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The voice advisory manikin (VAM): An innovative approach to pediatric lay provider basic life support skill education☆

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Summary
Aim: To determine the efficacy of immediate, standardized, corrective audio feedback training as supplied by the voice advisory manikin (VAM) compared to high quality standardized instructor feedback training for the initial acquisition of 1-rescuer lay provider pediatric BLS skills.
Materials and methods: Lay care providers of hospitalized children 8—18 years were randomized to VAM ($n = 23$) or standardized human instruction (SHI, $n = 27$) training in one-rescuer pediatric BLS. After an identical video/instructor introduction to CPR and 20 min of training in their respective group, quantitative CPR psychomotor skill data was recorded during 3-min CPR testing epochs. All manikins used in training and testing sessions were identical in outside appearance and feel of doing CPR. The primary outcome measure was CPR psychomotor skill success defined prospectively as 70% correct chest compressions (CC) and ventilations (V). Subjects not attaining these success goals retrained for 5 min in their respective training group and were retested. Data analysis using student t-test and χ^2-tests as appropriate.

Abbreviations: AHA, American Heart Association; BLS, basic life support; CC, chest compressions; CPR, cardiopulmonary resuscitation; SHI, standardized human instruction; V, ventilations; VAM, voice advisory manikin

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Results: VAM trainees delivered more total CC/min (58.7 ± 7.9 versus 47.6 ± 10.5, $p < 0.001$), correct CC/min (47.9 ± 15.7 versus 31.2 ± 16.0, $p < 0.001$), total V/min (7.8 ± 1.2 versus 6.4 ± 1.4, $p < 0.001$), and correct V/min (5.4 ± 1.9 versus 3.1 ± 1.6, $p < 0.001$). Overall error rates per individual were lower in VAM trainees for chest compressions ($18.1 \pm 23.2\%$ versus $34.9 \pm 28.8\%$, $p < 0.03$) and ventilations ($32.0 \pm 19.7\%$ versus $50.7 \pm 24.1\%$, $p < 0.005$). More VAM (12/23, 52%) than SHI (1/26, 4%) trainees passed the initial skill tests ($p \leq 0.0001$). After remediation and retesting, the difference in rate of attaining success goals remained significant: VAM 15/23, 65% versus SHI 7/26, 27% ($p = 0.008$).
Conclusion: Immediate, standardized, corrective audio feedback training as supplied by the voice advisory manikin (VAM) can improve initial pediatric basic life support skill acquisition for lay providers even when compared to one-on-one, standardized instructor-led training.
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Introduction

Chest compressions and ventilations are essential pediatric basic life support skills. Unfortunately, the immediate acquisition of the basic CPR psychomotor skills after traditional instructor-led classes is often poor.[1–7] In addition, the quality of CPR performance has been shown to be poor in and out of the hospital.[8,9]

Rates of bystander CPR and cardiac arrest outcomes are poor in children, in spite of the fact that most cardiac arrests occur in or around the home with caretakers present.[10,11] Provision of bystander CPR is associated with improved outcomes in pediatric animal models and in epidemiological studies of both adults and children.[10,12–15] Improved CPR competence and performance can improve cardiac arrest outcomes.[16] Therefore, increasing parental CPR psychomotor skill competence/confidence to provide support of basic respiration and circulation is desirable, and will be likely to improve survival from pre-hospital cardiac arrest in children.

A computerized voice advisory manikin (VAM) is a novel approach to teach the psychomotor skills of CPR. Acceptable limits for ventilations and compressions are pre-set, and the subject receives immediate, computer-analyzed, corrective audio feedback when the skill delivered falls outside of the pre-set range trigger. This approach to training has been shown to improve the acquisition and retention of CPR psychomotor skills in adult care providers.[17–21] However, its effectiveness in training pediatric lay care providers has not been evaluated. Therefore, we performed a randomized trial of lay person BLS instruction comparing psychomotor skill acquisition between a training program using VAM and a standardized program of high quality, one-on-one, BLS human instruction. We hypothesized that the voice advisory manikin through immediate, computer-driven, corrective audio feedback would improve the initial skill acquisition of lay care provider one-rescuer pediatric BLS skills, even when compared to high quality, one-on-one, human instructor training of identical duration.

Materials and methods

Please refer to Figure 1 for a flow sheet representation of the study design.

Participant selection

Parents and lay care providers of hospitalized children 8–18 years of age at the Children's Hospital of Philadelphia were approached for inclusion in the study during the period from March 2004 to September 2005. These patients were hospitalized on the general inpatient pediatric wards, the cardiac intensive care unit, or the pediatric intensive care unit. A brief screening process was done to determine inclusion into the study. All participants had to have English literacy to a 6th grade educational level (manikin audio feedback at this level). Individuals were excluded from participation if they had completed formal CPR training in the preceding 12 months. In addition, those individuals with medical conditions that might limit the participant from completing a 3-min session of continuous CPR, such as asthma or heart disease, were also excluded from participation.

Written parental/guardian permission (informed consent) was obtained prior to any study related procedures being performed. A member of the investigational team and/or study coordinator approached the parent/guardian to assess if they would be willing to participate in our study. The study and informed consent was explained to the participants. They were given opportunity to ask questions regarding the study and were supplied with a study description sheet containing a brief

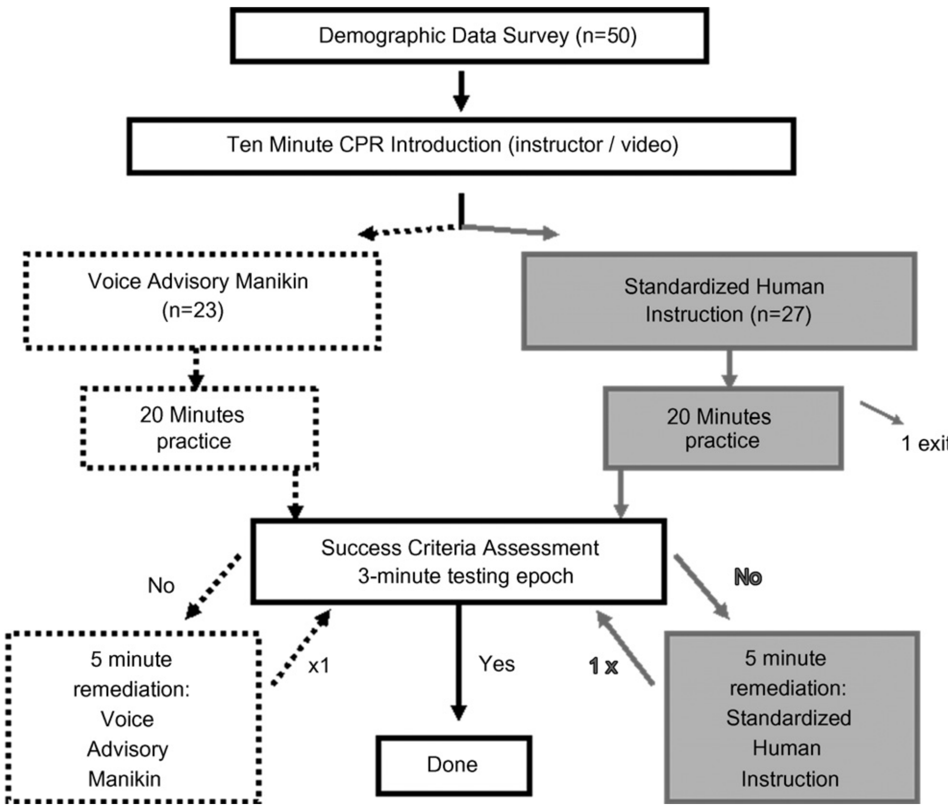

Figure 1 Study design flow sheet.

overview of the study and contact telephone numbers of study investigators, in case of further questions.

All subjects completed a written demographic data survey recording their age, sex, years of education, and previous CPR experience more than 12 months previously. Contact information was also collected from each participant, as a future objective of this study is to determine skill retention at 12 and 24 months after initial testing.

CPR introduction

A 10-min scripted didactic CPR introduction followed which consisted of a visual demonstration of CPR psychomotor skills by a certified pediatric CPR instructor on a BLS manikin and a 6-min excerpt from the American Heart Association video on pediatric basic life support skills. No ''hands-on'' manikin practice time for participants was provided during this standardized introduction.

Training sessions

Subjects were randomized to receive either standardized human instruction or voice advisory manikin training as described below. Instructors were BLS certified and equally versed in both training methods. The name of the instructor leading each training session was recorded. Instruction was one-on-one.

Standardized human instruction

Participants were instructed in one-rescuer pediatric basic life support skills during a 30 min training session. This consisted of the previously mentioned 10-min scripted introduction to CPR and 20 min of manikin practice time during which they received individualized BLS instructor feedback on the delivery of their psychomotor skills, without automated, corrective computer feedback (i.e., training that parents of our high risk critically ill infants and children usually receive before going home, with the BLS instructors screened and specifically scripted for high quality training). CPR was taught according to the existing AHA 1-rescuer BLS guidelines with a 15:2 compression to ventilation ratio. CPR psychomotor skills were practiced on a Resusci Junior manikin (Laerdal Medical, Stavanger, Norway). This intensive 20-min training session focused only on the psychomotor/physical skill delivery aspects of CPR. Subjects received extensive corrective feedback at the instructor's discretion with the hope of mastering the psychomotor aspect of CPR during

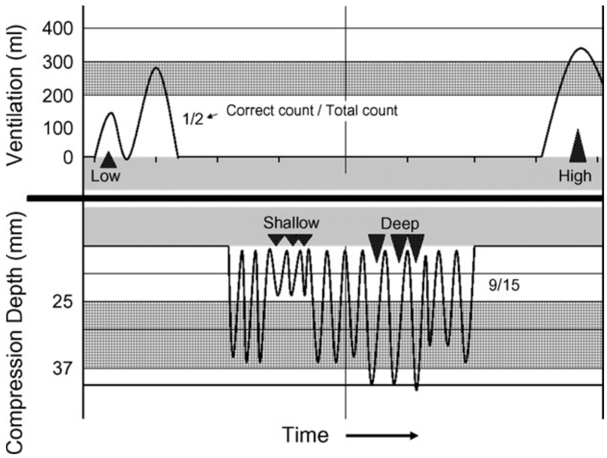

Figure 2 Computer screen visual feedback representation. Note grey grid indicating high and low levels for feedback trigger (ventilation: 200—300 ml, chest compression depth: 25—37 mm).

the training. At the end of the training session, time was allotted for participants to ask questions.

Voice advisory manikin (VAM) training

Participants were instructed in one-rescuer pediatric basic life support skills during a 30 min training session. This consisted of the previously mentioned 10-min scripted introduction to CPR and 20 min of practice time on the voice advisory manikin. The VAM is a Resusci Junior manikin indistinguishable in outside appearance and feel from the manikin used in the standardized human instruction; however, this manikin was specially modified by Laerdal Medical to interface with a laptop computer that had prototype voice advisory manikin software (Laerdal Medical PC Skillmeter VAM, Version 1.30.19) installed so that immediate, corrective audio and visual feedback could be provided to the participants on the delivery of their psychomotor skills. The VAM software allows performance ranges and triggers to be set for important CPR psychomotor skills (chest compression rate, depth, avoidance of CPR free intervals, ventilation rate, etc). CPR psychomotor skill performance that did not fall within the pre-set limits triggered prioritized, corrective audio feedback which continued until that psychomotor skill performance was corrected. Positive feedback was provided when all psychomotor skills were performed correctly. For the first 5 min of manikin practice, the participant was encouraged to look at the computer screen (visual and audio corrective feedback) to gain a sense of the feedback that VAM provides (Figure 2). However, for the final 15 min of training, only corrective audio feedback was provided. For this study, feedback on hand position and incomplete release during decompression was not assessed or provided due to the software/manikin capabilities available at the time of the study. At the end of the training session, time was allotted for participants to ask questions.

CPR psychomotor skill success assessment

Immediately following training, all participants underwent a CPR psychomotor skill evaluation during a 3-min epoch of continuous CPR. The primary outcome measure was CPR psychomotor skill success attainment, defined prospectively as 70% correct chest compression and ventilation delivery. Subjects not achieving this skill success were retrained according to their original VAM or. SHI assignments. After 5-min of remediation/retraining in their original group, subjects were tested a second and final time.

Testing sessions were carried out on a modified Resusci Junior manikin. This manikin was connected to a laptop computer (Dell SmartStep 200N, Windows XP Home Edition) that had the prototype voice advisory manikin software installed with the audio feedback function disabled. The outside visual appearance and feel of performing CPR was no different from the manikins used in the introduction or either training session. The internal modifications of the manikin and the VAM software enable the manikin to detect chest compression and ventilation delivery, and to quantitatively analyze the delivered CPR skills. Data output from the VAM software is averaged over the entire 3 min epoch for the number of total and correct chest compressions and ventilations delivered, rate of delivery, chest compression depth, and ventilation tidal volume.

Data analysis

The primary outcome of interest was attainment of CPR psychomotor skill success, defined above as 70% correct chest compression and ventilations; this was expressed as a dichotomous outcome (attained or not attained). Secondary outcomes were number of chest compressions per minute, correct chest compressions per minute, ventilations per minute, correct ventilations per minute, and error rates per individual. Subjects who underwent more than one testing session had these secondary outcomes averaged across all testing sessions (maximum of two), and a single average value was analyzed per subject.

Descriptive statistics were expressed across all groups as means and standard deviations. Univariate analysis was made between VAM and SHI groups

Table 1 Demographic data

	Age (years)[a]	Sex (females)	Education (years)[a]	Previous CPR (Y)
Voice advisory manikin	42.0 ± 6.7	20/23 (87%)	14.5 ± 2.1	11/23 (48%)
Standardized human instruction	45.2 ± 12.1	15/26 (58%)	13.9 ± 2.1	12/26 (46%)
p value	ns	0.04	ns	ns

[a] Data are mean ± S.D.

for CPR psychomotor skill attainment using chi square analysis; univariate analysis between VAM and SHI for secondary outcomes was performed using a two sample *t*-test. All statistical analysis was performed using STATA statistical software (Version 8.0, 2003, Stata Corporation, College Station, TX).

Results

Fifty of 54 (93%) families approached for screening gave consent to participate. One individual who assented to participate was physically unable to complete all training/testing and was excluded from data analysis. The demographic data survey results are contained in Table 1. Participants were similar in age, years of education, and previous CPR experience more than 12 months ago. There were more females randomized to the voice advisory manikin training group (VAM: 20/23 (87%) versus SHI: 15/26 (58%), $p = 0.04$).

CPR quantitative data

Participants randomized to receive VAM training delivered more total chest compressions per minute (58.7 ± 7.9 versus 47.6 ± 10.5, $p < 0.001$), correct chest compressions per minute (47.9 ± 15.7 versus 31.2 ± 16.0, $p < 0.001$), total ventilations per minute (7.8 ± 1.2 versus 6.4 ± 1.4, $p < 0.001$), and correct ventilations per minute (5.4 ± 1.9 versus 3.1 ± 1.6, $p < 0.001$). Figures 3 and 4 are graphic representations of the chest compression and ventilation delivery data respectively.

Differences between groups are most evident in the psychomotor skill performance data from their initial testing session. During test #1 VAM trainees delivered more correct chest compressions per minute (47.8 ± 16.6 versus 26.6 ± 17.7, $p < 0.001$) and correct ventilations per minute (5.3 ± 2.1 versus 2.7 ± 2.5, $p < 0.001$), while performance differences in test #2 were not statistically different between the groups (chest compressions: $p = 0.67$, ventilations: $p = 0.29$). Overall error rates per individual were lower in VAM trainees for chest compressions (18.1 ± 23.2% versus 34.9 ± 28.8%, $p < 0.03$) and ventilations (32.0 ± 19.7% versus 50.7 ± 24.1%, $p < 0.005$).

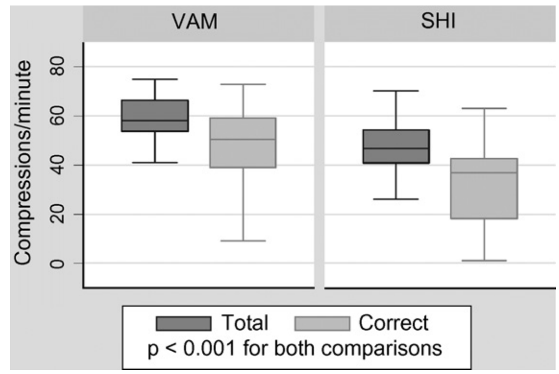

Figure 3 Total and correct chest compressions delivered per minute. Data presented as median with interquartile ranges (VAM: $n = 23$; SHI: $n = 26$).

CPR skill evaluation

More VAM trainees (12/23, 52%) than SHI (1/26, 4%) trainees met CPR prospective criteria for psychomotor skill success (70% correct chest compression and ventilation delivery) on their initial 3-min test ($p \leq 0.0001$). After remediation and retesting, the overall rate of those meeting criteria for success in the VAM group remained significantly higher: VAM 15/23, 65% versus SHI 7/26, 27% ($p = 0.008$). For every criterion of psychomotor skill

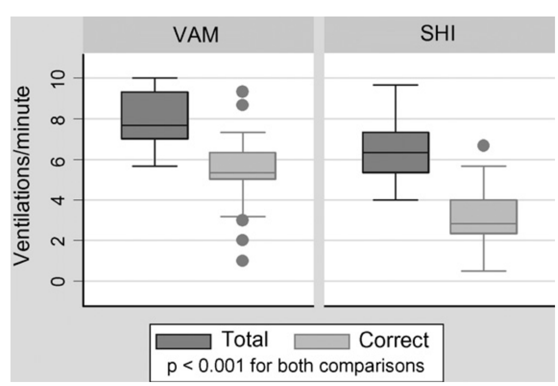

Figure 4 Total and correct ventilations delivered per minute. Data presented as median with interquartile ranges (VAM: $n = 23$; SHI: $n = 26$).

success, VAM training achieved higher proportions of success than the high quality individualized SHI on their initial testing session (60%: 18/23 versus 2/26, $p < 0.001$; 50%: 18/23 versus 5/26, $p < 0.001$; 40%: 18/23 versus 9/26, $p = 0.004$; 30%: 19/23 versus 11/26, $p = 0.007$; 20%: 20/23 versus 13/26, $p = 0.007$).

Discussion

The voice advisory manikin has been shown to increase skill acquisition and retention in adult health care providers,[18,20,21] and to prevent the time dependent decline of CPR psychomotor skill performance during prolonged delivery,[22] but its use in pediatric lay care providers has not been evaluated. This study is distinctive in that an educational program using the voice advisory manikin was applied to a unique subject group, parents of critically ill children with high risk for cardiac arrest, not health care providers. This is an important population as most cardiac arrests in children occur in or around the home with caretakers present and rates of bystander CPR are poor.[10,11,23] This study is also the first to document that an instructional program using VAM can educate using pediatric rates and ratios for psychomotor skill delivery.

Our study demonstrates that CPR psychomotor skill acquisition was significantly better in pediatric lay care providers who completed CPR training with the computer automated, corrective voice advisory manikin feedback compared with individualized high quality standardized human instruction. The VAM trainees were able to deliver more chest compressions and ventilations, both total and correct, during the testing cycles. The increase in delivery is most pronounced during the first testing session suggesting that the voice advisory manikin increases the speed at which psychomotor skill proficiency is obtained in lay care providers.

CPR classes are traditionally taught in instructor led classes with emphasis on the cognitive aspects of CPR. However, no study has shown that didactic lecturing on arrests improves CPR skill delivery.[24] In fact, inadequate emphasis on the psychomotor aspects of CPR during supervised manikin practice time has been implicated as a specific cause of inadequate skill acquisition.[2,7,25–27] Unfortunately, there are no evidence based guidelines for the standardization of manikin practice time, the amount of ''hands-on'' training is instructor dependent, and observation of instructor led classes demonstrates a large variability in actual time allocated for practising the psychomotor skills on manikins.[7,28,29] Even when classes are focusing on the psychomotor aspects of CPR, classes are not standardized, and instructors are not consistently correcting poor CPR skill performance.[4,24] Although most learners have an optimal pace at which he/she can achieve competence, large classes have difficulty assessing and accommodating the learning styles of all individuals.[28] Given that pediatric cardiopulmonary arrest outcomes and the prevalence of bystander CPR are poor[10,11,23] in spite of documentation that bystander CPR improves outcomes,[14] coupled with the above inadequacies of traditionally taught CPR classes, it seems reasonable to search for innovative approaches to teaching CPR to the lay public. The voice advisory manikin system fills such a role.

Due to its immediate corrective audio feedback, voice advisory manikin trainees are given the opportunity to correct their poorly delivered skills in real time. As bad habits are unlikely to develop, superior rates of psychomotor skill success are obtained. In addition, the manikin allows subjects to train at their own pace, taking into account differences in learning speeds. It also affords the participant to train in an environment of their choice, not necessarily in a large group setting as in traditional classes. In short, VAM is an effective alternative not hindered by the shortcomings of current instructor led CPR education.

Special efforts were made to provide the highest quality of individualized, one-on-one instruction to participants to make certain that we compared ''good quality'' computerized VAM training with ''good quality'' SHI training. The acquisition of CPR psychomotor skills in the standardized human instruction group is as good or better than end of course skill performance following full length CPR courses currently published in the literature (published correct chest compression rates 2–12%, correct ventilation rates 10–25%).[1,2] Therefore, although the VAM trainees performed superiorly, the standardized human instruction in this study was at least comparable, if not superior to, currently reported CPR educational methods.

Several limitations of this study should be acknowledged. First, there is an inherent selection bias in volunteer participants. In this study, participants were motivated care providers of children hospitalized in an intensive care unit. In addition, some families, such as those addressing stressful end of life discussions, for example, are unlikely to even be approached for such a study. Therefore, this study group may not be representative of a larger population under more average circumstances. Despite this fact, we believe that the similarity between the two groups is indicative of a successful randomization which would minimize the effect of such bias on the result of interest. In addition, although we refer to the instructor led training group as ''standardized,'' we realize that a 30-min instructor-led course is not completely comparable to a full AHA course. However, there is evidence in the literature that a 30 min video self-instruction is at least equivalent, if not superior to, a full length traditional instructor-led course.[30,31] Therefore, we believe that a system such as the voice advisory manikin could be, at the very least, a successful adjunct to an abbreviated traditional course improving the immediate acquisition of CPR psychomotor skills of lay providers.

Conclusions

This study demonstrated that the voice advisory manikin system can improve the initial skill acquisition of one-rescuer pediatric basic life support skills in lay providers through immediate, corrective audio feedback when compared to high quality individualized human instruction. The mechanism of improved CPR skill competence appears to be related to faster acquisition of skill proficiency. Additional investigations evaluating the psychomotor skill errors of incomplete chest compression release/improper hand position and psychomotor skill retention are warranted.

Conflict of interest

We acknowledge the following potential conflicts of interest: Helge Myklebust is an employee of Laerdal Medical, Inc. (Director of Research), and Vinay Nadkarni was a volunteer uncompensated educational consultant for the Laerdal Foundation at the time of this project. Laerdal Medical, Inc. supplied the prototype voice advisory manikin used in the project at no cost to the investigators. However, the investigators had sole responsibility for the data and analysis, and there were no restrictions by Laerdal Medical on analysis or publication of the data.

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