Research Article
https://doi.org/10.23934/2223-9022-2021-10-2-357-366

Modern Technologies and Approaches to Organization of Theoretical and Practical Basic Resuscitation Training for the Lay Public

A.A. Birkun

Department of Anesthesiology, Resuscitation and Emergency Medicine
S.I. Georgiyevsky Medical Academy, V.I. Vernadsky Crimean Federal University
5/7 Lenina Blvd, Simferopol, 295006, Russian Federation

✉ **Contacts:** Aleksey A. Birkun, Candidate of Medical Sciences, Associate Professor at the Department of Anesthesiology, Resuscitation and Emergency Medicine, S.I. Georgiyevsky Medical Academy V.I. Vernadsky Crimean Federal University. Email: birkunalexei@gmail.com

ABSTRACT Out-of-hospital cardiac arrest (OHCA) is a serious social and economic problem, and control over it is highly dependent from the overall performance of the system of public first aid and resuscitation training. Coverage of the population with theoretical and practical training in basic cardiopulmonary resuscitation (CPR) is significantly limited in the Russian Federation, and the quality of training is generally low. Based on the analysis of international scientific literature and current international guidelines, this review is delineating modern organizational approaches and technologies of resuscitation training that help to enhance the efficiency and increase the accessibility of CPR training for lay people. In particular, the paper discusses methods of resuscitation training utilizing distant learning technologies, technical means for CPR skills training using feedback and virtual reality technologies, target audience and retraining intervals. Guided by the results of analysis of the cumulative experience, the directions for optimization of the resuscitation training system in Russia are proposed, that offer a perspective to improve coverage of the population with basic CPR training, increase the rates of bystander resuscitation and decrease mortality from OHCA.

Keywords: cardiopulmonary resuscitation, distant learning, online course, technologies, methods, virtual reality, defibrillation, accessibility
For citation Birkun AA. Modern Technologies and Approaches to Organization of Theoretical and Practical Basic Resuscitation Training for the Lay Public. *Russian Sklifosovsky Journal of Emergency Medical Care*. 2021;10(2):357–366. https://doi.org/10.23934/2223-9022-2021-10-2-357-366 (in Russ.)
Conflict of interest Authors declare lack of the conflicts of interests
Acknowledgments, sponsorship The study had no sponsorship

Affiliations

Aleksei A. Birkun	Candidate of Medical Sciences, Associate Professor of the Department of Anaesthesiology, Resuscitation and Emergency Medicine, Medical Academy named after S.I. Georgievsky of V.I. Vernadsky Crimean Federal University; https://orcid.org/0000-0002-2789-9760, birkunalexei@gmail.com

AED – automated external defibrillation,
OHCA – out-of-hospital cardiac arrest
ERC – European Resuscitation Council
FA – first aid
CPR – cardiopulmonary resuscitation

INTRODUCTION

The survival rate for out-of-hospital cardiac arrest (OHCA) as a whole does not exceed 8% across the globe [1], however, timely cardiopulmonary resuscitation (CPR) by eyewitnesses of the cardiac arrest increases the chance of survival by approximately 2–4 times [2].

The rates of bystander CPR in a witnessed OHCA vary widely depending on the country or region [3–5], which is associated, in particular, with different approaches to organizing first aid (FA) training program for lay people. It is known that effective CPR training contributes to improving bystander CPR and increases the survival rate of OHCA patients [6, 7].

The current Russian FA (including CPR) training system, is imperfect: opportunities for mass FA training for people without medical education are limited, approaches to monitoring and ensuring the quality of the education have not been developed, and the quality of training is poor [8–10]. Due to the limited coverage of the population by FA training and its low efficiency, witnesses of critical conditions in most cases do not attempt to provide assistance [11, 12] which significantly reduces the likelihood of favorable outcomes.

In order to choose ways to improve the domestic system of teaching the population in proving FA for OHCA, it is advisable to study international experience. For this purpose, a review of modern scientific

literature on the organization and technologies of teaching CPR skills to non-healthcare professionals has been carried out.

MATERIALS AND METHODS

In April 2020, in bibliographic databases (RSCI, Google Scholar, PubMed, Scopus, Web of Science), a search and subsequent analysis of foreign and domestic scientific publications and international recommendations on teaching people without medical education the theoretical foundation and skills of providing assistance for OHCA were performed. An additional search for sources on the topic of the review was carried out in the references of the corresponding publications.

RESULTS AND DISCUSSION

CPR TRAINING METHODS

According to the current recommendations of the European Resuscitation Council (ERC), basic CPR and automated external defibrillation (AED) training courses should be tailored to the target audience and simplified as much as possible; and in order to increase the training coverage among the population, it is advisable to expand the range of teaching methods [7]. For teaching resuscitation you can use classroom training, distance learning using modern information and communication technologies and multimedia, as well as a combination of classroom and distance learning - the so-called "blended" training [7].

Instructor-led face-to-face training, involving classroom learning of theoretical material and hands-on training through simulation tools is considered the gold standard for resuscitation training and remains the most common method [7, 13]. The availability of classic face-to-face CPR training is limited and depends on the availability of qualified instructors, financial capability and logistical factors [14, 15]. The recommended student-to-instructor ratio for such training is 6: 1 [16]. According to sociological studies, barriers to learning CPR in the classroom are the lack of time, the need for personal attendance at classes (including the problem of transport accessibility) and psychological discomfort associated with being in an unfamiliar environment [15, 17–19]. In addition, face-to-face training is not associated with a strictly unified pedagogical approach to all students, which can have a negative impact on learning outcomes [15, 20].

The need to expand the CPR training coverage among the population as well as the drastic advancement of modern digital technologies have stimulated the development of new training methods that are no less effective and sometimes even more advantageous than conventional classroom resuscitation training.

Peer-led CPR training is classroom tuition for laymen, when the instructor is also a person without medical education who has previously completed the necessary learning. This method of teaching is not inferior in efficiency to traditional training under the guidance of professional instructors [21-24], and even has certain advantages. Engaging not healthcare professionals as trainers reduces the cost of CPR training and, therefore, increases its availability [7, 14]. Besides, expanding the pool of trainers to include non-specialists allows more time to be devoted to individual trainees, which can have a positive effect on practical training effectiveness [14]. At the same time non-specialist instructors gain experience in teaching and mentoring, develop organizational and communication skills [7, 14, 21]. A survey of students who were trained according to the “student instead of teacher” method showed that they positively assess training by non-professionals and prefer this form of tuition over learning under the guidance of professional teachers [14].

Blended distance-classroom training involves partial or complete replacement of classroom theoretical teaching with distance learning [25]. After self-study of theory, students undergo practical training under the guidance of an instructor using simulation equipment. This approach allows reducing instructor workload as well as duration and cost of education [7]. Studies assessing the effects of blended CPR training have shown no less training effectiveness (in relation to the impact on knowledge and resuscitation skills) and satisfaction of students with such teaching compared to conventional in-class training [16, 18, 26, 27].

Out-of-class learning with practical training, combining video viewing and (or) the use of computer training programs (including online courses) with independent synchronous or asynchronous training of practical skills on a simple (for example, inflatable) dummy, has a number of positive qualities and is recommended by the international resuscitation community as an acceptable alternative to face-to-face training [7, 13]. Numerous studies have demonstrated that this form of training is equally effective in

comparison to classroom teaching, with regard to the resulting level of theoretical knowledge and practical skills possessed, as well as the degree of skill fade [28–32]. The advantages of out-of-class education include autonomy of learning (at a convenient time and in a comfortable environment), reduction of training duration and cost, as well as standardizing the educational process (ensuring a uniform pedagogical approach for all students) [13, 31].

Distance learning without hands-on training. Tests of various programs of distance theoretical basic resuscitation training in the format of online courses or sets of training materials have shown a significant positive effect on students' level of knowledge [16, 33, 34]. According to *de Vries and Handley* (2007), online theoretical training in basic CPR and AED also contributed to the effective development of FA skills, but the interpretation of the results of this study requires caution due to the small number of observations and the lack of control comparisons with other teaching methods [35]. In a recent study of the effects of distance teaching using a massive open online course on basic CPR and AED in Russian, the motivating effect of learning was confirmed: the proportion of students who expressed a high level of readiness to perform resuscitation in case of cardiac arrest of a stranger increased by almost twice (from 44 to 81%) [36].

TRAINING TO USE AED

Early bystander defibrillation in an OHCA situation has a significant positive impact on survival rates [2]. AEDs are intuitively designed and automatically provide the user with clear, spoken instructions. Thanks to this, AEDs can be effectively used by untrained OHCA eyewitnesses, but even a short training increases the willingness to use the device and improves the FA skills [13, 37]. A number of studies have shown that self-study and blended training of lay rescuers in the use of AEDs is as effective as classroom-based instructor-led training [30, 38, 39]. On this basis, the American Heart Association has recommended blended distance training in basic CPR with AED as an alternative to the traditional method of education [13]. In cases when face-to-face training provision is not available at all, self-study is recommended [13].

COMPRESSION-ONLY CPR TRAINING

In the first minutes after cardiac arrest not induced by asphyxia, continuous chest compressions without rescue breathing may be as effective as the full CPR (that combines chest compressions with artificial ventilation) [40, 41]. Despite the fact that the full resuscitation is a priority and recommended method of providing FA by OHCA eyewitnesses [2], in cases when the bystander is not able to perform artificial ventilation, it is advisable to perform compression-only CPR [42]. Analysis of real OHCA cases of presumed cardiac aetiology showed that the survival rate of adult victims in general did not depend on whether the resuscitation carried out by witnesses on scene was full or limited to continuous chest compressions [43]. The best practice for teaching lay people to perform FA in OHCA instances involves mastering the full range of basic resuscitation [7]. Compression-only CPR training is proposed to provide in order to increase teaching coverage in cases when the opportunities for CPR training are limited in time, for example, at mass events dedicated to the popularization of CPR [7].

CPR TRAINING TOOLS

CPR mannequins with feedback device provide the user with audio and visual information about the effectiveness of the resuscitation. Compared to conventional dummies, the use of such equipment gives higher rates of correctness of the chest compression frequency and depth and the return of the chest to its original position after compression [13, 44]. Through the use of accelerometers (with or without pressure sensors), simulation equipment records and displays in real time data on the frequency, depth and number of compressions performed [45]. Additional sensors can determine the position of the palm on the chest for compressing, the frequency and volume of mechanical ventilation, the compression-ventilation ratio [46]. Some dummies provide real-time visual or audio feedback (or both) that indicate erroneous actions and allow correcting the resuscitation technique during the training [46]. Automatic recording of CPR-quality parameters allows students, after performing a resuscitation attempt on a dummy, to visualize the mistakes made and optimize their FA skills [7].

In addition to mannequins with built-in sensors, in order to assess the chest compression quality special devices can be used which sensors are placed on the sternum [46]. Such feedback systems can be stand-alone portable devices or be part of modern manual or automatic defibrillators. They enhance CPR quality both in

resuscitation training (can be used with dummies without built-in feedback functions) and in clinical practice [45, 46]. While operating these feedback systems, the user applies pressure to the chest through the sensory platform. In some cases, this can cause wrist discomfort for the user, increase fatigue and bear the risk of injury [45, 47].

High-tech mannequins and stand-alone devices with a feedback function can optimize resuscitation skills, but the high cost of such equipment significantly limits the possibilities of its use for mass CPR training [45, 48].

Sound rhythmic accompaniment of training on a dummy using a metronome or musical compositions can positively affect the correctness of the chest compressions [46, 49, 50], therefore this technique is recommended for cases when training using feedback technology is not available [13]. Metronomes are generally available as free smartphone apps. AEDs have a built-in metronome [45].

Modern smartphones and smartwatches have wide multimedia capabilities and are equipped with a built-in accelerometer which makes it possible to use these personal devices in resuscitation training. The number of smartphone users in the world is constantly growing and by 2021 may reach 3.8 billion people (compared to 2.5 billion in 2016) [51]. For smartphones and / or smartwatches, a number of mobile applications have been developed and tested to provide feedback in the CPR skills practice [52]. With these applications, similar to a feedback dummy, a smartphone can record the quality of chest compressions and display them on the screen in real time, as well as provide CPR audio feedback with a metronome. An alternative or addition to the soundtrack can be the mobile device's rhythmic vibration or the display flashing on and off [48]. Experimental studies indicate that the use of this technology can have a positive effect on the CPR quality, improving the frequency and depth of chest compressions [48, 53–55]. According to *Gruenerbl A et al*. (2015), the use of smartwatches as a means of accompanying CPR allows students to eliminate the fear of causing harm to the victim by their actions [48]. The disadvantage of using a smartphone compared to a smartwatch is the need to hold it while compressing with the overlying hand which can disrupt the technique of closed-chest cardiac massage, limiting the depth of pressure, and hinder a full overview of the indicators displayed on the screen [52, 53, 56]. The high availability of mobile technologies opens up opportunities for using the principle of real-time feedback not only in CPR teaching, but potentially and in real cases of FA in OHCA situations.

A popular direction of scientific developments in the field of lay people training for basic CPR and AED is the creation of virtual reality (VR) training programs [57]. For example, a joint effort of Italian scientists and computer game developers uses a VR headset with motion sensors and a simple CPR dummy to provide a complete immersion of the user in a highly realistic OHCA scenario with the possibility of interaction with objects of the virtual environment [57]. During resuscitation of a virtual victim, motion sensors record the frequency and depth of chest compressions, ensuring that measurements are no less accurate than a standard dummy with a feedback device [57]. Resuscitation Council UK's interactive training tool Lifesaver VR allows using the free app of the same name installed in a smartphone and relatively inexpensive VR glasses for a smartphone in the first person to participate in the OHCA video scenario: make decisions related to FA in real time and conduct compression (on a dummy or a ordinary pillow), receiving feedback from the program - information about the adequacy of the compression rate and depth [58]. In a randomized study comparing the effects of Lifesaver VR training with face-to-face instructor-led training, VR training is found inferior to traditional training in terms of chest compression depth, but provides a similar compression rate [59]. Although scientific experience demonstrating the effectiveness and benefits of using VR in teaching basic CPR skills is still limited [57, 59, 60], resuscitation training using this technology appears to be at least a promising tool for popularizing and improving knowledge about the problem and principles providing help in OHCA situations.

STUDENT CONTINGENT

Mass CPR training for lay rescuers is a key educational task of modern resuscitation medicine [7]. At the same time, it is difficult to achieve effective training coverage of the entire population. Legislating compulsory CPR training (for example, at school or in the workplace) increases the number of potential OHCA witnesses with the skills to provide care, may contribute to an increased number of eyewitness resuscitation cases and improve survival rate after OHCA incidence [7, 61]. In addition, current international guidelines for CPR training [7, 13] identify several categories of people whose training may have special advantages.

Basic resuscitation and AED training for schoolchildren has great prospects, since this approach creates conditions for extensive coverage of the population, including all strata of society, regardless of social status and standard of living [62, 63]. Children, especially before puberty, are widely open to CPR training, learn effectively and can subsequently disseminate resuscitation knowledge in their families [7, 63]. Resuscitation training at school not only provides children with the necessary knowledge and lifesaving skills for OHCA situations, but also develops a sense of responsibility, forms a willingness to help other people [63]. Trained schoolteachers can teach resuscitation to children as effectively as medical professionals [64]. Education of schoolchildren is considered one of the most important ways to involve the population in the process of providing FA and reducing mortality from OHCA around the world [7, 63]. The International Liaison Committee on Resuscitation, ERC and the World Health Organization recommend teaching resuscitation to children in schools for two hours per year, starting at age 12 or younger [63]. Compulsory resuscitation education in schools is regulated by legislation in several European countries (for example, Belgium, Denmark, Italy, Portugal, France) [65] and in many states of the United States [66]. After the introduction of compulsory CPR training for schoolchildren, an increase in the incidence of FA for OHCA provided by eyewitnesses and a decrease in mortality were noted in the corresponding regions [6, 7].

In 70–80% of cases, OHCA occurs in homes [67, 68]. In this the eyewitness is often an older family member who does not possess resuscitation skills [69]. Teaching basic CPR to the family members and caregivers of patients at high risk of cardiac arrest (for example, patients with coronary artery disease, life-threatening cardiac arrhythmias, or previous cardiac arrest) provides them with the necessary FA skills, may help reduce anxiety of the family members and the patient himself, have a positive effect on their emotional status, and also support caregivers' confidence in their own skills and their willingness to provide care [7, 13, 69].

It is considered expedient to purposefully educate the population in local communities associated with high incidence of OHCA and low bystander CPR rates, in particular, in populations with a low socioeconomic status [7, 70, 71].

THE FREQUENCY OF RETRAINING

The ERC recommends basic CPR refresher training at least every 12-24 months [7]. However, according to some data, the decline of basic CPR skills is observed as early as 3 months after the initial training, so more frequent training is advisable for people who may encounter an OHCA situation with a high probability [7, 13].

The effectiveness of various CPR brief, frequent training programs to refresh knowledge and / or resuscitation skills has been supported by many studies [28, 72–74]. Frequent retraining not only maintains and improves CPR skills, but also keeps and increases willingness to perform resuscitation [7]. After initial full (theoretical and practical) training, effective maintenance of the ability to start CPR during cardiac arrest can be achieved through, inter alia, brief theoretical refresher training. Thus, an assessment made three months after initial resuscitation training showed that viewing a three-minute CPR and AED instructional video on a mobile phone screen was effective in maintaining resuscitation skills and willingness for FA [73].

CONCLUSION

Cardiopulmonary resuscitation training is a key component of the "formula for survival" - a generally recognized concept that determines the priority algorithm for effective organization of FA in out-of-hospital cardiac arrest [75]. By expanding the coverage of the population with high-quality resuscitation training, it is possible to achieve an increase in the frequency of first aid given by laypeople and a decrease in mortality in out-of-hospital cardiac arrest [7].

Both the overall coverage of the population of the Russian Federation with CPR training, and the frequency and quality of first aid for out-of-hospital cardiac arrest in Russia cannot be accurately estimated due to the lack of unified mechanisms for recording and monitoring these indicators at the federal level. In general, domestic studies indicate a low frequency of first aid and a low level of willingness of lay people to provide first aid, including out-of-hospital cardiac arrest situations [11, 68, 76, 77]. And the main factor limiting the readiness of Russian residents to provide assistance to victims is the lack of relevant knowledge and skills [11, 76, 77].

The regulatory and legal framework of the Russian Federation provides for compulsory first aid (including cardiopulmonary resuscitation) training for civil servants and military personnel, employees of enterprises,

people mastering programs of general, secondary vocational and higher vocational education, students of driving schools and other categories of the population [10, 78] However, the quality of the existing training is poor [8, 79–81], which is due to the lack of an effective unified first aid training system: training programs are heterogeneous in content and organizational and methodological support, often contradict current legislation and international recommendations, training of teachers and first aid instructors is not standardized, and there are no uniform mechanisms for monitoring the quality of education [8, 10].

The possibilities of voluntary CPR training in Russia are also significantly limited. Courses that teach the theoretical foundation and skills of providing care for out-of-hospital cardiac arrest are few in number, mostly fee-based and geographically sharply limited, furthermore, there is no independent expert assessment of the quality of training for existing courses [82].

As shown by a survey of the Crimean population, about 53% of the adult inhabitants of the peninsula have ever been trained in CPR [12]. Of these, for 18% the remoteness of training was from 1 to 5 years, for 54% - more than 5 years. The level of cardiopulmonary resuscitation knowledge was low. People who have never received resuscitation training usually either did not know where to learn or did not think about the need for cardiopulmonary resuscitation training. More than 50% of respondents reported that they would like to undergo such training [12].

Increasing the availability of face-to-face resuscitation training is a very important, necessary, but time-consuming and resource-intensive process. Through the use of alternative methods of CPR teaching and modern digital technologies, it is possible to expand the coverage of the population with training even with lack of time and resources. Based on the results of our analysis of international experience, the following directions of optimization of the domestic system of CPR training seem to be expedient.

1. Development, testing, reviewing and implementation of domestic cardiopulmonary resuscitation training programs based on the "student instead of teacher" methodology, blended distance learning and outside the classroom self-study.

2. Implementation of modern technologies of feedback and rhythmic audio and visual accompaniment of training based on the use of personal mobile devices and corresponding software applications in the process of face-to-face and distance learning of cardiopulmonary resuscitation skills.

3. Organization of targeted resuscitation training for family members of patients at high risk of developing cardiac arrest and people caring for such patients, as well as compulsory cardiopulmonary resuscitation training in schools with appropriate regular retraining.

In addition, to ensure the effective functioning of the cardiopulmonary resuscitation training system in the Russian Federation, it is necessary to create a unified program for monitoring the coverage of the population with resuscitation training and the effectiveness of such training, as well as the introduction of unified mechanisms for expert assessment and quality assurance of existing and newly created training programs.

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Received on 22.04.2020

Review completed on 19.06.2020

Accepted on 29.09.2020