Chapter

Public-Access Defibrillation in Sudden Cardiac Arrest

Ruslan Linchak, Sergey Boytsov, Andrey Ardashev and Artem Kuzovlev

Abstract

Sudden cardiac arrest caused by cardiac and extracardiac pathology is one of the leading causes of death in developed countries. Public-access defibrillation is one of the key techniques for improvement of the pre-hospital and in-hospital resuscitation success and survival rates of resuscitated patients in the case of a sudden cardiac arrest caused by ventricular fibrillation and pulseless ventricular tachycardia. This book chapter will discuss the relation between the type of a sudden cardiac arrest and the survival rate and the "chain of survival" concept and the role of early public-access defibrillation, as well as the function of public-access defibrillation programs and the contribution of automated external defibrillators in pre-hospital and in-hospital resuscitation.

Keywords: cardiac arrest, cardiopulmonary resuscitation, chain of survival, public-access defibrillation

1. Introduction

Sudden cardiac arrest (SCA) caused by cardiac and extracardiac pathologies is one of the leading causes of death in the developed countries [1]. Mechanisms of SCA development are as follows: (a) ventricular fibrillation (VF) and pulseless ventricular tachycardia (PVT), shockable rhythms, and (b) asystole (As) and pulseless electrical activity (PEA), non-shockable rhythms.

2. Pre-hospital sudden cardiac arrest

In the United States, pre-hospital SCA develops approximately in 350,000 people per year. In Russia, 200,000–250,000 patients suddenly die from heart diseases every year. In most European countries, an average of approximately 87 cases of SCA per 100,000 people was registered every year before 2010; 84 cases were registered from 2011 to 2015 [2, 3]. Over the past 25 years, a progressive decrease in the incidence of VF was observed, which to a certain extent is related to the primary and secondary prevention of heart diseases and SCA.

The time of registration (diagnosis) of SCA is crucial. For example, in the case of a prolonged (>5–8 min) pre-hospital cardiac arrest, VF before the start of cardiopulmonary resuscitation (CPR) was registered only in 25% (20–40%) of patients. However, if ECG was registered within the first minutes of the SCA at public places equipped with an automated external defibrillators (AED), VF was registered in 49–76% [4, 5]. Data of the analysis of the cardiac rhythm carried out from 2006 to 2012 demonstrated that 25–50% of SCA resulted from VF and PVT [1, 6, 7]. According to two multicenter studies carried out in the United States and Europe from 2011 to 2015, VF and PVT were registered in 15.5 and 12.5–22%, respectively [3, 8]. The survival rate of resuscitated patients with pre-hospital VF/PVT in various regions of Canada and the United States before 2010 ranged from 7.7 to 40% (median 22%), while the overall survival after all kinds of pre-hospital SCA (As, PEA, VF/PVT) ranged only from 3 to 12.6% (median 8.4%) [9]. In the European studies, the survival rate in VF/PVT in Denmark increased from 16.3 to 35.7% and in As/PEA from 0.6 to 1.8% over the period from 2005 to 2012 [10]. In the Netherlands over the specified time period, the survival rate increased only in the case of VF/PVT (from 29 to 41.4%); in the case of the development of As/PEA, it remained nearly unchanged (3.1–2.7%) [6].

According to the recent studies (2011–2015) in five US states, the survival rate in all kinds of SCA (n = 65,000) averaged 11.4% (the range by states varied from 8.0 to 16.1%); in VF/PVT it was 34% (varied depending on the state from 26.4 to 44.7%). In 27 European countries (2014), the survival rate in all kinds of SCA (n = 10,600) amounted to 10.7% (by countries: from <5 to 31%), after the primary VF, it was 29.7% (by countries: from 5.3 to 58%), and after all the cases of primary and secondary, it was on average 21% [3, 8].

2.1 Sudden cardiac arrest at home

According to Weisfeldt et al. [5], if the AED was available to the first witness of a home cardiac arrest, VF/PVT was registered in 36% of cases and in 25% of cases if CPR was started by the staff of the emergency medical service (EMS). In that case the survival rate was on average 12% (2.8 times less than the number of resuscitated patients at public places equipped with the AEDs). The causes of such a low survival rate after CPR at home were apparently as follows: (a) frequent unwitnessed SCA, (b) frequent lack of the AED for the first witness of the SCA, and (c) small incidence of SCA caused by a cardiac pathology (primary SCA) [1, 11].

3. In-hospital cardiac arrest

According to two studies (1999–2005) in hospitals in the United States and several European countries, the primary VF/PVT was registered in 24–35% of patients; the survival rate in this study [12] was an average of 37%, and in the study [13] it ranged from 18 to 67%. In the study [14] it was found that in the United States, the incidence of the in-hospital VF/PVT decreased from 23.5 to 18.5% over the period from 2000 to 2009; while the survival rate increased from 28 to 39%. When the primary As and PEA developed (about 70% of all SCA cases), the survival rate was on average 11 and 12%, respectively (ranged from 1.2 to 14%) [12, 13]. It was also noticed that during CPR in approximately 20% of patients with the primary As or secondary PEA (i.e., terminal), VF/PVT develops; this combination was associated with a reduced survival rate. For instance, in the case of the primary As with the development of the secondary VF/PVT during the CPR, the survival rate was 8% (without secondary VF/PVT it was 12%), and with the primary PEA, it was 7% (without secondary VF/PVT it was 14%) [12].

In the studies conducted in Norway from 2009 to 2013, the in-hospital primary VF/PVT was registered in 27–32% of patients; As was found in 19–23% and PEA in 48% of patients. The survival rate of patients with VF/PVT amounted to 53% and in patients with cardiac pathology it was 61%; the survival rate in the case of As was 17%, in the case of PEA it was 13%, and the overall survival was 25% [15, 16]. In the UK (data analyzed from 2011 to 2013 in 144 hospitals) the VF/PVT caused SCA in 17% of patients, As in 23.6% of patients, and PEA in 49% of patients; the survival rate was 49% for VF/PVT, 8.7% for As, and 11.4% for PEA, and the overall survival was 18.4% [17]. In Italy (data analyzed from 2012 to 2014 in 36 hospitals) VF/PVT was registered in 19% of patients; the overall survival rate was 14.8% [18].

Therefore, both pre-hospital and in-hospital SCA caused by the primary VF/PVT, unlike the SCA caused by the primary As and PEA, are characterized by significantly higher survival rates of resuscitated patients. Analysis of the data from international studies published from 1990 to 2005 showed that if CPR during a prolonged SCA was initiated 5–8 min after the onset of SCA, the overall survival rate was on average 6.4%. However, if the pre-hospital CPR and AED are conducted within the first 3–5 min after the onset of SCA by trained personnel (non-health-care workers), the survival rate can reach up to 74–49%. These data were obtained when AEDs were placed in airports, airplanes, and casinos. This high survival rate was provided by the introduction of the "chain of survival" concept and the program of immediate start of basic CPR and rapid application of the AED. It should be noted that in cases of development of VF or PVT, each minute of delay of the CPR start reduces the probability of the survival by 7–10% and delay of the defibrillation by 10–15%. Unfortunately, even in the leading European countries, rapid start of CPR by an accidental witness of the SCA was undertaken only in one third of cases, and basic CPR with AED was carried out even more rarely. In this regard the main objective of the 2005–2010 international CPR guidelines as well as changes in educational materials was to increase the survival rate due to earlier and high-quality basic CPR with an extensive use of the AEDs [4, 19–21].

It should be noted that the causes of low survival rates after pre-hospital SCA are more difficult to study with evidence-based medicine methods. Many studies have focused on short-term outcomes of CPR: return of spontaneous circulation and short-term survival. However, the main criteria of successful pre-hospital resuscitation are long-term results, i.e., survival to discharge and survival and quality of life within 1–5 years after SCA (long-term survival).

4. The chain of survival concept

4.1 The "chain of survival"

The "chain of survival" concept was formulated by the experts of the American Heart Association in the early 1990s. According to this concept, the success of CPR and the survival rate of patients with pre-hospital SCA may be increased if the following criteria are met: early recognition and call for help, early bystander CPR, early defibrillation, early advanced life support, and standardized post-resuscitation care. In this case, the survival rate can be increased by more than twofold [22, 23]. Delay in any step of the chain of survival leads to a deterioration of the CPR results and reduction of the survival rates [5–7].

When heart rate monitoring is not available, SCA is diagnosed within no more than 10 s by means of the following clinical signs: unconsciousness, no normal breathing or agonal breathing, and no pulse on the carotid artery. Within the first minutes after SCA, the agonal respiration develops in 40% of the victims. Sudden cardiac arrest can in the beginning cause a short convulsive episode (seizures) which can be mistaken for epilepsy. The final changes in skin color, most often pallor or cyanosis, are not diagnostic for SCA [1].

After the diagnosis of SCA, the local EMS should be notified immediately (at the pre-hospital stage, ambulance service, and in-hospital, anaesthesiologists and intensivists), and CPR should be started with chest compressions of appropriate quality. In most countries of the world, the average time from a call to the EMS service before it arrives in place is 5–8 min. During this time the patient's survival depends on the CPR and AED providers [1, 5–11].

Immediate start of chest compressions increases survival in SCA by 2–3 times. Chest compressions and defibrillation performed within 3–5 min from the development of SCA provide survival rate of 49–75%. Every minute of delay with defibrillation reduces the likelihood of survival by 10–15%. Early defibrillation is possible if an AED located in a public place is available [1, 5–11].

4.2 Quality of cardiopulmonary resuscitation

In the European Resuscitation Council Guidelines for Resuscitation 2015 [1, 4], the reference criteria for the quality of chest compressions are the following: hand position on the center of the chest; rate 100–120 per minute with as few interruptions as possible; depth at least 5 cm, but not more than 6 cm; allow the chest to recoil completely after each compression; and do not lean on the chest. Chest compression fraction (the percentage of time from the total time of CPR spent only for chest compression) should be at least 60% of the total time of CPR. Pauses in chest compressions should be no more than 10 s for mouth-to-mouth ventilations and no more than 5 s for defibrillation. Hyperventilation should be avoided during CPR (recommended ventilation rate—10–12 breaths/min) since it leads to an increase in intrathoracic pressure, a decrease in coronary perfusion pressure, and an increase in mortality rate.

There is evidence that chest compression depth range of 4.5–5.5 cm in adults leads to better outcomes (survival-to-discharge) than all other compression depths during manual CPR [24–26]. Compression depth of more than 6 cm is associated with an increased rate of injury in adults when compared with compression depths of 5–6 cm during manual CPR [27]. A higher survival rate (survival-to-discharge) was found among patients who received chest compressions at a rate of 100–120/min, compared to >140/min and 120–139/min [28, 29]. The low chest compression release velocity (CCRV) worsens the outcome of CPR: the odds ratios for survival for CCRV ≥400 mm/s and 300–399.9 mm/s was 4.17 and 3.08, respectively; CCRV ≥400 mm/s was associated with a higher rate of favorable neurological outcomes; an increase in the CCRV for every 10 mm/s was associated with an increase in the survival rate [30, 31]. Our data [Kuzovlev et al., 2018; unpublished] show that during the in-hospital CPR, the quality of chest compressions was extremely low (rate 124.9 ± 22.3/min; depth 4.6 ± 1.1 cm; chest compressions in target 5.4 ± 18.3%; CCRV 324.5 ± 93.5 mm/s), but it significantly improved with feedback devices (rate 111.9 ± 7.3/min; depth 5.2 ± 0.4 cm; chest compressions in target 68.3 ± 26.4%; CCRV 352.1 ± 40.2 mm/s). CCRV was moderate and did not improve with feedback devices.

5. Early defibrillation concept

In 1991 the American Heart Association experts formulated the concept of early defibrillation. According to this concept, early defibrillation is the most important link in the chain of survival: in the hospital, it must be performed within the first 2–3 min of SCA and within 3–5 min during the pre-hospital stage. The main principle of early defibrillation is that the first rescuers arriving to the patient should have the AED; if it is not available, manual defibrillator should be available [1, 4].

6. Public-access defibrillation concept

A wide use of the AED outside the hospital by minimally trained personnel without medical education formed the basis of the concept of public-access defibrillation, which was formulated by the American Heart Association experts in 1994. Based on this concept, programs of the pre-hospital use of the AED by the first SCA witnesses were developed in the United States and Europe. According to studies published in 2010–2016, use of the AED by the first responders caused by the primary VF/PVT significantly increases the number of survivors to discharge [6, 32–35]. Therefore, a wide use of AEDs can improve outcomes in the pre-hospital SCA. However, AEDs are not frequently used in a number of European countries. For example, according to Agerskov et al. [33], in Denmark, the first responders of SCA applied the AED before the EMS arrival only in 3.8% of patients.

7. Public-access defibrillation (PAD) programs

Public-access defibrillation programs include a number of elements: contact with a local EMS, location of the AED and criteria for its selection, and principles and quality of training in basic CPR/AED.

7.1 Contact with a local emergency medicine service and its dispatcher

The European Resuscitation Council Guidelines for Resuscitation 2015 [1, 4] emphasize the essential role of interactions between an EMS dispatcher and basic CPR and AED providers. The dispatcher plays an important role in the early diagnosis of SCA and starting of high-quality CPR (the so-called telephone-assisted CPR), as well as in searching for the AED and ensuring its delivery to the scene [1, 36]. Organization of cardiac arrest centers and their contacts with regional and local EMS should be encouraged because it is associated with an increase in the survival rates and improvement of neurological outcomes in patients with pre-hospital cardiac arrest [1].

7.2 Location of the AED and criteria for its selection

There are several criteria for selection of the AED location. Time factor is one of the most significant criteria. It is economically feasible to place the AEDs in those public places where one SCA may be expected once per 5 years [1, 3]. According to the European Resuscitation Council experts, the ideal location for the AED must be at such a distance that a first responder could spend no more than 1.5 min to take it and return back to the patient. In this case an EMS dispatcher can help the provider to locate the AED. For this purpose it is necessary to register AEDs located in public areas. According to M. Agerskov et al. [33], in Denmark, only 15% of all SCA cases were registered within 100 meters from the location of the AED.

7.3 Training in basic CPR/AED

It is noteworthy that in the case of the pre-hospital cardiac arrest caused by VF, early high-quality chest compressions and defibrillation are key factors to the success of the resuscitation and survival [1, 4]. According to [37, 38] effective training of nonprofessionals in the basic CPR/AED increases the long-term survival (by the 30th day and 1 year of observation). It was also shown that well-trained EMS managers were able to improve CPR carried out by first responders [1, 39, 50].

8. In-hospital public-access defibrillation

Worldwide, depending on the model of the device, in-hospital AEDs are used in three modes: semiautomatic, fully automatic, and manual. Semiautomatic and, less frequently, manual modes are used in PAD. It should be noted that there are still no results from randomized clinical trials comparing the use of the hospital manual defibrillators and the AED in semiautomatic mode. At the same time, three observational studies were conducted which detected no increase in survival rates using the AED [40–42], and one study even demonstrated its decrease as compared with the use of manual defibrillators [43]. The results of study [44] suggest that the AED use may delay the start of the basic CPR and increase the duration of pauses in chest compressions which can be deleterious in SCA related to non-shockable rhythms (primary asystole and PEA, when defibrillation is contraindicated).

Based on the results, the European Resuscitation Council experts (2015) recommend to use the AED in the semiautomatic mode in those hospitals units where there is a risk of delay in defibrillation for a few minutes (more than 2–3 min) and the first responders have no experience in manual defibrillation. In those hospital units where quick access to manual defibrillators can be provided, manual defibrillation should be conducted either by trained medical personnel or the resuscitation team—this is preferred to the use of the AED because it reduces the time from the onset of the SCA to the first shock. However, in such cases, experience in the visual analysis of the electrocardiogram (ECG) is required [1, 50]. The European Resuscitation Council Guidelines for Resuscitation 2015 for the use of automatic and manual defibrillators for the PAD are based on the studies conducted in the United States and Australia [40–50]. It should be however noted that no similar studies were conducted in Russia; therefore, at present time, this recommendation can be introduced in the practice of those Russian hospitals which have special resuscitation teams and/or trained staff experienced in a fast analysis of ECG and work with manual defibrillators.

9. Conclusion

Sudden cardiac arrest caused by cardiac and extracardiac pathology is one of the leading causes of death in developed countries. The success of CPR and the survival rate of patients with pre-hospital SCA may be increased if the following criteria are met: early recognition and call for help, early bystander CPR, early defibrillation, early advanced life support, and standardized post-resuscitation care. In this case, the survival rate can be increased by more than two-fold. Public-access defibrillation is one of key techniques for improvement of the pre-hospital and in-hospital resuscitation success and survival rates of resuscitated patients in the case of a SCA caused by ventricular fibrillation and pulseless ventricular tachycardia.

Conflict of interest

None.

Notes/thanks/other declarations

None.

Author details

Ruslan Linchak[1], Sergey Boytsov[2], Andrey Ardashev[3] and Artem Kuzovlev[4]*

1 National Medical Research Center for Preventive Medicine, Moscow, Russia

2 National Medical Research Center for Cardiology, Moscow, Russia

3 Department of Arrhythmias, Medical Research and Education Center, M.V. Lomonosov Moscow State University, Moscow, Russia

4 Federal Research and Clinical Center of Intensive Care Medicine and Rehabilitology, V.A. Negovsky Research Institute of General Reanimatology, Moscow, Russia

*Address all correspondence to: artem_kuzovlev@mail.ru

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