Managing the Unique Size-related Issues of Pediatric Resuscitation: Reducing Cognitive Load with Resuscitation Aids

Robert Luten, MD, Robert L. Wears, MD, MS, James Broselow, MD, Patrick Croskerry, MD, PhD, Madeline Matar Joseph, MD, Karen Frush, MD

Abstract

A resuscitation is a complicated event that requires for its optimal outcome the effective completion of a distinct series of actions, some simple, some complex, most occurring simultaneously or in close proximity. In children, these actions are determined not only by the clinical situation, but also by a series of age and size factors particular to each child. Different tasks require different levels of *cognitive load*, or mental effort. Cognitive load describes the mental burden experienced by the decision maker and will be higher when the task is less familiar or more demanding. In the setting of resuscitation, it refers to the cumulative demands of patient assessment, the ongoing decisions for each of the various steps, and decisions around procedural intervention (e.g., intubation). In children, the level of task complexity and, hence, cognitive load is increased by the unique component of variability of pediatric age and size, introducing logistical factors, many of which involve computations. The purpose of this paper is to examine the effects of age/size-related variables on the pediatric resuscitative process and to explore how these effects can be mitigated using resuscitation aids. The concept of cognitive load and its relation to performance in resuscitation is introduced and is used to demonstrate the effect of the various aids in the pediatric resuscitative process. **Key words:** cognitive load; pediatrics; resuscitation; children; decision making; resuscitation aids. ACADEMIC EMERGENCY MEDICINE 2002; 9:840–847.

There are two important practical considerations in a resuscitative process: 1) delay in the time needed to implement a given action or prolonged *implementation time* and 2) error in decision making as a result of, or in part from, suboptimal or inadequate *critical thinking time.*

Implementation time is a term that describes the time lapse from evaluation and decision to implementation of an action. Besides the obvious repercussions of a delay in implementation of critical care, clinical performance is also dependent on reliable and rapid feedback; i.e., the shorter the interval between action and consequence in the feedback loop, the better. A major failure in the feedback process is time delay. One might argue that any resuscitation aid that shortens this interval will carry an important feedback advantage, with the potential for improving clinical performance.

Implementation time may be prolonged and more prone to error in pediatric resuscitation because of the multiple age- and size-related factors particular to children, which must be addressed in the resuscitation sequence beginning with the evaluation phase to the accomplishment of a completed action. Figure 1, sections A and B, graphically compares the resuscitative processes in the adult vs. child in which implementation time is prolonged because of the necessity of addressing these multiple factors. (The graphic representations in Figure 1 are for demonstration purposes only and not based on actual comparative resuscitation data.)

The second issue to be considered is critical thinking time, or time specifically dedicated to the intellectual activity of evaluation, prioritization, and synthesis of information concerning a given patient based on his or her specific clinical condition. For purposes of discussion, we divide intellectual or "thinking" activities into two broad groups (Table 1). The first group includes activities that require little, if any, conscious input. The principal feature of these activities is their high degree of familiarity, which leads us to refer to them as automatic (passive, learned rule-based) thinking ac-

From the Department of Emergency Medicine, University of Florida, Jacksonville, FL (RL, RLW, MMJ); the Department of Emergency Medicine, Catawba General Hospital, Hickory, NC (JB); the Department of Emergency Medicine, Dalhousie University, Halifax, Nova Scotia, Canada (PC); and the Division of Emergency Medicine, Department of Surgery, Duke University Medical Center, Durham, NC (KF).

Received October 12, 2001; revision received January 8, 2002; accepted February 6, 2002.

Drs. Luten, Wears, and Broselow are shareholders in Broselow Medical Technologies, involved in the design and production of color-coded materials.

Address for correspondence and reprints: Robert Luten, MD, Department of Emergency Medicine, Shands Jacksonville, Jacksonville, FL 32209. Fax: 904-244-4508; e-mail: luten@ufl.edu.

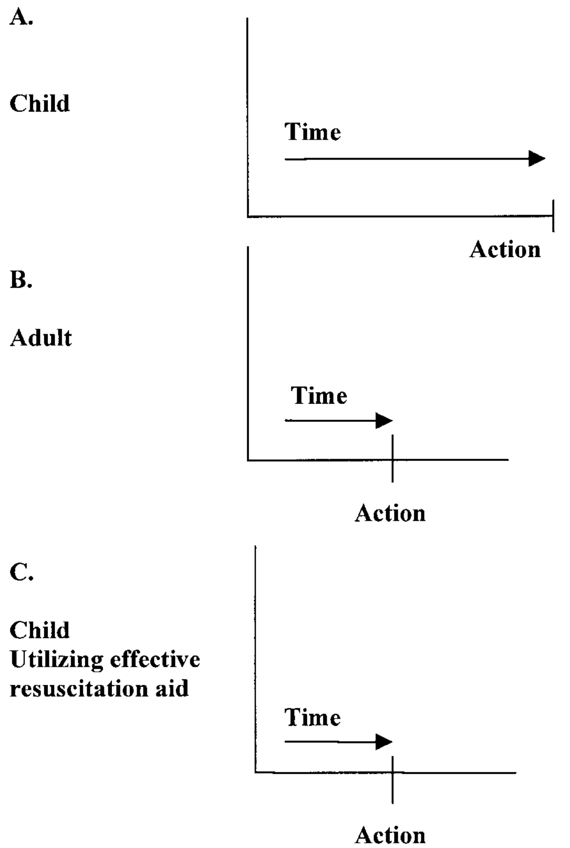

Figure 1. Graph of implementation times. *Implementation time* represents the time from decision to completed action. It may be prolonged in the child (**A**) as compared with the adult (**B**) because of the time needed to complete the logistical steps of resuscitative process. With rapid completion and/or elimination of logistical steps using an effective resuscitation aid, implementation time can be shortened (**C**). (This graph was created to visually demonstrate general concepts and is not based on actual clinical data.)

tions.[1,2] Examples include simple activities such as eating and more complex activities such as driving a car to work. They may also be referred to as parallel thinking processes, because they can occur simultaneously; i.e., doing one does not preempt or interfere with doing another. These automatic activities are performed with a great deal of accuracy and require minimum mental effort.

The second type of thinking activity is designated as nonautomatic (active, integrative knowledge-based) thinking actions.[1,2] These actions are more sophisticated and, correspondingly, require more conscious input because of their greater degree of unfamiliarity. They can vary from simple calculations to more sophisticated activities such as driving to an unfamiliar location, or other activities that include evaluation, feedback, and prioritization of information, such as the assessment and formulation of a plan for a child in shock or respiratory failure. Nonautomatic activities are effortful, and tend to be prone to error. This type of action may also be called preemptive since doing one nonautomatic action may interfere or even preclude the ability to do another nonautomatic activity. More than one automatic activity and one nonautomatic activity may be done without preempting any, but only one nonautomatic activity can be done at a time since one preempts or interferes with the other. As an example, one can drive a car (automatic activity), eat a sandwich (automatic activity), and make up a grocery list (nonautomatic activity). However, one cannot read a newspaper and balance a checkbook at the same time (both nonautomatic activities). In terms of resuscitation, the calculation of drug doses, drug volumes, tidal volumes, etc., are all nonautomatic activities, and all are related to the varying sizes of children. These calculations may interfere with/preempt evaluation and prioritization of patient management (a nonautomatic activity).

AGE AND SIZE-RELATED CONSIDERATIONS IN RESUSCITATION: THE EFFECT OF RESUSCITATION AIDS

In adult resuscitation, most clinicians are familiar with drug doses, commonly used equipment sizes, and normal physiology; there is little or no need to recall, access, or calculate these variables (they are thus automatic activities). Therefore, the clinician's mind is free for other nonautomatic activities such as evaluation and prioritization, the *critical thinking* activities of a resuscitation. This is *not* the case in pediatric resuscitation. Body weight requires estimation, drug doses require calculation, equipment sizes may also need calculation, and the relevant formulas must be recalled. The clinician therefore is not free from addressing these issues. Since these activities require higher-level, nonautomatic thinking, they can interfere with the *critical thinking* of resuscitation, another nonautomatic activity. Age- and size-related considerations of pediatric resuscitation, how they affect the resuscitative process, and how they may be addressed are outlined below.

1. Estimation of Weight. In order to dose medications, the patient's weight must be known or estimated, as most dosing in children is done on a per-kilogram basis. Clinical estimations of patient weight in both newborns and older children have been shown to be inexact.[3,4] Many systems recommended for pediatric resuscitations use precalculated doses in the reference material.[5–9] However, failure to correctly estimate a child's weight renders these systems inaccurate. Systems that use length as predictor of weight[3,4,10,11] provide sufficiently ac-

TABLE 1. Cognitive Aspects of Pediatric Resuscitation—Definition of Terms*

- *Implementation Time*—Time from evaluation and decision to completion of an action. The goal of resuscitation systems is to minimize this time by eliminating logistical factors which prolong it unnecessarily.
- *Critical Thinking Time*—A finite period of time in a resuscitation, variable depending upon the nature of the clinical situation, during which critical thinking can occur.
- *Critical Thinking*—A complex thinking process that involves the interaction of evaluation, synthesis, and prioritization of information inherent in managing a resuscitation.
- *Automatic vs. Nonautomatic Thinking Processes*—

Thinking Process	Descriptor	Characteristics	Common Example	Example in Resuscitation
Automatic (passive, learned) thinking actions require little, if any, conscious mental action	*Parallel* processes, i.e., multiple automatic processes, can occur simultaneously without interference	Fast, effortless, highly accurate, rule-based	Driving a car, eating	*Automatic* Bag–valve–mask ventilation of an apneic patient, color matching
Nonautomatic (active, integrative) thinking actions are more sophisticated, multifaceted processes, and require conscious effort	*Preemptive* process, i.e., actions interfere with or even preempt doing other hierarchical actions	Slow, effortful, prone to error, knowledge-based	Making a grocery list, balancing a checkbook	*Complex* Calculating drug doses, calculating equipment formulas, calculating fluids, calculating tidal volumes

*The terms defined herein are descriptive only and, at the risk of oversimplification, are used to convey concepts in an understandable language for clarification of the pediatric resuscitative process.

curate patient weights for emergency dosing. Moreover, length measurements give a consistent estimation of ideal body weight, even if actual body weight differs (obese or emaciated patients), which is more appropriate for emergency drug dosing.

2. Choosing Appropriate-size Equipment. A particular problem with children is the large size variation (3-kg newborn to 70-kg adolescent). There exist multiple charts, formulas, and references for choosing appropriate-size equipment in children. Taken individually, the formulas seem simple and functional; e.g., endotracheal (ET) tube lip-to-tip insertion length is 3 × tube size in mm (3.5 mm × 3 = 10.5 mm insertion length). However, in the heat of a resuscitation, recollection and computation of multiple formulas are time-consuming and error-prone. The most critical piece of equipment for pediatric resuscitation in terms of sizing is the ET tube. There are several formulas and anthropomorphic measurements recommended for estimation of correct ET tube size in children. Examples of some are: internal diameter (ID) mm = (age + 16)/4,[12,13] (age + 18)/4,[14] width of the fifth finger,[12,15] and width of the fingernail,[15] as well as age- and weight-based charts. Of all the above methods, (age + 16)/4 has been shown to be the most accurate[12,15]; however, the formula requires recall or quick reference, knowledge of age (not always known in emergencies), and error-free calculating. The formula also cannot be used for estimation of tubes below 4.0 mm (3.5-, 3.0-, and 2.5-mm) or for patients less than 1 year of age, since (0 + 16)/4 = 4, therefore, a 4.0-mm tube would be the smallest tube possibly selected.

Anthropomorphic measurements such as size of the little fingers, the fingernail, or the nasal alae would seem practical in emergencies since they require no memory or calculations, but studies have shown these measurements to be less accurate than other methods[16] to predict ET tube size. Comparisons of age, weight, and length measurements have consistently shown length to be superior to age or weight[12,16] in estimating correct tube size, especially for emergency intubation where age and weight are not known. In any system, selection of a tube for pediatric resuscitation one size larger and smaller is recommended.

3. Recall or Reference to Doses. This is one of the areas that has been widely addressed to a large extent. Most clinicians or departments have a method of accessing dosage information to eliminate having to rely on memory.

4. Calculation of Doses. There is abundant evidence that physicians' and nurses' abilities to calculate drug doses in an emergency are error-prone.[17–19] This area has seen some improvement. Many emergency departments use cards, computer printouts, books, or charts with precalculated doses. These systems are only as accurate as the weight referenced, however. As such, they may be less-than-optimal to ineffective, or even toxic if unmeasured, estimated weights are used. In contrast, length-based body-weight or ideal-body-weight estimates provide consistently accurate weights for precalculated dosing systems[3,20] (Shah A, personal communication, data from work in progress, 2001).

5. Calculation of Drug Volume and Delivery. This is an underappreciated area for potential delay and error. Most systems are physician-oriented, giving only precalculated doses (usually in milligrams) and do not precalculate the volume of drug to draw up, leaving nursing personnel to do these calculations in the stress of a resuscitation. Again, the literature on calculations done in nonemergencies by nurses demonstrates that it is also an error-prone practice.[20] Clearly, the stress of a resuscitation or other emergencies can only exacerbate the potential for error. Ideally, a resuscitation system should include the precalculated drug volume in milliliters from available concentrations. Another simple, rapid, and calculation-free method is the use of prefilled syringes with a marker identifying the volume of drug required for the size of the patient. The correct amount of drug will be delivered if the syringe is drawn up or emptied to the appropriate line, thus eliminating the need for dose calculation or referencing at the physician or nursing level, and, from a practical point, transforms this process into an automatic (passive, learned) activity.

6. Other Dose/Size-related Variables. There are other age/size-related variables that must be calculated and therefore increase time during the resuscitation period and have also increased potential for error. Many times these variables are listed in formula form, without including calculations for a given patient. Individually, they are simple and require minimal time and calculation; however, collectively, they may be problematic. Examples include:

Fluids
- Bolus (20 mL/kg)
- Maintenance fluids (formulas)
- Burn fluids (formulas)

Airway variables
- Tidal volume (10–15 mL/kg)
- ET tube insertion length
  - (distance in mm = 3 × ET size in mm)
- Respiratory rate (RR) for age

When decisions are made there is a trade-off between accuracy and the amount of effort that is put into the decision.[21,22] This is fairly inconsequential when the decision is not a complex or difficult one. However, when the cognitive demand goes up (cognitive overload), something has to change. If we assume that the level of effort remains the same, then the decision maker can settle for a suboptimal strategy, which means that accuracy must inevitably suffer, or, alternatively, opt for a simplifying strategy. The suboptimal strategy here is to take longer to make the decision. This can be consequential, if the window of opportunity for successful intervention is short compared with the decision time.

Thus, in order to preserve accuracy (critical in pediatric resuscitation) and avoid the error inherent in delayed decision making, the only reasonable strategy is to simplify. Simplification actually reduces the cognitive effort or load, and therefore allows accuracy to be maintained, or even improved.

Resuscitation aids are used to mitigate the complexity introduced by age/size variables in pediatric resuscitation. Table 2 describes the resuscitation aids in terms of their completeness, ease of application, resilience, and performance reinforcement. The *completeness* of a resuscitation aid or system refers to its ability to eliminate age/size variables: give the actual tube size for a patient versus a formula that requires calculation, the actual dose versus a formula that requires calculation, the actual fluid volume versus volume per kilogram, etc. In other words, completeness refers to the ability of the system to reduce the cognitive load by transforming nonautomatic activities into automatic ones. The *ease of application* is subjectively rated in terms of difficulty of a practitioner incorporating the system into his or her practice.

Resilience of the system relates to its performance under suboptimal conditions; i.e., does the system function if computers "go down," if patient weight is incorrectly estimated, or if the patient is measured incorrectly with a length-based tape?

Performance reinforcement refers to the ability of the system to maintain accuracy and prevent "downstream" errors, i.e., those that happen after an accurate action has occurred in the resuscitative process by providing ongoing reinforcement of information. For example: a wall chart posted in plain view with dosages and drug volumes visible, or color or other code matching of patient dose to patient ID armband.

The resuscitation aids are divided into those that depend on an estimation of weight (*estimation-based methods*) for access and those that depend on a length measurement for access (*measurement-based methods*) (Tables 2 and 3). The aids are presented in hierarchical order from the least to the most sophisticated from left to right. Three estimation-

TABLE 2. Characteristics of Resuscitation Aids for Pediatric Resuscitation

	Estimation-based Methods			Measurement-based Methods		
	Memory	Drug/Equipment Cards	Precalculated Equipment Drug Cards, Charts, and Computer-assisted Aids	Charts	Tape & Reference	Therapeutic Code System
Function/remarks	System depends upon recall of all pertinent variables.	System consists of cards or charts with dose, formula, vital signs, which are available at the time of a resuscitation. No calculations of drug doses or formulas are included, relying on the practitioner to do this during the resuscitation.	Wall charts or cards with doses precalculated to eliminate this variable during a resuscitation. An estimated weight is used to access information.	Consist of charts with equipment accessed by a length measurement.	Consist of a tape that requires a two-step process for weight estimation and a reference manual.	Zone dosing accessed by a length measurement. A code then identifies patient's group according to size. The code can be a number, a sign, a color, or a descriptive name such as small infant or large child.
Completeness	Most incomplete of the systems.	Completeness of the system is variable, from drug dosing only cards, to more inclusive charts.	Variable. Precalculated drug doses are included; however, other variables may be lacking, for example, endotracheal (ET) tube formulas, per-ilogram fluid volumes or tidal volumes vs actual calculated ET tubes or volumes for a given patient. Other variables example: lip-tip insertion length may not be included.	Only a few available; some include equipment and not medications.	Drug doses only.	Complete list of drugs and equipment.
Ease of application	Most difficult, based on an individual preferences input.	The system is self-explanatory but prior knowledge is essential in order to know what information is included.	Fairly easy to understand and master.	Requires inservice, but results are reproducible.	Requires prior in-service for use, but otherwise simple, and results are reproducible.	Requires inservice.
Resilience	Can function without tape or length measurement, but accuracy is dependent upon accuracy of estimation.	Loss of the chart/card incapacitates the system.	Loss of chart or card incapacitates the system. Computer printouts are dependent upon technology. Computer early error may not have internal checking function.	Unavailability of tape requires clinical estimations of weight, which may be inaccurate.	Unavailability of tape requires clinical estimations of weight, which may be inaccurate.	Unavailability of tape requires clinical estimations of weight, which may be inaccurate.
Performance reinforcement	None.	Provides minimal reinforcement since no calculations are included, and calculation associated error and time delay is inherent.	Precalculated charts provide some ongoing reminder to staff of correct dose and equipment. Availability of charts and staff training required.	Similar to precalculated charts.	Little reinforcement since manual is in the possession of one provider only.	Coding of therapeutic information to patient by coded armband provides visual (recognizable) key.

TABLE 3. Effects of Resuscitative Aids on Reducing Cognitive Load Secondary to the Logistical Factors of Pediatric Resuscitation

	Estimation-based Methods			Measurement-based Methods		
	Memory	Drug/ Equipment Cards	Precalculated Equipment Drug Cards, Charts, and Computer-assisted Aids	Charts	Tape & Reference	Therapeutic Code System
Weight estimation	0	0	0	+	+	+
Equipment selection	0	Variable	Variable, depending upon completeness	Variable	Variable	+
Location of equipment	0	0	0	0	Variable	+ if stored by code
Recall reference to doses	0	+	+	+	+	+
Drug dose calculation	0	0	+	+	+	+
Age/size variables	0	0	Variable	Variable	Variable	+

*0 = no effect; + = improves performance.

based methods are described. Memory, the first method, is the most error-prone as it is dependent totally on human factors. It is also the least consistent between providers. Drug/equipment cards or charts contain drug doses, formulas, and vital signs that are available at the time of the resuscitation. No calculations of drug doses are provided, thus requiring the practitioner to perform these functions at the time of the resuscitation. Precalculated drug/equipment cards, charts, and computer-assisted aids all provide precalculated variables, thereby eliminating the necessity of performing this function during the resuscitation. An estimated weight is used to access this information.

The measurement-based methods use a length-based measurement to access the system. The first is a chart accessed by a length measurement.[5,10] The second method uses a tape and a reference manual.[11,23] The last group consists of a therapeutic coding system, accessed by length measurement.[24] A patient group or dosing zone is accessed by a length measurement. A code then identifies the patient's group or zone according to size. The code can be a number, a sign, a color, or a descriptive name such as "small infant" or "large child."

The resuscitation aids, by eliminating logistical barriers such as drug dosing or equipment access, reduce the burden of nonautomatic (active, integrative) activities and therefore free mental resources for *critical thinking*. Thus, not only is implementation time reduced (Fig. 1, section C), but mental errors are potentially prevented. Historically, physicians seem to have had an interest in memorizing (lists, mnemonics, differentials, etc.), and seem somewhat guilt-prone when they have to look something up, or "crib." This has generated some historical inertia against using aids as described herein, similar to the protestations that come out when algorithmic decision making is advocated (criticized as "medicine-by-numbers"). Given the increased information loading that has occurred in medicine, and given the improved technology, every effort should be made to bypass or reduce cognitive activity, and relegate to the automatic level where possible. The error potential of the resuscitative process decreases as nonautomatic activities are eliminated or converted to automatic activities. The conversion of nonautomatic activities to automatic activities occurs with use of the resuscitation aids from left (memory, estimation-based) to right (therapeutic code, measurement-based).[1,2] Strategies to enhance the usefulness of a resuscitation aid are outlined in Table 4.

DISCUSSION

During the pre–pediatric advanced life support/advanced pediatric life support (PALS/APLS) era, it became apparent that clinicians felt uncomfortable with pediatric resuscitation. Some of the obvious reasons were related to the lack of a developed, accessible, child-specific body of knowledge, the infrequency of treating critically ill children, and the emotional experience of having a child vs. an adult as a patient, i.e., the high cost of failing. The life support courses and the growth of pediatric emergency medicine as a specialty have both had an impact on enhancing care and raising comfort levels in dealing with critically ill children. It has been the authors' experience, however, that the age/size-

TABLE 4. Strategies to Enhance the Usefulness of Resuscitation Aids

Access

- Eliminate human error. Convert estimation methods to measurement methods by using one of the current length/weight or length/equipment adjuncts.[1,2,8,9]

Completeness

- Include all information pertinent to the resuscitation and postresuscitative process.
- Precalculate all variables from drug doses to endotracheal tube size. Include drug volumes as a parameter.

Ease of Application

- Simplify the application of the system by reducing the number of components and making them easily recognizable.
- Include in-service applicable to the entire team, establishing a common language to communicate information.

Resilience

- Develop thorough understanding of the system so that technological failures do not nullify the entire advantage.

Performance Reinforcement

- Provide accessible, uncomplicated, visual reminders that provide redundancy within the system that repeatedly reinforces accuracy and prevent ``downstream'' error. Example: A wall chart, or matching a correct dose of medication to the proper patient by matching coded dose to patient armband.

related factors were, and still are, responsible for a significant portion of this discomfort (Luten R et al., unpublished blinded surveys of life support course participants, 2001) and that these can be mitigated with the use of resuscitation aids. The improvement in discomfort is not totally related to prior training or background. Even though a person is well versed in formulas for equipment selection and recall of drug doses (a pediatric-oriented practitioner), the elimination of the necessity to do estimations and calculations during a resuscitation (thus eliminating nonautomatic activities) frees the practitioner for *critical thinking*, and thus eases his or her discomfort by reducing cognitive load, regardless of prior training. By breaking the cognitive load down into manageable parts, several things are accomplished. The distinction between *automatic* and *nonautomatic* behaviors begins to unravel the process and reduce its complexity. An effective strategy for enhancing performance in resuscitation is to transform some cognitive tasks from nonautomatic behaviors to automatic ones.[1,2] The more behaviors that can be relegated to an automatic level, the less the uncertainty in the decision-making process. The need for decisions exists only where uncertainty exists, so if there is no uncertainty, there is no need for a decision maker. Further, errors occur only when decisions are made. Thus, reducing the entropy or uncertainty in any process will inevitably lead to a reduction in the number of decisions required and therefore in the number of errors made.

Future research needs to not only confirm the concepts described in this article, but also examine the entire process of individual decision making and team function in resuscitation. The same factors that lead to increased cognitive demand for individual providers also affect the resuscitation team as a whole. The team has been compared with an information processing unit,[25] and efforts need to be applied to maintain and optimize what is referred to as the "collective cognition"[26] of the team. The same factors affecting individual performance, i.e., the cognitive demands of nonautomatic vs automatic processes with resultant delay and error, are also operative for the team. Optimal team function involves proper apportionment or spreading of the cognitive load between the various working components of the team—doctors, nurses, ancillary staff—and utilization of resuscitation aids to reduce the load.

Apart from the cognitive demands placed on team and individual providers in the actual resuscitative process, additional logistical issues related to each practice environment need to be considered. Thus, characteristics of team dynamics, the resuscitation area, physical location and organization of equipment, and equipment maintenance and function all require evaluation. Mock codes provide a cognitive "walk-through" of the resuscitative process. This cognitive simulation or mental rehearsal serves several useful purposes. It provides opportunities for familiarization with equipment and identification of potential deficiencies, practicing common scenarios, and evaluation of team cohesion. It provides an opportunity to reduce the performance anxiety that these situations typically generate. Interestingly, a discordance between confidence level and performance skills has been observed in residents, and can be demonstrated in simulation scenarios.[27] Putting trainees into well-simulated code scenarios has a parallel with the behavioral technique of "flooding," which may lead to a significant reduction in anxiety after several exposures.[28] The increasing cognitive familiarity that develops through repeated exposures would be expected to lead to a systematic desensitization[29] to the fears typically provoked by the management of critically-ill children.

CONCLUSIONS

In the process of discussing the effects of size-related considerations in pediatric resuscitation and the use of resuscitation aids, this article has placed emphasis on some of the critically important cognitive aspects of the pediatric resuscitation process. A limitation of the study is the theoretical nature of the discussion, and the risk of oversimplifying some cognitive concepts. An effort has been made to reduce mental activity down to two basic modes of action, automatic and nonautomatic thinking processes. This permits a simple, organizational approach to the activities involved in pediatric resuscitation. The primary aim of this article has been to define some basic cognitive components of the resuscitative process and to describe the significance of age/size-related issues in pediatric resuscitation and the role of resuscitation aids in this context. Ultimately, a more in-depth analysis of pediatric resuscitation, and other critical emergency processes, might be appropriate using this cognitive approach. The goal is an *optimization of the cognitive resources* available to the resuscitation team, and a corresponding reduction of error in such demanding activities.

In summary:

1. Cognitive load is an important and critical feature of the pediatric resuscitation process.
2. Cognitive load depends on the degree of uncertainty in the process.
3. The degree of uncertainty determines the number of decisions that will need to be made.
4. The more complex, nonautomatic decisions in the process, the greater the cognitive load.
5. Increased cognitive loading means increased error.
6. In the setting of pediatric resuscitation, size-related variables introduce the need for nonautomatic activities and decisions, thereby increasing the cognitive load. The size-related variables are unique to the resuscitation of children.
7. These nonautomatic, size-related decisions can be relegated to an automatic level using resuscitation aids.
8. Resuscitation aids can reduce cognitive load and therefore reduce error.
9. Some resuscitation aids are better than others. There is a need to optimize and refine the operating characteristics of resuscitation aids.

References

1. Schneider W, Schiffrin RM. Automatic vs controlled processing. Psychol Rev. 1977; 84:1–64.
2. Reason J. Human Error. Cambridge, UK: Cambridge University Press, 1990.
3. Lubitz DS, Seidel JS, Chamcides L, et al. A rapid method for estimating weight and resuscitation drug dosages from length in the pediatric age group. Ann Emerg Med. 1988; 17:576–80.
4. Chan GM, Moyer-Mileur L, Rallison L. An easy and accurate method of estimating newborn birthweight for resuscitation. Am J Perinatol. 1992; 19:371–3.
5. Luten RC, Wears RL, Broselow J, et al. Length-based endotracheal tube selection in pediatrics. Ann Emerg Med. 1992; 21:900–4.
6. Bruce C, Gutierrez-Mazorra J. Pediatric Emergency Drug Manual, Fourth Edition. Birmingham, AL: Children's Hospital of Alabama, 1984.
7. Simon HK, Weinkle DA. Over the counter medications. Do parents give what they intend? Arch Pediatr Adolesc Med. 1997; 151:654–6.
8. Barone M. Harriet Lane Handbook, Fourth Edition (cover insert). St. Louis, MO: Mosby–Year Book, 1996.
9. Greens S. ED Pocket Pharmacopeia. Loma Linda, CA: Tarascon Publishing, 1999, p 5.
10. Oakley P. Inaccuracy and delay in decision making in pediatric resuscitation, and a proposed reference chart to reduce error. BMJ. 1988; 297:817–9.
11. Garland JS, Kishaba RG, Nelson DB, et al. A rapid and accurate method of estimating body weight. Am J Emerg Med. 1986; 4:390–3.
12. Davis D, Barbee L, Ririe D. Pediatric endotracheal tube selection: a comparison of age-based and height-based criteria. J Am Assoc Nurse Anesthetists. 1998; 66:299–303.
13. Chameides L. Textbook of Pediatric Advanced Life Support. Dallas, TX: American Heart Association, 1997.
14. Lee CM. ''Training'' of pediatric endotracheal tubes. Anesth Analg. 1987; 66:920.
15. King B, Baker MD, Braitman LE, et al. Endotracheal tube selection in children: a comparison of four methods. Ann Emerg Med. 1993; 22:530–4.
16. Keep PJ, Manford ML. Endotracheal tube sizes for children. Anesthesia. 1974; 29:181.
17. Perlstein PH, Colison C, White M, et al. Errors in drug computation during newborn intensive care. Am J Dis Child. 1979; 133:376–9.
18. Baldwin L. Calculating drug doses. BMJ. 1995; 310:1154.
19. Rolfe S, Harper NJN. Ability of hospital doctors to calculate drug doses. BMJ. 1996; 310:1173–4.
20. Traub SL, Kichen L. Estimating ideal body mass in children. Am J Hosp Pharm. 1983; 40:107–10.
21. Bayne T, Bindler R. Medication calculation skills of registered nurses. J Contin Educ Nurs. 1988; 19(6):258–62.
22. Simon HA. A behavioral model of rational choice. Q J Econ. 1955; 69:99–118.
23. Losek JD, Garland JS. First Five Minutes, 10th Edition. Milwaukee, WI: Maxishare, 2001.
24. Wolpe J. Psychotherapy by reciprocal inhibition. Stanford, CA: Stanford University Press, 1958.
25. Cohen MS, Orasanu J, Calderwood R, Zsambok CE (eds). Decision Making in Action: Models and Methods. The Naturalistic Basis of Decision Biases. Greenwich, CT: Ablex Publishing Corporation, 1992.
26. Duffy R. Team decision-making biases: an information-processing perspective. In: Klein GA, Orasanu J, Calderwood R, Zsambock CE (eds). Decision Making in Action: Models and Methods. Norwood, NJ: Ablex Publishing, 1993.
27. Galegher J. Intellectual teamwork and information technology: the role of information systems in collaborative intellectual work. In: Carroll J (ed). Applied Social Psychology in Organizations. Hillsdale, NJ: Erlbaum, 1990.
28. Nadel F, Lavelle J, Fein J, et al. Assessing pediatric senior residents' training in resuscitation: fund of knowledge, technical skills, and perception of confidence. Pediatr Emerg Care. 2000; 16(2):73–6.
29. Stampfl TG, Levis DJ. Essentials of implosive therapy: a learning-theory-based psychodynamic behavior therapy. J Abn Psychol. 1960; 72:496–503.