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An automated voice advisory manikin system for training in basic life support without an instructor. A novel approach to CPR training

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Abstract

Twenty-four paramedic students with previous basic life support training were randomised, performing cardiopulmonary resuscitation (CPR) on a manikin for 3 min without any feedback followed by 3 min of CPR with audio feedback from the manikin after a 2-min break, or vice versa. A computer recorded information on timing, ventilation flow rates and volumes and all movements of the sternum of the manikin. The software allowed acceptable limits to be set for all ventilation and compression/release variables giving appropriate on-line audio feedback according to these settings from among approximately 40 pre-recorded messages.

Students who started without feedback significantly improved after feedback in terms of the median percentage of correct inflations (from 2 to 64%), with most inflations being rapid before feedback (94%), compressions of correct depth (from 32 to 92%), and the duration of compressions in the duty cycle (from 41 to 44%). There were no problems with the median compression rate, sternal release during decompressions, or the hand position, even before feedback. There were no significant differences in any variables with and without feedback for the students who started with feedback, or between the audio feedback periods of the two groups. It is concluded that this automated voice advisory manikin system, a novel approach to basic CPR training, caused an immediate improvement in the skills performance of paramedic students.

Keywords: Basic life support; Cardiopulmonary resuscitation; Training; Education; Manikin

Resumo

Randomisaram-se vinte e quatro paramédicos em treino, com formação em suporte básico de vida (SBV) prévio para fazerem reanimação cardio pulmonar (RCP) em manequim sem alerta sonoro durante três minutos seguido de intervalo de dois minutos e outro período de 3min no manequim com alerta sonoro, ou vice versa. Fez-se o registo electrónico das variáveis referentes aos intervalos de tempo, aos fluxos e volumes das ventilações e de todos os movimentos do esterno do manequim. O software faz a avaliação sonora em contínuo e aceita todas as variáveis referentes à ventilação e relação compressões / descompressões incluídas nos limites previamente definidos em função de 40 compressões pré registadas.

Os que iniciaram o treino sem apoio dos comentários sonoros melhoraram significativamente o seu desempenho no que se refere à percentagem média de insuflações correctas (2 para 64%), sendo que muitas das insuflações eram demasiado rápidas (92%), á profundidade das compressões (32 para 92%) e á duração das compressões no ciclo (de 41 para 44%). Não se identificaram problemas com a frequência média das compressões, com a pressão sobre o esterno durante as descompressão, nem com a posição das mãos. No caso dos candidatos que iniciaram o treino com o manequim com alerta sonoro não se verificou qualquer diferença nas variáveis estudadas antes e depois das duas fases do treino, nem se verificou qualquer diferença significativa entre os dois grupos durante o treino com o manequim com alerta sonoro. Conclui-se que manequim com alerta sonoro automático é uma

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inovação no treino em reanimação e é capaz de provocar uma melhoria imediata na melhoria do treino com estudantes paramédicos.

Palavras chave; Suporte Básic de Vida (SBV); Reanimação cardio pulmonar; Treino; Formação; Manequin

1. Introduction

Training programs for cardiopulmonary resuscitation (CPR) have been implemented worldwide during the last four decades following guidelines established by bodies such as the European Resuscitation Council (ERC) [1] and the American Heart Association (AHA) [2]. These programs specify course content and management and guidelines for CPR practice and testing, including criteria for the correct performance of CPR.

Tests immediately after a traditional instructor-led course with lectures, demonstrations, feedback and evaluation have been associated with poor skills performance [3–6]. It has been discussed whether this is caused by the course content, the instructor, or the pedagogic technique [3,7,8]. Several innovative courses have been introduced in an attempt to improve results. Some use videos with or without student interaction [5,6,9], and Wik et al. [4] designed a peer training course with the option of training at a time suitable for the trainee, with or without a formal instructor present. In a recent review of life support first aid training, Eisenburger and Safar [3] concluded that the time required for the acquisition of knowledge and skills vary greatly between students, and that individualised practice coached by video has advantages over instructor-led courses.

While the education research which has been reported indicates that the use of manikins is necessary for obtaining the necessary skills [3], all reports of feedback systems based on manikins have included the use of an instructor. Any direct feedback from the manikin itself has been limited to only a few aspects like visible indicators to confirm correct depth and volume, or indication of incorrect depth and volumes. The instructors will normally suggest improvements in the technique. We wanted to test if an automatic voice based feedback system, voice advisory method (VAM), without the presence of an instructor, could be used to improve the quality of basic life support (BLS) by paramedic students.

2. Materials and methods

A class of 24 paramedic students was studied in September 1999. All had given informed consent to participate in a study concerning new methods of teaching and training CPR, but had no information on the methods that were to be tested. They had been students for 11 months at the time of the study and had gone through a 4-h BLS course using an AMBU manikin 11 months previously. The study was performed immediately before their first advanced life support course, but many of the students had been exposed to advanced life support on patients during their practical rotations with the paramedics out of the hospital.

The students were brought one at a time into a room with no prior information. They were told to perform basic CPR on a manikin as correctly as possible for two 3-min periods with no feedback from us. We informed them that the manikin was connected to a computer, which would give them audio feedback during one of these periods. The manikin was a modified Skillmeter Resusci Anne (Laerdal, Stavanger, Norway) connected to a laptop computer (Compaq Armada 777 = DMT) with the experimental software VAM (Laerdal, Stavanger, Norway). There was no change from the standard Skillmeter Resusci Anne manikin detectable by the students except for the cable connecting it to the computer. The computer screen and the Skillmeter screen were visible only to the instructors.

The mechanics and feel of doing CPR were in no way altered from a standard manikin, but the modifications of the manikin and the VAM software provided on-line information to the computer relating to all variables in the ventilation and compression efforts. The computer received and stored information on timing, ventilation flow rates and volumes, and the movements of the sternum with and without chest compression release. This enabled the computer to make calculations on the chest compression rate, depth, speed of compression and release movements, and the duration of the chest compression/release cycles.

The VAM software allowed limits to be accepted for all these factors. For ventilation, the acceptable volume was set at 400–1200 ml (accepting both ERC and AHA recommendations), thus in all circumstances only volumes below 400 or above 1200 ml were registered as incorrect. The maximal acceptable inflation rate was set at 1000 ml/s, the compression depth 38–51 mm (1.5–2 in.), the compression rate 90–120/min, and the inflation/compression rate at 2/(12–17).

The VAM software also allowed the computer to give on-line audio feedback to the students. The software selected the appropriate messages from a list of approximately 40 messages, including: "Not so deep", "Deeper, please", "Press faster", "Switch fast from ventilations to compressions", "Blow slower, please", "You are doing fine", and "Continue the way you are doing now" (see Appendix A for complete list of feedback messages). We did not allow feedback on the hand position or incomplete chest release during decompression.

Corrective feedback was triggered by CPR performance outside the accepted limits listed above and silenced as soon as that part of CPR was performed within the set limits. There was no feedback on the part of the CPR being performed correctly until everything was within the accepted limits. Therefore, positive feedback was given at intervals unless something was performed outside the set limits.

The students were divided in two groups from a random list. One group first performed CPR for 3 min without any feedback, followed by a 2-min break, and thereafter CPR for another 3 min with audio feedback from the computer (Group 1). All ventilation and chest compression variables were continuously recorded. The other group performed the same sequence in the reverse order with audio feedback during the first 3 min of CPR (Group 2).

Each ventilation or compression was scored as either correct, if within the limits set above, or incorrect if outside these limits. The variables to be evaluated statistically were the percentage of correct inflation (both volume and flowrate), inflations that were too fast, correct compression depth, compression part of the duty cycle, decompression with incomplete release, compressions with hand position too low, and the mean compression rate. The results with and without feedback within each group were then compared, and the results with feedback between the two groups analysed. For statistical analysis, the distribution of the results was first evaluated. As in many instances it was not a normal distribution, Wilcoxon's rank sign test was used in the evaluations and all P-values are reported. All results are given with medians with 25 and 75%.

The number of mistakes during the first and during the last sequence of 2 ventilations/15 compressions in each of the two 3-min test periods (with and without feedback) was also registered. The percentage of compressions of correct depth, inflations of correct volumes, and inflations with too high inflation rates were then calculated for each group of students and tested by χ^2-test.

3. Results

Group 1, who started out without feedback, had a significant improvement with audio feedback in the median percentage of correct inflations (from 2 to 64%), with most inflations being too rapid before feedback (94%), compressions with correct depth (from 32 to 92%), and the duration of compressions of the duty cycle (from 41 to 44%) (Table 1). There were no significant changes in the median compression rate, which was already within the accepted limits before feedback, in the percentage of compressions with incomplete release during decompression, or in the incidence of the hand position being too low. In the last two cases, the median percentage was already zero during the initial period.

During the initial 3 min without feedback (Fig. 1), in Group 1, there was no improvement in the inflation rate or the percentage of correct inflations, but there was an improvement in the percentage of correct compressions. Audio feedback caused an immediate improvement in all three factors, with a further improvement during the 3 min.

In Group 2, all three factors (inhalation rate, the percentage of correct inflations, and correct compressions) improved during the initial 3 min with feedback (Fig. 2). Initially, when the feedback stopped, there was

Table 1
The median (25–75 percentile) percentage of correct inflations, too fast inflations, correct compression depth, compression part of duty cycle, decompressions with incomplete chest release, compressions with hand position too low, and the compression rate without (w/o) and with (w) on-line computerised audio feedback (VAM) during 3 min periods of manikin CPR[a]

	Group 1			Group 2			p w VAM Group 1 vs 2
	w/o VAM	w VAM	P within Group 1	VAM	w/o VAM	P within Group 2	
Correct inflations	2 (0–37)	64 (49–79)	0.002	68 (44–85)	77 (46–96)	0.308	0.977
Inflations too fast	94 (62–100)	25 (17–49)	0.002	25 (12–43)	5 (0–48)	0.722	0.644
Correct compression depth	32 (6–68)	92 (87–95)	0.002	89 (78–93)	95 (79–99)	0.433	0.119
Compression rate per min	106 (98–113)	105 (99–111)	0.423	99 (96–107)	106 (99–112)	0.126	0.235
Compression part dutycycle	41 (37–47)	44 (38–50)	0.001	43 (37–49)	43 (39–49)	0.086	0.541
Incomplete release	0 (0–0)	0 (0–17)	0.500	0 (0–0)	0 (0–3)	0.500	0.385
Hand position too low	0 (0–7)	0 (0–13)	0.625	0 (0–7)	0 (0–0)	0.875	0.838

[a] Group 1 started without feedback, group 2 started with feedback.

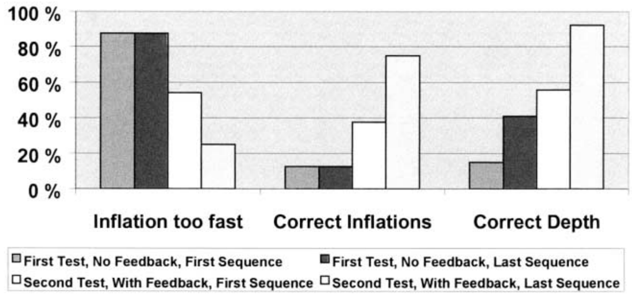

Fig. 1. The percentage of inflations with too high inhalation rate (> 1000 ml/s), correct inflations (400–1200 ml volume and correct inflation rate), and compressions with correct compression depth (38–51 mm) during the first and last sequence of 2 ventilations/15 compressions without and thereafter with audio feedback in Group 1 of 12 paramedic students.

no change in the percentage of inflations with too high inhalation rates or correct inflations, but a deterioration tendency was seen during the 3 min without feedback. The percentage of correct compressions was not reduced by the removal of feedback.

4. Discussion

On-line audio feedback from a computer caused immediate improvement in the performance of CPR by paramedic students who had 4 h of BLS training 11 months previously. In a group who first performed without feedback, inflation volume, inhalation rate, and compression depth improved with feedback. In the other group who started out with feedback, the same variables improved during the 3 min of feedback.

These results cannot be explained by practice alone. In the first group, which started without feedback, 3 min of practice did not change the performance of ventilations; the only improvement was in the percentage of compressions of correct depth. This compression depth improvement may be explained by fatigue during the session, since most of the students started with too vigorous compressions. In the second group, which started with feedback, both ventilations and compressions improved dramatically during the same first 3 min. In this group, there was no further improvement in the second 3-min period when feedback was removed, but a deterioration tendency was observed in the ventilation variables, while the other group immediately improved their performance when feedback was added in this second 3-min period. Part of the performance of compressions might be due to practice, but not all. Group 2 with initial feedback had a higher rate of correct compressions than Group 1 without feedback at the end of the first 3 min, and both the groups reached figures of over 90% correct compressions at the end of their feedback periods.

Neither result can be explained by pre-test differences between the two groups of paramedic students. The groups were composed by randomisation, and all had the same educational background with no difference in the number of real-life CPR attempts previously attended. It is also clear from Fig. 2 that the performance of Group 2 improved during the initial period.

Mouth-to-mouth ventilation was the most poorly performed part of CPR before feedback, and the main problem was that the inflations were given too rapidly. This occurred despite the acceptance of a wide range of volumes, 400–1200 ml, and inflation rates as high as 1 l/s. This is agreement with studies by Wenzel et al. [10] who found that there was only a 5% chance that medical students would achieve the same mouth-to-mouth ventilation performance 6 months after their BLS training, and that professional rescuers ventilating a manikin with a self-inflatable bag would use only 0.5 s for inspiration despite knowing that they should use 2.0 s and being aware of the possible implications thereof [11]. Although the ventilation improved greatly with on-line computer feedback, the median was still 25% of the inflations with an inflation rate > 1 l/s in the present study.

The chest compression part of the CPR was performed closer to the standards set before feedback than the ventilation part, the problem being almost always

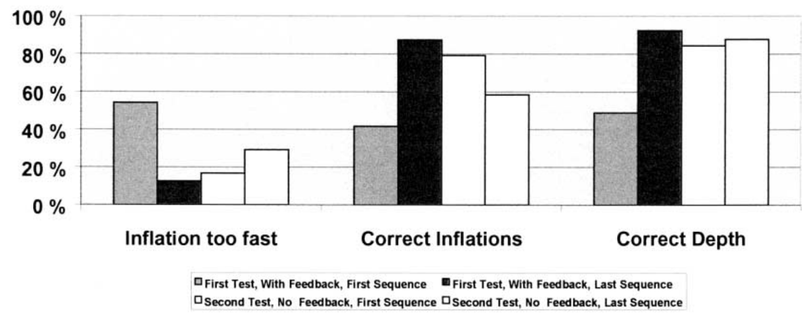

Fig. 2. The percentage of inflations with too high inhalation rate (> 1000 ml/s), correct inflations (400–1200 ml volume and correct inflation rate), and compressions with correct compression depth (38–51 mm) during the first and last sequence of 2 ventilations/15 compressions with and thereafter without audio feedback in Group 2 of 12 paramedic students.

excessively deep compressions. This incidence was reduced from 67 to only 8% with feedback. Many previous studies of CPR performance have not reported poorer results for the ventilation part, compared with the compression part of CPR [4–6]. This could be due to the fact that they have not evaluated the inflation rate or inspiratory time, but only the ventilatory rate and volume [4–6]. Although it has long been stressed that the inflation rate must be slow to avoid stomach distension [1,2], published scoring systems for the assessment of CPR do not include such an evaluation [12,13].

It was not possible to compare the performance of the skills where we had chosen to silence the feedback system (incorrect hand position or incomplete release during decompression), as the median frequency of incorrect performance was already zero for both categories without feedback.

CPR is traditionally taught in instructor-led classes [3]. This encompasses several problems. It has been difficult to enlist the population most likely to witness a cardiac arrest [14,15]. The pace is controlled by the course design and the instructor and may not accommodate all learners. A premise is the concept that specially trained instructors provide adequate quality control of the student's performance. This has been questioned, and in one study AHA instructors lacked even the basic knowledge reflected by AHA tests and their instructional practice deviated from the AHA guidelines [16]. In a study of traditional US CPR classes, instructors frequently did not correct inaccurate techniques during practice sessions and did not evaluate the coherent performance of CPR during testing [17]. In a third study [7], the instructors did not teach in a standardised way despite a clearly defined curriculum. Skill practice time was limited and errors in performance were not corrected. A checklist was an inaccurate tool for performance evaluation, and despite a documented poor performance, the instructors consistently scored the performance as acceptable and both instructors and students believed the level of performance was high [7].

In Eisenburger and Safar's [3] recent review on life support first aid (LFSA) training they concluded that "Courses by instructors have not achieved LSFA skill acquisition by most people. LFSA measures are mostly psychomotor skills. No study shows that lecturing about physiology, medicine and risk factors improves skill performance". They further conclude that manikin practice should be coached individually to perfect performance.

Based on the arguments above, it seems reasonable to consider alternative approaches to CPR instruction and training.

The VAM system is a novel approach to psychomotor skill acquisition. The most important difference from traditional CPR training is that it gives immediate on-line feedback, which will not differ from the set guidelines and errors in performance will not go unnoticed. In addition, it can be: (1) taught at a selected pace; (2) in a setting selected by the student; (3) flexible in scheduling; (4) immediately adjusted to changes in guidelines; (5) if used with instructors, it is suitable for training large a number of people with few specially-trained instructors; and (6) the instructor might not get tired or uninterested as easily as in a setting where they need to concentrate on giving feedback on psychomotor skill details.

The present study shows that the VAM system can improve CPR performance of paramedic students with previous BLS training almost instantaneously. This was because of the VAM system itself, and not because of practising BLS for 3 min. The performance improved dramatically with VAM after 3 min of non-VAM CPR with no differences in performance with VAM between the groups with and without previous non-VAM CPR. Whether the system is as effective in other training settings or can improve the retention of CPR skills must be tested in other environments.

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Appendix A. Voice prompts used in the model

1. Quicker, please
2. Compress quicker
3. Slower, please
4. Compress slower
5. Not so deep
6. Don't compress so deep
7. Compress deeper
8. Deeper
9. Blow slower, please
10. Slower
11. Blow in more air
12. More air
13. A little less air
14. Less air
15. Switch faster to ventilations
16. Compress fifteen times
17. Switch faster to ventilation
18. Blow twice

19. And again
20. One more time
21. Just blow twice
22. Very good
23. Fine
24. Continue as you do now

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