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Simulation and education

Time matters – Realism in resuscitation training

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ABSTRACT

Background: The advanced life support guidelines recommend 2 min of cardiopulmonary resuscitation (CPR) and minimal hands-off time to ensure sufficient cardiac and cerebral perfusion. We have observed doctors who shorten the CPR intervals during resuscitation attempts. During simulation-based resuscitation training, the recommended 2-min CPR cycles are often deliberately decreased in order to increase the number of scenarios. The aim of this study was to test if keeping 2-min CPR cycles during resuscitation training ensures better adherence to time during resuscitation in a simulated setting.
Methods: This study was designed as a randomised control trial. Fifty-four 4th-year medical students with no prior advanced resuscitation training participated in an extra-curricular one-day advanced life support course. Participants were either randomised to simulation-based training using real-time (120 s) or shortened CPR cycles (30–45 s instead of 120 s) in the scenarios. Adherence to time was measured using the European Resuscitation Council's Cardiac Arrest Simulation Test (CASTest) in retention tests conducted one and 12 weeks after the course.
Results: The real-time group adhered significantly better to the recommended 2-min CPR cycles (time-120 s) (mean 13; standard derivation (SD) 8) than the shortened CPR cycle group (mean 45; SD 19) when tested ($p < 0.001$.)
Conclusion: This study indicates that time is an important part of fidelity. Variables critical for performance, like adherence to time in resuscitation, should therefore be kept realistic during training to optimise outcome.

1. Introduction

Current guidelines of advanced life support (ALS) and basic life support with the use of automated external defibrillator recommend a standard of 2 min of cardiopulmonary resuscitation (CPR) with as few and short pauses as possible between rhythm controls.[1,2] A combination of continuous high quality of CPR and minimised hands-off time during rhythm controls/defibrillation ensures the highest possible quality of resuscitation.[3–7] The recommended algorithm is critical as every interruption in chest compressions (CC) decreases the coronary and cerebral perfusion.[3,8,9]

We have anecdotally observed doctors who shorten the CPR cycles during resuscitation attempts in real-life in different departments at Danish hospitals as well as in training situations. This was done by using a stopwatch or counting the 30 compressions:2 ventilations cycles.[10] In the clinical setting when shortened CPR cycles were observed they were corrected immediately. This shortening of CPR cycles increases the number of pauses used for rhythm controls/defibrillation, and such increased hands-off time impairs the quality of resuscitation[3–7] as illustrated in Fig. 1.

Our own observations have been affirmed by informal interviews with instructors/educators from Denmark, the United States and Australia. The failure to adhere to the recommended 2 min CPR cycles may be attributed, among others, to the way the simulation-based training is conducted. The 2-min CPR cycles are often deliberately shortened during resuscitation training (fake-time training) to save time and thereby increase the number of scenarios. Fake-time training may unintentionally be transferred to real-life situations when ALS is provided. Training that unintentionally results in the acquisition of incorrect knowledge, skills or behaviour has been termed *negative training*.[11] We speculated whether the shortened CPR cycles we have observed represent examples of such *negative training*. We therefore explored whether a shortening of the CPR cycles between rhythm controls/defibrillation during

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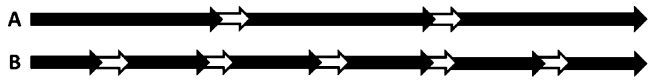

Fig. 1. (A) Real time (2 min) CPR cycles (black arrows), (B) fake-time CPR cycles (30–45 s) with an increased number of pauses for rhythm control/defibrillation (white arrows) and consequently a cumulated increased hands-off time.

simulation-based resuscitation training was transferred to later resuscitation attempts.

The aim of this study was to test if keeping 2-min cycles of CPR during resuscitation training (real-time training) as opposed to fake-time training results in better adherence to recommendation of 2-min CPR cycles during resuscitation in a simulated setting.

2. Methods

We conducted a prospective, randomised, controlled, single-blinded intervention study embedded in a voluntary extra-curricular ALS course.

Eligible participants were 131 4th year (7th semester) medical students from the Faculty of Health Sciences, Aarhus University, Aarhus, Denmark. Participants were recruited among the 131 4th year medical students through email advertisements and through face-to-face invitations prior to lectures. Seventy-three students expressed their interest to participate and were randomised to either the intervention group or the control group. Sixty-four were invited to the course to meet the sample size calculation. Participants were equally divided by gender (Intervention group: 16 women and 16 men. Control group 18 women and 14 men). All were between 20 and 25 years of age. Exclusion criteria were prior ALS or other critical care training.

The ALS course was set up as a one-day course following the European Resuscitation Council (ERC) ALS Guidelines 2010. Course schedule and scenarios are outlined in Table 1.

The course consisted of 3 h of lectures and 4 h of simulation (with 12 scenarios, each lasting 20 min). Scenarios were conducted in teams of four and with rotating roles. Each participant was assigned the role of team leader in three scenarios and the role of team member in the remaining scenarios. The role as team leader was allocated by randomisation prior to the course where the teams were also set. The team leader allocated the team member roles including the tasks of CPR, drugs management and timekeeping. Course were standardised by an external observer and by keeping all aspects identical except for the intervention.

Table 1
Course program.

ALS course program	
08.00–09.15	Course introduction and lectures: ABCDE-approach, CPR and AED, ALS algorithm
09.15–10.15	Simulation scenario 1 + 2 + 3: • Pulseless electrical activity – hypervolemia • Ventricular fibrillation – AMI • Ventricular tachycardia – AMI
10.30–11.00	Lectures: Reversible courses – T's and H's
11.00–12.00	Simulation scenario 4 + 5 + 6: • Asystoly • Tension pneumothorax • Sepsis
12.00–12.20	Lectures: Peri-arrest arrhythmias
12.50–13.50	Simulation scenario 7 + 8 + 9: • Pace of 3 degree AV block • Atrial fibrillation • Tachycardia
13.50–14.45	Lectures: Post-resuscitation care
14.45–15.45	Simulation scenario 10 + 11 + 12: • Hypokalaemia • Toxic • Pulseless electrical activity – tension pneumothorax and hypervolemia
15.45–16.00	Course evaluation

The intervention group (real-time) was trained during simulation scenarios using real-time, that is, 120 s of CPR between rhythm controls/defibrillation in the simulation scenarios. In contrast, the control group (fake-time) was trained during simulation scenarios using fake-time CPR cycles, that is, a shortening of the 120 s cycle to 30–45 s of CPR between rhythm controls/defibrillation in the simulation scenarios. Participants were blinded to the intervention[12,13] and they were unaware of the differences between the two groups.

All CPR time cycles during the 12 simulated scenarios were kept in either real-time (120 s, the intervention group) or fake-time CPR cycles (30–45 s, the control group).

In the post-scenario debriefing, the issue of time was not addressed systematically in any of the two groups. Faculty addressed the issue of time in the intervention group (real-time) only if they did not adhere to the 2 min of CPR between rhythm controls/defibrillation.

During the scenarios, faculty told the control group (fake-time) that 2 min had passed when, in reality, CPR had been performed only for 30–45 s. As a consequence of this design, the issue of time was only discussed during the debriefing if the participants addressed it.

The timekeeping devices were visible at all times (wall clock in every room and a stopwatch displayed on the defibrillator) during the course and the sequential assessments. The only restriction in time keeping was that use of the defibrillator's "advisory mode" was not allowed, as this would keep participant on track by counting the time; thus, the defibrillator was set to "manual mode".

The participants were explicitly told that all other possible time keeping tools and methods of keeping track of time could be used during the course and during assessment.

Participants were assigned a sequential ID number when signing up. We used these ID numbers to randomise participants to either the intervention (real-time) or the control (fake-time) group. The randomisation sequences was generated using http://www.randomizer.org.

All participants are ensured further and more comprehensive ALS training on subsequent semesters as part of their medical curriculum. Their educators were informed of the results of this study to compensate for any negative training that may have affected participants due to this study.

2.1. Assessment

Participants were assessed in their role as a team leader in an early retention test one week after the course and in a late retention test 12 weeks after the course. For practical reasons, the early tests were separated by a period of four weeks between the control group (fake-time) (tested first) and the intervention group (real-time) (tested last). The validated ERC Cardiac Arrest Simulation Test (CASTest), which has been developed for the ERC ALS provider course,[14] was used in both retention tests. A resuscitation team of four people was available during both tests to ensure that the setting was the same during the course and the tests. Faculty assistants acted as team members during the tests and were in no other way involved in the course. The team leader was instructed to allocate tasks to the assistants. In the same way they had allocated tasks to team members during the course including CPR, drugs management and timekeeping. All with the exception of diagnostic advice, including ECG interpretation.

The sequence of the test scenario consisted of non-shockable rhythm twice (pulseless activity; PEA1 and PEA2), shockable rhythm twice (ventricular fibrillation; VF1 and VF2), and return

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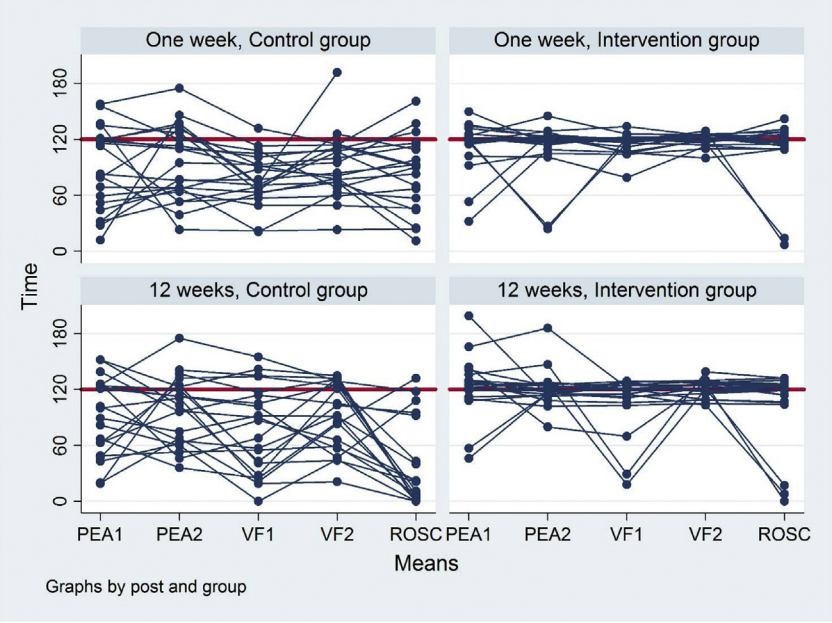

Fig. 2. Shows the deviation from 120 s in the 1 week and 12 weeks (left: fake-time CPR interval group (control); right: real-time CPR interval group (intervention).

of spontaneous circulation (ROSC). All five CPR cycles were used as measure points for data collection.

All tests were video-recorded to ensure accurate time measurement of CPR cycles.

2.2. Statistical analysis

Sample size calculation was based on a pilot study which demonstrated an average difference of 25 s (standard deviation (SD) = 25) between the intervention group (real-time) and the control group (fake-time). Assuming a difference of 25 s, a power of 80% and a two-tailed α of 5%, 16 participants in each group were required to detect a difference. To compensate for potential dropouts, 64 students were invited to participate in the courses.

Data were analysed using the statistical software Stata/IC 11.2 (StataCorp LP, Texas, USA). Results are presented as the mean ± SD. The statistical significance ($p < 0.05$) of the outcome of the intervention group and the control group was tested by applying permutation test, as an assumption about the normal distribution could not be made. The non-parametric Monte Carlo permutation test (n = 10,000) uses a random shuffle of data to get the correct distribution of test statistic under a null hypothesis.

2.3. Ethics

All participants gave written consent to participate in the study and to be video-recorded during early and late retention tests.

The Central Denmark Region Committees on Health Research Ethics and the Danish Data Protection Agency were approached, but waived their right to approve or dismiss the described study because of the low-risk profile of the study and the nature of collected data involved.

3. Results

The intervention group (real-time) showed statistically significant better adherence to the 2-min CPR than the control group (fake-time) with a deviation from the prescribed 120 s of (mean (SD)) 13 s (SD 8) for the intervention group (real-time) and 45 s (SD 19) for the control group (fake-time) ($p < 0.001$, Monte Carlo permutation test (n = 10,000)). The hands-off time for the control group (fake-time) was increased by 30% compared with that of the intervention group (real-time). No differences in the results were seen between the one-week retention test and the 12-week retention tests within the groups (intervention group (real-time), $p = 0.47$; control group (fake-time), $p = 0.50$). Illustrated in Fig. 2. Fifty-four participants completed the course, and of these 42 completed both the early and the late retention test. Table 2 outlines the mean and SD for the individual time of CPR cycles.

The dropout rate did not differ between the groups, and no differences in participant characteristics were found between the groups in terms of age, experience, gender and stated reasons for dropout. Nor were any differences observed in adherence to the 2-min CPR cycle ascertained between dropouts after the one-week retention test and dropouts who completed both tests ($p = 0.41$). Participation in mandatory hospital placements was the only parameter identified where dropouts differed from those who completed both retention tests. Dropouts were excluded from the data set entirely to ensure data integrity, which left 21 participants in each group. Flowchart of participants and dropouts are illustrated in Fig. 3.

The individual variation in average time of CPR cycles and a statistically significantly shorter time of CPR cycle at ROSC was more evident among participants in the control group than among

Table 2
Results of the one-week and 12-week tests for the real-time group and the fake-time group. Results are reported in seconds as the deviation from 2 min. Mean and standard deviation (SD) are given.

	PEA1	PEA2	VF1	VF2	ROSC
Fake-time CPR interval group (control)					
One week					
Mean (SD)	41 (±35)	38 (±28)	44 (±26)	36 (±26)	44 (±32)
Twelve weeks					
Mean (SD)	40 (±32)	34 (±27)	51 (±37)	35 (±29)	87 (±43)
Real-time CPR interval group (intervention)					
One week					
Mean (SD)	14 (±23)	15 (±27)	7 (±10)	5 (±4)	17 (±31)
Twelve weeks					
Mean (SD)	19 (±24)	11 (±16)	17 (±29)	7 (±5)	22 (±38)

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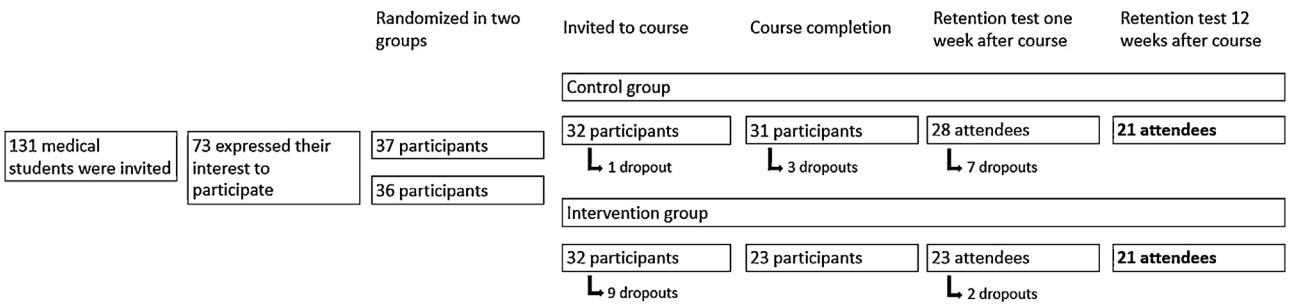

Fig. 3. Participant flowchart.

participants in the intervention group where the phenomenon was found to be statistically significant larger ($p < 0.001$) as illustrated in Fig. 4.

4. Discussion

A statistically significantly better ability to stay adherent to time, that is to perform CPR for 2 min between pauses to control rhythm and defibrillate, was found in the intervention group (real-time) compared to the control group (fake-time) ($p < 0.001$). This is most likely directly related to the timing aspects of the simulation scenarios and not to the knowledge acquired through written material or didactic teaching, which were identical for the two groups. Accordingly, the post training performance directly links to instructions. If omissions are made or participants are not corrected during training, conditioning might happen, thus imposing negative learning.

During simulation scenarios, ALS instructors in general tend to shorten the CPR cycles as they seek to increase the number of repetitions where rhythm and shock decisions are made. The physician's role during ALS includes many tasks. Among others the importance of pattern recognition, the specific knowledge required to ensure swift decision-making when looking at the heart rhythm, ability to identify the aetiology of the cardiac arrest and treatment of the reversible causes. It is likely that the many parallel tasks to be handled in part have caused CPR cycles to be shortened (faked) to maximise the number of repetitions and consequently increasing the number of training opportunities to address as many important aspects of resuscitation as possible.

Resuscitation is a prototypical time-critical algorithm-based medical intervention in which time fidelity is of paramount importance. When timing is neglected and CPR cycles are shortened, participants are conditioned to essentially ignore time, thus imposing negative learning. Our study indicates lack of adherence to time in the test after simulation scenarios using shortened CPR cycles. This lack of adherence may be transferred to resuscitation attempts in the clinical setting. Thus, the lack of adherence we found caused by the training resembles similar instances observed by the authors in the clinical setting. This observation warrants that we consider how future simulation-based training in resuscitation should be conducted to avoid the potential negative effect of fake-time training on real-life resuscitation.[11,15]

We speculate that fake-time training may lie at the root of the skewed perception of time observed in the clinical setting. Skewed perception of time is a well-known phenomenon[16–20] often associated with traumatic and stressful situations.[21] Real-life situations requiring resuscitation are, indeed, stressful situations, and it is possible, that even training sessions may be perceived as stressful to some.[22–26] Whether stress is the reason or a factor contributing to the shortened CPR cycles is unknown.

An example of a stressful situation where negative training was a contributing factor was provided by the 2001 American Airlines flight 587 crash, which killed 260 passengers and 5 people on the ground. The investigation into the accident found that pilot error was, at least in part, to blame for the accident. Using a simulator, the

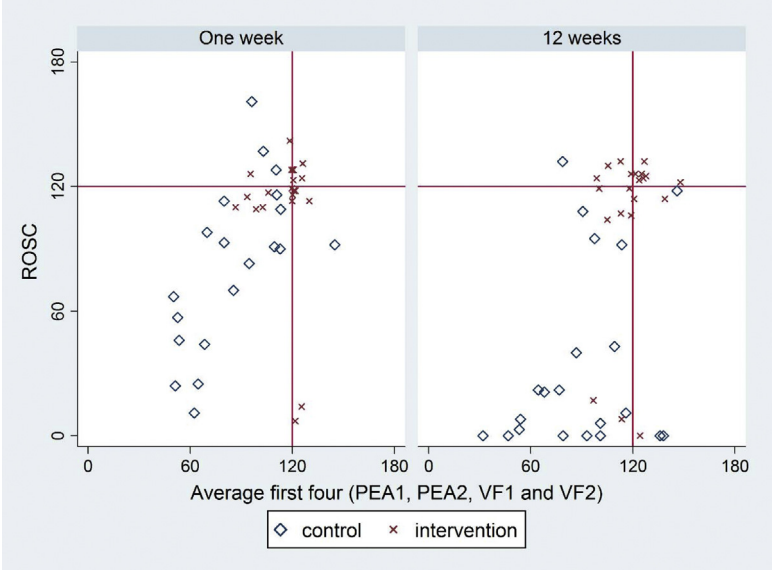

Fig. 4. Shows the deviation for the time ROSC compared to the average of the previous four time intervals (PEA1, PEA2, VF1 and VF2).

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pilot had been trained to perform a manoeuvre that was concluded to contribute to the crash. This manoeuvre was related to limitations of the simulator, which did not sufficiently represent reality. The investigation concluded that the limitations of the simulator caused negative training[27]: The pilot actually did what he was taught during simulation training. However, what he was taught was wrong. The consequences of negative training in ALS are parallel to those of the example above. It may not be equally dramatic, but, indeed, maybe equally severe for both the individual patient, given the resulting impaired perfusion due to the 30% increased hands off time, and for society as a whole, given the number of cardiac arrests in a year.

ALS fake-time training contrasts to other time-critical settings outside the healthcare environment like combat situations, aviation and space aeronautics where real-time simulation is used to a great extent to ensure accurate response in a given critical situation.[28–30] We accordingly recommend that ALS courses, like any time-critical setting, do not employ shortened CPR cycles in the future.

The study of time fidelity in ALS simulation revealed that some of the trainees had a significantly shorter CPR cycle from ROSC to the next control of rhythm than their own average CPR cycle during the preceding four CPR cycles (PEA1, PEA2, VF1 and VF2). The CPR cycle following ROSC is supposed and expected to be equal to the previous cycles. ALS guidelines emphasise 2 min of CPR after shock is delivered before renewed rhythm control, this was actively emphasised and reinforced during training. The group of individuals with a significantly shorter CPR cycle at ROSC formed a minority in the intervention group (real-time), but a majority in the control group (fake-time) (Fig. 4). This general lack of time consistency in the control group (fake-time) could be interpreted as a sign of insecurity or a need for continuous consulting and reliance on the information displayed on the defibrillator rather than on their knowledge and use of the ALS algorithm. Such insecurity or lack of confidence could be rooted in information overload[31] induced by shortened time CPR cycles which leaves little room for reflective thinking during the simulation scenarios. In this sense, information overload challenges the individual in question who experiences that his or her coping strategies are insufficient and ineffective.[31,32]

In our study, the reflective processes, including decision-making and task management during simulation scenarios, were introduced during the didactic lectures and they were emphasised in relation to the simulation scenarios during briefing as well as during debriefing. Consequently, the participants were instructed to practice the reflective processes actively during the 2-min CPR cycles to meet the principles of task management during critical situations.[23] However, only the intervention group (real-time) actually had 2 min. In contrast, the CPR cycles was shortened to 30–45 s in the control group (fake-time), which may have induced or exacerbated the information overload. Another explanation of the occurrences of the shortened CPR cycles is that participants are unconsciously incompetent. Although the importance of searching for the aetiology and reversible causes of the cardiac arrest were emphasised during training, the participants neglected to do so. Reverting to the rhythm control prematurely is the one thing they do know, because that was conditioned by the shortened CPR cycles during training and have consequently lead to negative training. This finding requires further exploration in a more diverse group of participants.

The importance of using real-time in ALS simulation scenarios is apparent and time fidelity ought to be incorporated when designing simulation scenarios. Whether time fidelity is equally important in all types of simulations is unknown, but it could likely be important in other time-critical situations such as trauma team training and critical care patient management, as time for reflective processes are equally important in these settings.

As simulation-based training in general is considered state-of-the-art in resuscitation training,[33,34] we must consider the consequences of not running the simulation scenarios in real-time, as this may have a negative effect on performance.[11,15]

4.1. Limitations of the study

One is the number of dropouts due to the interferences of a mandatory clinical placement of the participants. Another limitation is the participants being a novice group of medical students as negative learning may have less influence on an intermediate or expert group. In future studies a wider variation across the expertise range in subsequent studies would be worthwhile studying.

5. Conclusions

Participants trained in ALS using simulation retained the perception of time equivalent to how it was practiced during the simulation scenarios. Consequently, there was a statistically significant difference between the two groups ($p < 0.001$) in terms of their adherence to the 2-min CPR cycles. During post-tests, the time of CPR cycles were significantly shorter in the control group (fake-time) than in the intervention group (real-time).

Our study suggests that a shift to real-time simulations will provide instructors with sufficient time to improve the quality of training thereby avoiding lack of adherence to time as a result of negative training. Our findings indicate that ALS simulation scenarios should be using real-time CPR cycles to ensure adherence to the recommended 2-min CPR cycles during provision of ALS.

Conflict of interest statement

The authors have no conflicts of interest related to topics or data discussed in this paper.

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