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Chest Compression-Only Cardiopulmonary Resuscitation

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Abstract

The survival rate of out-of-cardiac arrest (OHCA) was very low, which was mainly due to the victims who do not receive cardiopulmonary resuscitation (CPR) immediately. It was estimated that if people who quickly get chest compression-only CPR while awaiting medical treatment have double or even triple the chance of surviving. In the true world, many individuals are unwilling to do mouth-to-mouth breathing due to fear of infections or unable to do mouth-to-mouth breathing at the same time in the situation of only one bystander. This article has performed an extensive review in order to update the concept of chest compression-only CPR.

Keywords: cardiac arrest, cardiopulmonary resuscitation (CPR), chest compression, out-of-hospital cardiac arrest (OHCA), return of spontaneous circulation (ROSC)

1. Introduction

More than 300,000 Americans died from cardiac arrest each year [1]. Cardiopulmonary resuscitation (CPR) provided by a bystander may improve outcome [2] but is generally performed in less than 30% of the cases [3, 4].

Survival rate of out-of-cardiac arrest (OHCA) is only about 7% [5] in previous 2 decades. According to etiology, cardiac arrest can be divided into asphyxial and non-asphyxial types. Asphyxial arrest is caused by situations inducing low blood oxygen status, like drawing, suicide on the hanging, monoxide carbon intoxication, etc. The non-asphyxial arrest is due to dysfunction of cardiac electrical activity [6]. This article will focus in non-asphyxial OHCA patients. The major reason of low survival rate of OHCA patients is that they do not receive CPR immediately. The 2010 American Heart Association (AHA) guidelines made a change of the sequence of CPR from A, airway; B, breathing; C, chest compression (A-B-C) to C-A-B to put an emphasis on chest compression and its rate and depth. This change could make CPR more easy to start and minimize delaying time for ventilation. Starting CPR from mouth-to-mouth ventilation is a big barrier in real world due to fear of communicating infectious disease or other reasons. Except that it is easier to start CPR from chest compressions, this change from A-B-C to C-A-B make the cardiac arrest patient earlier to receive chest compression which is the most important element of CPR. The delay time for ventilation would also be shorter than before, like receiving ventilation after 30 chest compressions or is about only 18 seconds of delay at the speed of at least 100 chest compression/minute or even shorter if there two bystanders who resuscitated children or infant. Chest compression-only CPR is encouraged in certain condition like only one rescuer, untrained rescuers, or multiple rescuers who are unwilling to do mouth-to-mouth ventilation [7]. There are randomized trials that support results of chest compression-only CPR recently [8, 9]. Chest compression-only CPR is easier to do by untrained bystander and is easier to be introduced by dispatcher by phone and increase actual provision by bystanders [10].

In this work, we will firstly describe our recent successful experience treating a case with OHCA after chest compression-only CPR who has complete neurological recovery [11] and perform an extensive review in order to update the concept of chest compression-only CPR.

2. Case presentation

A 55-year-old male had smoking history for 40 years but without prior history of diabetes mellitus, hypertension, or hyperlipidemia. He developed collapse suddenly in the presence of his exercise partners when playing tennis. One exercise partner called for emergency medical service (EMS) team, and another partner began chest compression-only CPR immediately. The compression-only CPR was performed by one bystander for the initial 8 minutes, followed by two persons alternatively. After 28 minutes, the paramedic team arrived. At that time, the patient was unresponsive, no detectable blood pressure, pulseless, and without spontaneous respiration. The EMS team secured the airway and performed ventilation via Ambu bagging and continuous chest compression. After 10 minutes of CPR, the EMS found a detectable carotid pulse, the ECG monitor showed sinus rhythm but with wide QRS complex. For the prehospital resuscitation, the return of spontaneous circulation (ROSC) was achieved after 28 minutes of chest compression-only CPR by bystanders plus 10 minutes of assisted ventilation/chest compression by EMS. The patient had a blood pressure of 180/105 mmHg, heart rate of 88/minute, respiratory rate of 12/minute, and SpO2 of 99%. Nevertheless, he was still unresponsive with Glasgow Coma Scale of E1V1M1. The patient was then transported to our emergency department where he received endotracheal intubation immediately. The vital signs revealed body temperature, 36.1°C; pulse rate, 125 bpm; respiratory rate, 20/minute; blood pressure, and 122/96 mmHg, but the coma scale was E1V1M1. He was transferred to the intensive care unit promptly. His conscious level mildly improved from E1V1M1 to E2VTM3 after admitted at the intensive care unit. On the third admission day, his consciousness recovered (from E2VTM3 to E4V5M6), and he was extubated. He was transferred to the general ward on the fourth hospital day. On the fifth hospital day, the percutaneous coronary intervention and electrophysiological study were suggested, but patient refused due to a personal reason. A computed tomographic coronary angiogram studied on the sixth hospital day showed significant stenosis of the right coronary artery and heavy calcifications of both left anterior and left circumflex coronary arteries. On the seventh hospital day, he was discharged without any neurological or memory impairment. Thus, this case supports the present CPR guideline that recommends effective chest compression without assisted ventilation by laypersons for managing patients in cardiac arrest.

3. Searching strategy

We use a medical term as "chest compassion-only CPR" and search relevant papers from the PubMed, Medline + Journals@ Ovid, and Cochrane library. There were no restrictions for sex or populations. We do not restrict search criteria to humans or animals. We only limit search criteria to English language, review articles, and publication year from January 2010 to August 2017. We limit that the publication year is hoping to get the most updated information. We found that there were 35 review articles from PubMed, 11 review articles in Medline + Journals@ Ovid, and 1 review article in Cochrane, respectively. The repeated data were found in 10 articles; thus, only 37 articles were obtained in the systemic review. We will report the updated information relevant to the chest compression-only CPR. Other issues including mechanical chest compression devices, pharmacological agents in cardiac arrest, and post-resuscitation care are not included in this article.

4. Increasing rates of bystander CPR

Successful treatment of OHCA patients remains an unmet health demand. The crucial components of treatment consist of early recognition of cardiac arrest, prompt and effective CPR, effective and early defibrillation, and organized post-resuscitation care. The initiation of bystander CPR followed by a prompt emergency response delivers high-quality CPR, which is critical to patients' outcomes. Before 2010, most OHCA patients do not receive any bystander CPR even if there is a bystander at the scene [12]. One of the probable reasons is due to the A-B-C sequence of CPR, which makes rescuers feel difficult to start CPR from opening the airway and delivering breaths with mouth-to-mouth ventilation. The bystanders would rather call emergent medical service (EMS) team and await emergency staff to arrive to start CPR. Thus, such cardiac arrest patient's outcome is very poor. Bystanders do not start CPR because they are afraid of get hurt, contacting infectious disease, not enough confidence to practice complicated conventional CPR, and following legal problems [13]. Changing CPR sequence as C-A-B in 2010 AHA guideline might encourage rescuers more easily to begin CPR from starting with chest compressions compared with staring from mouth-to-mouth ventilation. Besides, this change can let OHCA patients receive chest compression earlier without delay due to giving ventilation. Giving ventilation first not only delays chest compression but also increases thoracic pressure, decreases venous return, and decreases coronary artery pressure. This vicious cycle brings poor prognosis of cardiac arrest victim. A recent report found that the chance of selecting compression-only CPR markedly increased from 36.4% in 2005–2007 to 63.7% in 2011–2012 [14]. This change in results may be explained by the increase of dispatcher instruction to lay rescuers, concept change after the 2010 AHA guideline, and most importantly the dissemination of compression-only CPR in the CPR training program [15, 16]. Thus, a few recommendations may be helpful to increase rate of bystander CPR including to broaden CPR training, provide reassurance to increase participation, improve EMS quality which are discussed in this section.

4.1. Broaden CPR training

In order to spread and accelerate CPR education, new approaches are required to reach a larger public audience. Lynch et al. have develop and validate a 30-minute CPR self-instruction program for laypersons [17]. This CPR course has provided a useful tool for education outside the classroom. Another way to broaden CPR training might be through recently developed automated external defibrillator (AED) programs. The Cardiac Arrest Survival Act (CASA; Public Law 106–505) mandated establishment of lay rescuer AED programs in federal buildings. Many state governments have carried out AED programs in public places, like airport, hotels, gymnasiums, schools, nursing homes, and train stations. CPR trainings held by governments are inspired to provide CPR training for future rescuers as part of the comprehensive community lay rescuer AED plans. The AHA has provided information to schools to help them prepare to respond to medical emergencies, including sudden cardiac death [18].

4.2. Dispatcher-assisted “telephone CPR”

The broadened CPR training is helpful to the public laypersons. However, these CPR trainings may not resolve the problem for the cardiac arrest victims that occur at home, where only a few untrained witnesses may commonly be present. The development of dispatcher-assisted “telephone CPR” may allow for CPR instruction in real time even when rescuers have not received prior training. Dispatcher-assisted “telephone CPR” is especially important for cardiac arrest at home where without trained rescuers or available AEDs. Dispatcher-assisted CPR instruction variations have been surveyed [19, 20] and have found that this “training” method was a useful technique to lay rescuers for direct CPR care.

4.3. Offer reassurance to increase participation

Bystander reluctance to perform CPR is common. The government officers must announce that the chance of disease transmission is very low. To the best of our knowledge, there was no case report of human immunodeficiency virus or hepatitis transmission through performance of CPR up-to-date. In combination with Occupational Safety and Health Administration recommendations for places of working, decision-makers should provide devices of mouth-to-mouth barrier and gloves where AEDs are available. Those devices can assist CPR performance when AEDs are used. CPR classes should be included in Good Samaritan legislation [21] and published near AED installations. The public should realize that the survival chance of OHCA victim can be double or triple if bystanders practicing CPR immediately, while the CPR performance is at little risk to the rescuer.

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4.4. Strengthen CPR practice and EMS quality

Lay rescuers and EMS training projects of the community must include a course of continuous quality improvement that includes reviewing of resuscitation attempts, CPR quality, and dispatcher CPR instructions that will be offered to bystanders. Healthcare provider systems must perform continuous quality improvement plans that include monitoring the quality of CPR practiced during any resuscitation efforts. These monitored data must be used to maximize resuscitation care quality, including CPR practice quality. Nowadays, several devices have been made to both estimate and offer feedback about CPR practice, either extra capabilities of CPR monitor of defibrillators or stand-alone equipment which rescuers can use before a defibrillator available at the scene of cardiac arrest [22, 23]. Some of these devices, like "piston-type mechanical cardiopulmonary resuscitation device," can also record CPR performance and provide opportunities for training [24]. These tools may have an important impact on this quality improvement goal.

5. Quality of chest compression element of CPR

Chest compression is the most important element of CPR. Excellent chest compression can maximize coronary perfusion pressure and increase the chance of ROSC. Chest compression helps blood from the heart to arterial system and coronary artery system. At the release phase of chest compression, the blood returns to the heart under negative thoracic pressure, so that external chest compression helps the "heart works again" and provides about 30% blood supply as normal heart works [25, 26].

New data continuously come out which validate the importance of both the practicing CPR *per set* and assuring CPR quality are most favorable. The International Liaison Committee for Resuscitation performed a systematic review of evidence for the optimal chest compression characteristics during the 2010 Consensus on Science and Treatment Recommendations Conference. The final conclusions of this review were recommendations for deeper (≧5 cm) and quicker (≧100/minute) chest compressions, ensuring full release of pressure between compression and minimizing interruptions in chest compressions [27]. Here we will discuss in-depth of each element of CPR.

5.1. Chest compression rate and depth

External chest compression rate is suggested at least 100/minute in 2010 AHA guideline. Chest compression number is an important determination of survival with good neurological function and ROSC which is the most powerful predictor of survival from OHCA [3]. The OHCA patient who receives chest compression rate between 100 and 120/minute has a greatest chance to survival to discharge according to 2010 AHA guideline [28].

Except chest compression rate, chest compression depth is suggested to at least 2 in (5 cm) in 2010 AHA guideline but not 1½–2 in (4–5 cm) before. Chest compression depth directly compresses the heart and increases to create intrathoracic pressure to generate blood flow, which bring oxygen to the brain and heart. Deeper chest compression is associated with higher chance of survival to hospital. Every 0.5 cm increase depth doubles the chance of successful resuscitation [29]. Enough depth of chest compression is also a key to survival. However, chest compression depth has a reverse relation to chest compression rate. The higher chest compression rate and the lower chest compression depth have been noted. If chest compression rate up to 145/minute is done, the depth of chest compression becomes unacceptable according to 2005 AHA guideline [30].

The 2010 AHA guideline suggests chest compression depth of at least 2 in (5 cm) in adult's CPR equally without consideration of patients' thoracic diameter and body size. If chest compression depth is too deeper (residual of chest diameter less than 2 cm), chest compression may not be helpful to patient but hurt intrathoracic organs and lead to complications. For low-body-weight patients, an alternative chest compression depth of one-fourth of the external anterior to posterior thoracic depth is recommended [31].

5.2. Allowing complete chest recoil

Not only emphasizing chest compression rate and depth, but allowing total chest complete recoil at each chest compression is also mentioned by 2010 AHA guideline. Complete chest recoil makes negative thoracic pressure to draw venous blood back to the heart and thus increases preload of the heart, higher coronary perfusion pressure, and good cerebral perfusion pressure. Allowing complete chest recoil at each chest compression is suggested at the speed of at least 100 chest compressions/minute. But this condition will make rescuer easily fatigue because upward force needs to be full against gravity which induce major energy consumption of the rescuer. Fatigue of rescuer will lead to chest wall incomplete decompression and smaller chest compression depth and increase residual intrathoracic pressure during chest decompression stage. Increased residual intrathoracic pressure will obscure venous return, make less increase in systemic arterial pressure when chest compression, and decrease cerebral and coronary perfusion pressure. Even 1 minute of incomplete chest decompression during CPR will bring negative effect [32]. Changing sequential persons is an effective way to keep cardiopulmonary resuscitation quality by keeping chest compression rate at least 100/minute and allowing complete chest recoil.

5.3. Minimalize chest compression interruptions

Minimalizing chest compression interruptions is an index of high quality of chest compression component. Chest compression phase replaces systolic pressure of the heart, and the recoil phase replaces diastolic pressure of the heart. Chest compression interruptions result in no cardiac support during CPR. This situation is called no flow time (NFT). Such chest compression interruptions make poor prognosis of OHCA [33, 34]. The change of the ventilation to chest compression ratio from 2:15 to 2:30 according to 2005 CPR guideline suggests to increase chest compression velocity per minute and minimalize interruptions induced by ventilation. These interruptions made 25% reduction in the NFT [35].

Chest compression is also interrupted by pulse and rhythm check. Cessation of chest compression for automated external defibrillators (AEDs) to analyze electrocardiogram can lead to 10% no flow time (NFT) events. When asystole and ventricular fibrillation (VF) are analyzed,

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additional confirmatory pulse checking makes delay chest compression. These two kinds of no flow times (NFTs) can be prevented by immediate chest compression when asystole is revealed by electrocardiogram or just defibrillated ventricular fibrillation (VF) rhythm. Filtering out artifact wave from chest compression by cardiac monitor or automated external defibrillator (AED) avoids chest compression interruptions and increases cardiopulmonary resuscitation (CPR) efficiency [36].

Pre-/post-defibrillation pauses may cause chest compression interruptions and create no flow times (NFTs) due to defibrillator charging, pulse and rhythm check, or lack of quick chest compressions [37]. Shortening pre-/post-defibrillation pauses of chest compression increases 13-fold chance of ROSC [38]. Besides, decrease pre-defibrillation pause of chest compression increases chance of successful defibrillation and effects of termination ventricular tachycardia (VT)/ventricular fibrillation (VF) situation [39]. Even now, a safe and effective tool for "hands-on" defibrillation solves chest compression interruption of pre-/post-defibrillation pause and increases chance of successful defibrillation. Though, it is still studied [40].

In out-of-hospital cardiac arrest (OHCA), transferring patient from arrest situation to ambulance is also a reason of no flow time (NFT) [41]. Rescuers should be educated that transferring cardiac arrest patient can lead to NFT. Besides, rescuer team should not move OHCA patient until ROSC is successful after giving professional advance life resuscitation or move OHCA patient with compressions and using Advance Cardiology Consultants and Diagnostics (ACCDs) [42].

Besides, many other reasons can influence the chest compression interruptions. Cardiopulmonary resuscitation scene has a high emotional stress; human behavior can cause nonspecific NFTs. Like poor leadership, poor task distribution by a leader who gives double or even triple orders which lead rescuer hard to member to produce high cognition load will result in poor rescuer concentration and poor awareness of CPR situations. The abovementions will cause nonspecific NFTs. In the contrast, if the leader gives rescuer members a single, clear order which can make rescuers decrease cognition load increases teamwork quality and decreases NFTs [43]. There are several common reasons causing NFTs [43], such as (1) rescuer fatigue and change chest compressor, (2) performing ventilation, (3) performing airway maintenance, (4) application CPR device, (5) pulse and rhythm check, (6) pre-/post-defibrillation pause, (7) performing vascular access, and (8) transferring patient to ambulance.

Rescuer fatigue and change chest compressor are the most common reasons to induce NFT events. Especially, chest compressor fatigue is usually found after 1 minute of CPR work. In 2010 AHA guideline, chest compressor change every 2 minutes is suggested. Changing chest compressors also interrupts chest compression. To minimize chest compression interruptions, chest compressor switch must be done within 5 seconds. If there are two rescuers, they should be positioned on either side of the patient. One rescuer should be ready and wait to change "working compressor" every 2 minutes [44].

5.4. Avoid excessive ventilation

In 2010 AHA guideline, rescue ventilation is less emphasized than before. During low blood flow due to cardiopulmonary resuscitation status, oxygen supply is mainly from limited blood flow, and chest compression presents as "working heart." Thus, chest compression is emphasized in the first few minutes of witnessed cardiac arrest [45]. Excessive ventilation increases high thoracic pressure which results in lower coronary perfusion pressure, decreased venous return, and poor survival rate [46]. In 2010 AHA guideline, suggested ventilator rate during CPR is giving two breaths (1 second each) during a brief (about 3–4 seconds) pause after is every 30 chest compressions [47].

In conclusion, chest compression is the key component of CPR. High quality of chest compression is the mostly important determination of ROSC which is the most important predictor of survival from cardiac arrest. Besides, high quality of chest compression combined by rate and depth, minimalizing chest interruptions, and avoiding excessive ventilation, is an important determination of survival with good neurological outcome [3].

6. Compression-only CPR

Compression-only CPR is easier to teach; it does not require mouth-to-mouth ventilation (which can be an impediment to bystanders starting CPR), and it reduces interruptions in chest compressions. Hupfl et al. [8] have conducted a systematic review and meta-analysis in two settings of CPR in OHCA patients—chest compression-only bystander CPR and standard bystander CPR (chest compression plus rescue ventilation). A primary meta-analysis included trials that patients of those trials were randomized to attribute to accept one of the two CPR techniques which are commended by dispatchers, and another meta-analysis included studies of chest compression-only CPR as observational cohort studies. Survival to hospital discharge was the primary outcome. The pooled data of three randomized trials revealed that chest compression-only CPR survival chance was greater (14% [211/1500]) than that of the standard CPR (12% [178/1531]; risk ratio 1.22, 95% CI 1.01–1.46). The absolute increase in survival was 2.4% (95% CI 0.1–4.9). In the secondary meta-analysis of seven observational cohort studies, no difference was recorded between the two CPR techniques (8% [223/2731] and 8% [863/11152]; risk ratio 0.96, 95% CI 0.83–1.11). They concluded that for adults with out-of-hospital cardiac arrest, instructions to bystanders from emergency medical services dispatch should focus on chest compression-only CPR.

A more recent review reported by Zhan et al. [6] have compared the effects of continuous chest compression CPR (with or without rescue breathing) versus conventional CPR plus rescue breathing (interrupted chest compression with pauses for breaths) of non-asphyxial OHCA in large scales of patients. They included three randomized controlled trials (RCTs) and one cluster RCT (with a total of 26,742 participants analyzed). According to CPR methods, this report divided CPR into "CPR administered by untrained bystander" and "CPR administered by a trained professional."

For the *CPR administered by untrained bystander*, bystanders administered CPR under telephone instruction from emergency services. They found that better OHCA patient survival to hospital discharge rate (2.4%; 14 versus 11.6%; RR 1.21, 95% confidence interval (CI) 1.01–1.46; 3 studies, 3031 participants) was those who received continuous chest compression CPR without rescue breathing compared with those who received interrupted chest compression with rescue breathing (ratio 15:2). For the *CPR administered by a trained professional* from emergency medical service (EMS) professionals, there were 23,711 participants who received either continuous chest compression CPR (100/minute) with asynchronous rescue breathing (10/minute) or interrupted chest compression with pauses for rescue breathing (ratio 30:2). Results revealed that lower risk of survival to hospital discharge was noted for continuous chest compression CPR with asynchronous rescue breathing (9.0%) compared with interrupted chest compression with rescue breathing (9.7%). Both have an adjusted risk difference (ARD) of −0.7%; 95% CI (−1.5 to 0.1%) (moderate-quality evidence).

Return of spontaneous circulation is likely to be slightly lower in people treated with continuous chest compression CPR plus asynchronous rescue breathing (24.2 versus 25.3%; −1.1% (95% CI −2.4 to 0.1)) (high-quality evidence).

This report found that following OHCA, bystander-administered chest compression-only CPR, supported by telephone instruction, increases the proportion of people who survive to hospital discharge compared with conventional interrupted chest compression CPR plus rescue breathing. However, when CPR performed by EMS providers, continuous chest compressions plus asynchronous rescue breathing did not result in higher rates for survival to hospital discharge compared to interrupted chest compression plus rescue breathing [6]. Thus, due to these experiences, it is reasonable to suggest that bystander should perform CPR and as soon as possible (1) do basic life support protocol, if trained (in CPR) and willing and (2) do compression-only CPR, if untrained or unwilling to include ventilation. Healthcare professionals should perform CPR with combined compressions and ventilations.

Another animal study compared survival of VF-arrested swine treated with chest compression-only CPR or with realistic bystander CPR where each set of chest compressions was interrupted with a realistic 16 seconds for ventilations. Survival was 80% with chest compression-only CPR and 13% with standard bystander CPR [48]. Similar authors have performed their extensive efforts to advocate and teach chest compression-only CPR as part of cardiocerebral resuscitation for patients with primary cardiac arrest in the state of Arizona. They found that for OHCA patients, the survival rate was 7.8% in those receiving guidelines of CPR and 13.3% for those who received chest compression-only CPR. In the subset of patients with a witnessed cardiac arrest and a shockable rhythm, the survival rate was 17.7% in those receiving guidelines of CPR and 34% in those patients receiving chest compression-only CPR [49, 50]. These findings support the usefulness of chest compression-only CPR in managing OHCA patients.

7. Future direction

It has been reported that the use of Internet-based CPR education and certification may expand current training program coverage, according to the expanding use of Internet via television, mobile telephone, and other personal devices [51]. In certain conditions, simpler procedure of by bystander resuscitation, like chest compression-only CPR, may broaden participation and remain a field that needs further studies [20]. For EMS-CPR and resuscitation companies, college or institute of EMT training systems, and other professional CPR providers, the use of accurate simulation with video recording and debriefing may be very useful in resuscitation training; the use of such patient simulators is rapidly an expanding area that deserves a lot of attention [52, 53].

8. Conclusion

OHCA remains a common event and is associated with high mortality. Strengthening the chain of survival with prompt initiation of high-quality CPR, minimizing interruptions in chest compressions and organized post-resuscitation care, provides focused opportunities to improve outcomes. CPR must be started as soon as possible after a victim of OHCA, and bystander should (1) do full CPR, if trained (in CPR) and willing and (2) do chest compression-only CPR, if untrained or unwilling to perform mouth-to-month ventilation. Healthcare professionals should perform CPR with combined compressions and ventilations. Improved survival rates depend on a public trained and motivated to recognize the emergency, activate EMS or the emergency response system, initiate high-quality CPR, and use an AED if available.

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