investigator (MJB) changed 1,113 of the 36,849 steps (or 3.0%) scored during the

TABLE 4. Most Common or Significant Performance Deficiencies in the Sepsis Clinical Assessment Module

Steps ($n = 46$)	Not Completed	95% CI
Basic management		
Check pulse (during seizure)	19%	(13.6%, 24.1%)
Prepare suction	97%	(94.3%, 99.1%)
Select correct OP airway	75%	(69.7%, 81.3%)
Insert OP airway correctly (if used)	69%	(63.1%, 75.5%)
Perform effective bag–mask ventilations	38%	(31.7%, 44.7%)
Correctly estimate weight	43%	(36.7%, 50.1%)
Intraosseous access		
Prep IO site	29%	(22.7%, 34.9%)
Aspirate or flush	40%	(33.0%, 46.2%)
Medication and fluid dosing		
Give correct dose of any benzodiazepine	76%	(N/A)
Give a fluid bolus for severe dehydration	85%	(80.1%, 89.7%)
Hypoglycemia management		
Test serum glucose	64%	(57.2%, 70.2%)
Give correct dose of $D_{25}W$	94%	(91.2%, 97.5%)

CI = confidence interval; $D_{25}W$ = 25% dextrose in water; IO = intraosseous; N/A = not applicable; OP = oropharyngeal.

TABLE 5. Subject Self-Assessment: Pre–Clinical Assessment Module Questionnaire ($N = 209$)

Question	
	Average (Range)
Number of years as a paramedic	7.7 (0–29)
Recent experience with any intubations	
ET intubation performed in the past 12 months	3.6 (0–14)
ET intubation performed in the past 30 days	0.5 (0–3)
Confidence in performing any intubations	*Percent Positive Response*
No confidence	0%
Little confidence	2%
Some confidence	20%
Considerable confidence	53%
Complete confidence	25%
Present level of fatigue	
Not fatigued	24%
Slightly fatigued	27%
Somewhat fatigued	35%
Very fatigued	9%
Extremely fatigued	5%
Anticipated effect of fatigue on performance	
None	50%
Slight	32%
Moderate	15%
Significant	1%
Completely	1%

ET = endotracheal.

TABLE 6. Subject Self-Assessment: Post–Clinical Assessment Module Questionnaire ($N = 146$)

Question	Percent Positive Response
Realism of asthma CAM	
Not realistic	3%
Slightly realistic	13%
Adequately realistic	44%
Very realistic	33%
Completely realistic	5%
Estimated number of steps completed in asthma CAM	
Major (essential) steps	78%
Minor steps	78%
Confidence in ability to intubate a pediatric asthma patient	
No confidence	1%
Little confidence	3%
Some confidence	26%
Considerable confidence	50%
Complete confidence	19%
Confidence in managing asthma patient similar to CAM	
No confidence	2%
Little confidence	9%
Some confidence	41%
Considerable confidence	41%
Complete confidence	7%

CAM = clinical assessment module.

CAMs. The most common discrepancy between the scoring form record and the videos for the arrest CAM and the asthma CAM was "Deliver ventilations at a rate of 20–30/minute," 9% and 10%, respectively. For the sepsis CAM, the most common discrepancy was "Avoid giving a second dose of seizure medicine," 21%.

A total of 4,445 steps from 72 simulations were independently reviewed by raters. The IRR was 86% (range: 66% to 94%) for the arrest scenario. The seizure scenario resulted in the highest IRR score of 91% (range: 77% to 100%). The asthma scenario resulted in 77% agreement (range: 63% to 80%). The IRR of the three scenarios combined was 85%, exceeding the acceptable level of agreement.

DISCUSSION

Prior studies have documented significant deterioration of paramedics' skills over time.[12,13] Miller et al.

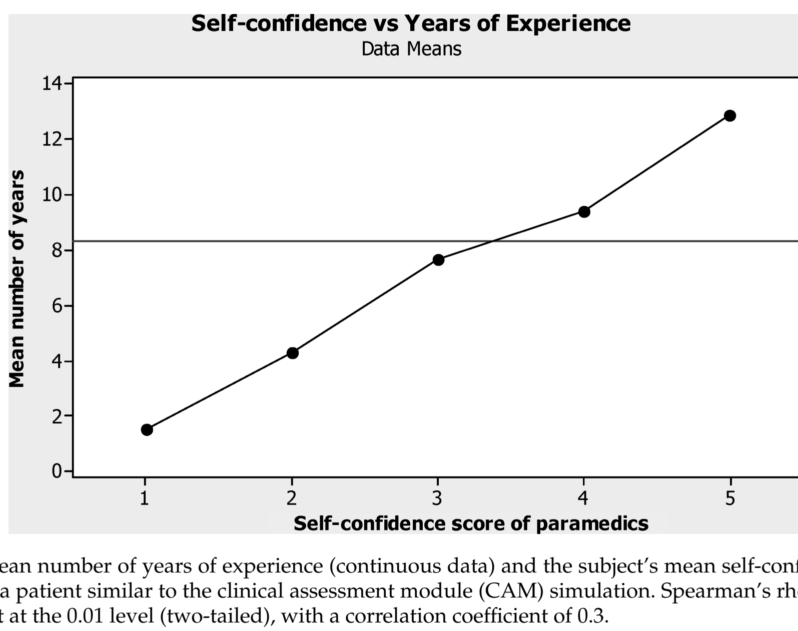

FIGURE 1. Comparison of mean number of years of experience (continuous data) and the subject's mean self-confidence score (ordinal data) in managing a pediatric asthma patient similar to the clinical assessment module (CAM) simulation. Spearman's rho test demonstrates a positive correlation that is significant at the 0.01 level (two-tailed), with a correlation coefficient of 0.3.

evaluated pediatric procedural skills in prehospital providers and reported cognitive and psychomotor skill degradation over time. They did not specifically assess decision-making skills.[14] Latman and Wooley found that emergency care attendants and EMT-Bs lost up to 10% of their knowledge 24 months after completion of an EMS training program. They demonstrated that the highest loss of competence was in the actual performance of basic skills. Attendants and EMT-Bs lost 55% and 50%, respectively, of basic skill proficiency.[1] Other investigators have also demonstrated that cognitive and procedural resuscitation skills atrophy with disuse.[15,16] Babl et al. also reported infrequent encounters with pediatric emergencies by paramedics in the city of Boston. The emergencies and procedures reported in their study were similar to those identified in our MERMaID database.[17] It is likely that the lack of correlation between skill performance and level of experience in our study was due to the low frequency of pediatric emergencies. Consequently, EMS medical directors and paramedic instructors cannot assume competency simply because a skill is occasionally used in the field, or because a paramedic can pass a written examination, especially when opportunities to apply the knowledge and skills are rare.

Despite its importance, the subject of knowledge and skill retention among EMS providers in the management of pediatric emergencies is infrequently discussed in the medical literature. A pediatric task force recommended "annual review of all skills necessary in treating critically ill or injured children."[18] Little research has been done to establish the required frequency of refresher courses and most effective methods for improving and maintaining skill and knowledge retention in prehospital providers. Sanddal et al. stated that "there is limited research on the effectiveness of teaching methods for prehospital emergency care providers, either in initial training or continuing education."[19] Herman et al. felt that "the ideal method to accomplish the goal of continuing education and recertification is necessary but has not been identified."[8] In 2004, Wood et al. concluded that EMS providers should receive cognitive continuing education biannually and psychomotor training on an annual basis.[20]

Before designing a curriculum for continuing education, educators should perform a needs assessment.[21] By targeting learner deficiencies, educators can create a more efficient curriculum. Some investigators used surveys and interviews to identify gaps in knowledge and skills. Based on a questionnaire sent to EMS administrators, Graham et al. concluded that training deficiencies in pediatric emergencies were common in the state of Oklahoma.[22] Losek et al. were able to determine the causes of unsuccessful prehospital intubations in children by interviewing providers within 24 hours after the resuscitation.[23] However, self-assessments can be inaccurate and biased, especially when they are based on personally determined standards.[24,25] Subjects in this study estimated that they had completed an average of 78% of the steps in the asthma scenario, though the actual percentage completed was 52%. Self-confidence in their ability to intubate children and to manage pediatric asthma emergencies remained average to high after the scenario.

Clinical simulations on both high- and low-fidelity simulators are showing promise as both teaching and evaluation tools that can bridge the gap between classroom and patient.[26] Health care educators have begun to embrace simulation as a means of enhancing the quality of patient care and reducing errors.[27] The CAMs were designed to test a combination of knowledge, cognitive skills (such as calculation and decision making), and procedural skills. These simulations allowed identification of the specific pediatric resuscitation skills of working paramedics that most needed improvement. The pediatric scenarios used in this study revealed several unexpected weaknesses in paramedic skills that would not have been easily identified by EMS medical directors because of the low frequency of pediatric emergencies. Hunt et al. found similar performance deficiencies among pediatric nurses and residents during simulated in-hospital pediatric emergencies.[28] The results of our study will be used to develop several paramedic educational modules focused on the most common and clinically significant problems in the prehospital management of seriously ill and injured children.

Various investigators have attempted to demonstrate construct, content, and predictive validity of patient simulation training programs using satisfaction and self-assessment surveys, simulated outcome measurements, time-to-solve and time-to-detect observations, structured performance checklists, and high-fidelity simulators.[29–36] Some investigators who have attempted to validate performance assessment tools used in simulations concluded that the accuracy, reliability, and validity of performance assessments are improved by devising precise, objective checklists.[36–40] We found that detailed checklists helped identify specific deficiencies that may not have been identified using global assessments of performance. The difference in overall performance scores between the high- and low-experience groups established the construct validity of the CAMs.

High-, intermediate-, and low-fidelity simulation manikins were used in this study. When combined with scripted role playing by actors, and with familiar equipment and drugs, all three manikins provided sufficient realism and content validity for the purpose of skill assessment in this level of health care provider. Future studies are planned to compare the effectiveness of paramedic training using these various simulation manikins.

LIMITATIONS

The CAM sessions were conducted over a period of time. Although the paramedics were strongly encouraged to not share any aspect of the CAM sessions with their peers or others, we could not guarantee that "contamination" of untested subjects did not occur. However, there was no obvious improvement in scores within EMS agencies over the course of the testing.

To minimize interrater variability, a single evaluator was used to derive a final performance score for each paramedic. Occasional mechanical failure of video equipment prevented us from validating all of the performance scores in this manner.

In general, a simulation does not have to reproduce precisely the anatomy, the situation, the environment, or every aspect of a procedure to be useful. However, it should have sufficient realism for the task being learned or assessed. Some steps in these resuscitations may not have been completed as a result of the artificiality of the environment (e.g., "Prepare suction."), inadequate realism of the manikin, or time constraints. However, the subjects received additional information from the evaluators and physical cues in the environment (e.g., nearby suction tubing). Eighty-two percent of subjects felt that the scenarios were "adequately realistic" or better. Despite the complexity of the scenarios, substantial percentages of paramedics did not use the entire allotted time. Based on responses to the surveys, it is unlikely that fatigue or lack of confidence substantially affected subjects' performances. Some of the deficiencies were strikingly consistent among different CAM scenarios (e.g., "Prep IO site." "Prepare suction." "Select correct oropharyngeal airway.") It is unlikely that all performance deficiencies resulted from the lack of appropriate cues, because many of the same deficiencies are occasionally observed in field reports. Steps required later in the resuscitation that were commonly missed because paramedics ran out of time are not listed in Tables 2–4.

Some paramedics expressed their concerns that testing their skills using simulations was quite stressful. Their stress may have affected performance. However, it is likely that the stress of managing a real, complicated, and seriously ill child would be equal to or greater than that of a simulated case. In addition, this degree of emotional response to the CAMs suggests that performance-based assessment using simulations provides more realism than using a written or skills station test.

These results may not be generalizable to all EMS agencies outside the state of Michigan. However, three of the five EMS agencies were nationally accredited through the Commission on the Accreditation of Ambulance Services. They are considered to be high-performance agencies with active, robust training programs, annual continuing education programs, and quality improvement processes. Consequently, it is likely that the skills of participating paramedics are at least equivalent to, if not better than, national averages.

CONCLUSIONS

The CAMs provided an objective evaluation of paramedics' ability to manage three simulated, but realistic, pediatric emergencies. Multiple deficiencies in paramedics' pediatric resuscitation skills were identified using these simulations. EMS educators and EMS medical directors should target these skill deficiencies, or attempt to identify skill deficiencies in their own paramedics, when developing continuing education in prehospital pediatric patient care.

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APPENDIX 1. Pediatric Cardiopulmonary Arrest ("Code") Scenario

Skill Set	Skill Components Scoring Sheet	Evaluator Guide
Phase 1: Airway & Breathing Assessment	– Check for responsiveness. – Check for spontaneous respirations. *(not present)* – Perform head tilt/chin lift airway maneuver. – Look in mouth for oral secretions or vomitus. *(not present)* – Select correct size mask. *("infant/child" size)*	Play audio: "mother-baby not breathing." Starting rhythm: asystole. *EMT*informs paramedic at the start of the scenario that "the infant's extremities and trunk are cyanotic." Mother is unable to answer questions.
Ventilation	– Select correct bag size. *("infant/child" size)* – Attach tubing to bag* and deliver high- flow oxygen (6–15 L/min). – Select correct size oropharyngeal airway. *(50 mm)* – Prepare suction device.* – Insert oropharyngeal airway. – Insert oropharyngeal airway correctly. – Use correct hand position on mask. – Perform bag–valve–mask ventilation.* – Begin ventilations within 60 seconds. – Check for chest rise with ventilations. – Auscultate lungs.* *(normal)* – Deliver ventilations at rate of 20–30/min. – Deliver ventilations at an appropriate tidal volume. *(approx. 40–75 mL, or roughly adequate with no excessive force)* – Verbalize "squeeze–release–release" and use 1:2 I-to-E ratio.	Provide information about physical exam only if requested. Paramedic should start BVM ventilations before turning over the task to the EMT.

(Contiuned on next page)

APPENDIX 1. (Continued)

Skill Set	Skill Components Scoring Sheet	Evaluator Guide
Circulation Assessment Circulation Management	– Attach cardiac monitor electrodes to chest.* – Check pulse. *(absent)* – Begin chest compressions.* – Begin chest compressions within 60 seconds. – Perform compressions at a rate of >100/min OR Correct EMT's slow compressions. – Correct EMT's hand position. – Call for additional, backup help.	If paramedic assigns chest compression to partner, *EMT* performs compressions at a rate of 80/minute and off center until corrected.
IO Access	– Put on gloves prior to IV/IO insertion. – Put on face & eye protection prior to IV/IO insertion. – Consider or attempt IV line.* – Abandon attempt at IV line within 90 sec. – Prep IO site. – Insert intraosseous line in the correct location (anywhere in proximal ½ of tibia.) – Aspirate blood or flush IO line with syringe & NSS. – Attach IV line to IO needle.*	IV line is unsuccessful. If IO attempted, it is immediately successful. *EMT*will state: "You got blood return immediately. Nice job."
Phase 2: Initial Drug Therapy	– Use Broselow tape to obtain correct weight.*(4–5 kg)* – Give epinephrine 1:10,000 concentration, 0.4–0.5 mL IO. *(conc = 0.1 mg/mL; dose = 0.01 mg/kg or 0.1 mL/kg)* OR – Give epinephrine 1:1,000 concentration 0.4–0.5 mL ET. *(10× IO dose) (conc = 1.0 mg/mL; dose = 0.1 mg/kg or 0.1 mL/kg)* – Check cardiac rhythm on monitor after epinephrine.[†] – Check pulse after epinephrine. *(absent)* – Give atropine 0.8–1.0 mL IO or 1.6–2.0 mL ET *(conc = 0.1 mglmL; dose = 0.02 mg/kg)*[†] – Check cardiac rhythm on monitor after atropine. – Check pulse after atropine. *(absent)*	When epinephrine is first given, change rhythm within 30 seconds to pulselesselectrical activity; rhythm = sinus bradycardia; rate ~ 50/min (preset). After second drug given (epinephrine or atropine), *EMT*informs paramedic that "the infant's abdomen is distending, and she's getting more difficult to bag." Repeat every 60 seconds until intubation.
Intubation	– Perform two-person BVM ventilations. – Select correct size laryngoscope blade. *(1.0 straight)* – Select correct endotracheal tube size. (3.5–4.0) – Insert the stylet into the ET tube. – Perform endotracheal intubation. – Auscultate gastric area. – Auscultate gastric area <u>before</u> lungs. – Auscultate lungs. – Maintain control of ET tube until secured. – Avoid excessive head/neck motion after intubation. – Secure ET tube (tape or pediatric tube holder). – Insert/secure ET tube to proper depth. *(3× tube size ± 1 cm, or 10–13 cm)* – Perform bag–tube ventilation with appropriate tidal volume. *(~40–75 mL)* – Perform bag–tube ventilation at 20– 30/min.	After intubation, check for bilateral chest rise on the mannequin. Do not give credit for intubation if it is esophageal.
Repeat Drug Therapy	Repeat initial dose of epinephrine within 3–5 minutes after first dose: – Give epinephrine 1:10,000 concentration, 0.5 mL IO OR – Give epinephrine 1:1,000 concentration 0.5 mL ET. – Check cardiac rhythm on monitor after epinephrine. – Check pulse after epinephrine. *(absent)* – Give repeat dose of atropine 1.0 mL or 2.0 mL ET *(conc = 0.1 mg/mL; dose = 0.02 mg/kg)* – Check cardiac rhythm on monitor after atropine. – Check pulse after atropine. *(absent)*	
Additional PEA Therapy Quality of CPR	–Deliver a fluid bolus of 100 ± 20 mL (20 mL/kg) of normal saline solution at any point after PEA develops. – Instruct EMT to continue ventilations AND chest compressions during drug delivery. – Assist EMT with ventilations or compressions while waiting for drug effect. – Avoid excessive pauses in compressions. *(>45 seconds during intubation; otherwise,>15 seconds)*	
Phase 3: Identification & Management of Complications	– Auscultate the gastric area. – Auscultate the lungs. – Insert the laryngoscope and inspect the position of the ET tube. – Reinsert the ET tube into the trachea. – Confirm ET tube placement. – Auscultate the gastric area. – Auscultate the lungs. – Secure ET tube (tape or pediatric tube holder). – Reconnect oxygen tubing.	When the paramedic first attempts to contact the base station, the *EMT*will discreetly a) unfasten the tube holder, pull the ET tube out of the trachea, then refasten the holder; and b) disconnect tubing from the bag. *EMT*reports that "the abdomen is distending again." Terminate scenario when paramedic contacts base station or initiates transport. (Base station does not respond.)

**Paramedic can ask EMT partner to perform this step.*

[†]These components were scored in conformance with the Michigan state's model pediatric protocols at the time of the study. These protocols have been subsequently updated.

APPENDIX 2. Pediatric Asthma Scenario

Skill Set	Skill Components (Scoring Sheet)	Evaluator Guide
Phase 1: Oxygen Therapy History	– Apply oxygen at 8–15 L/min.* – Apply oxygen within 60 seconds.* – Avoid using nasal cannula. – Apply cardiac monitor electrodes.* – Determine time of onset or duration. – Obtain past medical history. *(any one additional question related to prior pulmonary or cardiac problems)* – Inquire about medications. – Inquire about allergies.	*EMT* informs the paramedic at the start of the scenario that “the child is diaphoretic, breathing rapidly, audibly wheezing, has cyanotic lips, and when asked questions, points at her uncle.” Uncle will answer all questions, but DO NOT offer information if paramedic does not ask for it. *EMT* provides information about physical exam, but only if requested. If necessary, remind paramedic that chest does not move spontaneously. Pulse rate = *140/min.*
Physical Exam	– Auscultate lungs. – Measure respiratory rate. *(count; observe) (30/min by auscultation)* – Measure heart rate (by exam or monitor). *(120/min)* – Check level of consciousness. *(response to stimulus—talking; shaking) (awake but irritable)* – Check capillary refill. *(1.5 sec initially)* – Apply cardiac monitor electrodes (if not done yet)*	
Nebulizer	– Set up nebulizer correctly. – Deliver correct dose of albuterol (2.5–5.0 mg) by nebulizer. *(total dose)* – Give albuterol within 90 seconds.	At t = 3 minutes, *EMT* 1) informs the paramedic that “the child has become more agitated and is in more respiratory distress” and 2) suggests sedation. *(The child cries weakly and says, “I can’t breathe! I’m going to die!”)* Aunt is distraught and will not provide any additional information. *Pulse = 140/min.* At t = 4 minutes, *EMT* slumps the head & body forward and says “she’s breathing but she’s unresponsive.”
Phase 2: Ventilatory Support	– Lay patient supine within 15 seconds after unresponsiveness.* – Perform head tilt/chin lift airway maneuver.* – Select correct size oropharyngeal airway. – Insert oropharyngeal airway. – Insert oropharyngeal airway correctly. – Select correct size mask. – Select correct bag size. *(child or adult)* – Perform bag–valve–mask ventilation.* – Perform BVM ventilations within 60 seconds after unresponsiveness. – Verbalize “squeeze–release–release” and use 1:2 I-to-E ratio. – Deliver high-flow oxygen (8–15 L/min) through bag.* – Deliver 20–25 ventilations/min OR Correct EMT’s slow ventilations.*	If paramedic wants to transport the patient, EMT leaves to get stretcher until respiratory arrest. Respiratory rate = 6/min If pulse oximeter used, O_2 sat = 86%.
Management of Difficult Ventilations	– Reposition the head & neck and resume BVM. – Use two-person BVM ventilations for at least 30 seconds. – Auscultate lungs *(breath sounds distant, equal)* – Check pulse. *(70/min)* – Check for tracheal deviation. *(not present)* – Check capillary refill. *(2.5 sec)* – Apply cardiac monitor electrodes (if not done yet).*	At t = 5 minutes, or after 30 seconds of correct BVM ventilation, EMT informs paramedic that “the child is not breathing spontaneously; she’s getting more difficult to bag; and the chest is not rising much.”
Intubation	– Use Broselow tape to estimate weight. (25–*30 kg)* – Put on gloves prior to ET intubation. – Put on face & eye protection prior to ET intubation. – Prepare suction device. – Select correct size laryngoscope blade. *(#2.0)* – Select correct endotracheal tube size. *(5.0–5.5)* – Insert the stylet into the ET tube. – Perform endotracheal intubation. – Insert ET tube to proper depth *(3× tube size ±1 cm, or 14–17 cm)* – Confirm ET tube placement by colorimetric end-tidal CO_2. – Auscultate gastric area. – Auscultate gastric area <u>before</u> lungs. – Auscultate lungs. *(breath sounds distant, equal; wheezing)* – Maintain control of ET tube until secured. – Avoid excessive head/neck motion after intubation. – Secure ET tube (tape or pediatric tube holder) – Perform bag–tube ventilation at 20– 25/min. – Confirm ET tube placement by any method <u>after</u> securing tube.	After intubation, check for bilateral lung inflation on the mannequin. 30 seconds after endotracheal intubation: *Pulse = 120/min.* Cardiac rhythm = sinus tachycardia. If pulse oximeter used, O_2 sat = 90%.
Phase 3: Additional Asthma Therapy	– Select correct epinephrine concentration. *(1:1,000)* – Give correct weight-based dose (0.01 mg/kg) by volume (1 mg/mL) of epinephrine: 0.25–0.3 mL by SQ or IM injection or 0.5–0.6 mL by ET tube. – If IV inserted, avoid IV line until after intubation & epinephrine.	If epinephrine not yet given, *EMT* reports that “the patient is still hard to bag.” This statement is repeated every 60 seconds until epinephrine is given. If pulse oximeter used, O_2 sat = 96%. Terminate scenario when paramedic contacts base station or initiates transport. (Base station does not respond.)

**Paramedic can ask EMT partner to perform this step.*

BS = breath sounds; BVM = bag–valve–mask; CO_2 = carbon dioxide; EMT = emergency medical technician; ET = endotracheal; I-to-E = inspiratory-to-expiratory; IM = intramuscular; IV = intravenous; O_2 sat = oxygen saturation; SQ = subcutaneous; t = time.

APPENDIX 3. Pediatric Sepsis & Seizure Scenario

Skill Set	Skill Components Scoring Sheet	Evaluator Guide
Phase 1: Initial Assessment: *Appearance* *Breathing* *Circulation*	– Recognize presence of seizure activity within 60 seconds. – Reassure the father that the seizure will stop or will be treated. – Check for spontaneous respirations. *(present)* – Check pulse *(present; rate =160/min)* – Check capillary refill, skin color or temperature, or skin turgor. (Check one of three, at any time.) *(capillary refill delayed; skin mottled; skin turgor doughy; eyes deviated left)*	Provide information about physical exam only if requested. If asked, father estimates weight at "10 or 11 lb."
Airway & Oxygen	– Prepare suction equipment.* – Select correct size oropharyngeal airway. *(50 mm)* – Insert oropharyngeal airway. – Insert oropharyngeal airway correctly. – Select correct size non-rebreather mask. *("pediatric NRB" size)*	Record on computer when oxygen is applied. (O_2 sat changes automatically.) If IV line is attempted, it is unsuccessful. If an IO line is attempted, there is immediate blood return and normal flow. EMT provides cues.
Vascular Access	– Deliver high-flow oxygen (8–15 L/min) by non-rebreather mask within 90 seconds. – Apply cardiac monitor electrodes.* – Put on gloves prior to IV/IO insertion. – Put on face & eye protection prior to IV/IO insertion. – Consider or attempt an IV line.* *(unsuccessful)* – Abandon attempt at IV within 90 seconds. – Prep IO site. – Insert an IO line. – Aspirate blood or flush IO line with syringe & NSS.	
Phase 2: Anticonvulsant Therapy	– Correctly estimate weight at 6–8 kg, based on Broselow tape (pink zone) or age. Give a benzodiazepine: – Dilute benzodiazepine to 5 mg in 5 mL NSS (1 vial in 4 mL). *Diluted dosing:* – Midazolam (Versed) 0.3–0.4 mL IO or 0.6–0.8 mL IM *Undiluted dosing:* – Midazolam (Versed) 0.06–0.08 mL IO or 0.12–0.16 mL IM *(conc = 5 mg/mL or 0.2 mg/mL) (IO or IV dose = 0.05 mg/kg or 0.01 mL/kg) (IM dose = 0.1 mg/kg or 0.02 mL/kg)* OR *Diluted dosing:* – Diazepam (Valium) 0.6–1.6 mL *Undiluted dosing:* – Diazepam (Valium) 0.12–0.32 mL IO *(conc = 5 mg/mL or 0.2 mg/mL) (IO or IV dose = 0.1–0.2 mg/kg or 0.02–*0.04 *mL/kg) (PR dose = 0.5 mg/kg or 0.1 mL/kg)* – Avoid giving a second dose of benzodiazepine within 10 minutes.	Record on computer when benzodiazepine is given. (Seizure automatically stops 2 minutes after therapy.) Do NOT record rectal delivery—it will be ineffective because of erratic absorption. If a benzodiazepine dose is less than 1/10 of the lower end of the acceptable range, do NOT trigger the "Versed or Valium" menu item (which would stop the seizure).
Phase 3: History & Examination	Inquire about: – Duration of prior seizure. (10–*15 minutes)* – Symptoms or signs of recent illness (1 question). – Medications. – Allergies. – Prior medical illnesses. – Check pupils. – Check for nuchal rigidity. – Auscultate lungs. – Check for signs of trauma. *(none present)*	
Phase 4: Treat Shock & Hypoglycemia	– Give a fluid bolus of 120–160 mL of NSS. – Test serum glucose with dipstick.* *(30 mg%)* – Dilute $D_{50}W$ 1:1 (to $D_{25}W$) with normal saline or sterile water. OR Select D_{25} prefilled syringe. – Give 12–32 mL of the $D_{25}W$ solution IO. *(dose = 2–4 mL/kg; estimated weight = 7–8 kg)* OR – Give glucagon 1 mg IM.	
Phase 5: Management of Respiratory Depression	– Assess respirations once seizure stops. – Reposition head and neck. – Check pulse. *(present)* – Select correct size mask. *("infant/child" size, or neonate size with good seal)* – Select correct bag size. *("infant/child" size, or 500–750 mL)* – Attach tubing to bag and deliver high-flow oxygen (8–15 L/min) within 60 seconds after respiratory arrest.* – Perform effective bag–valve–mask Ventilation.* *(proper seal, adequate chest rise)* – Avoid or correct EMT's high-impulse ventilations. – Verbalize "squeeze–release–release" and use 1:2 I-to-E ratio. – Deliver ventilations at rate of 20–30/min.	(Hypoventilation automatically begins 3 minutes after therapy.) Record on computer when BVM ventilation is started and performed correctly. (O_2 sat will automatically rise.) EMT will do "high-impulse ventilations." Terminate scenario when paramedic contacts base station or initiates transport. (Base station does not respond.)

**Paramedic can ask EMT partner to perform this step.*

BVM = bag–valve–mask; conc = concentration; $D_{25}W$ = 25% dextrose in water; $D_{50}W$ = 50% dextrose in water; EMT = emergency medical technician; I-to-E = inspiratory-to-expiratory; IM = intramuscular; IO = intraosseous; IV = intravenous; NRB = non-rebreather; NSS = normal saline solution; O_2 sat = oxygen saturation; PR = per rectum.