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Comparison of the Effects of Three Different Counting Methods on Cardiopulmonary Resuscitation Quality and Rescuer Fatigue

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Abstract

Background: Chest compression with adequate depth and number is one of the main indicators of high-quality cardiopulmonary resuscitation (CPR). Nevertheless, no proper counting technique is suggested to provide sufficient number of massages.

Aim: To compare the effects of three techniques of chest compression counting on the quality of CPR and rescuer fatigue.

Method: In this clinical trial, 30 rescuers (divided into three groups) performed all the three techniques of chest compression counting (without counting [common], alternate [counting from 1 to 10], and continuous [counting from 1 to 100]) in 90 different resuscitation events at Ghaem Hospital of Mashhad, Iran, in 2015. Rescuer fatigue was evaluated using visual analogue scale to evaluate fatigue, and quality of massage was evaluated by the level of end-tidal CO_2 ($ETCO_2$); massage was calculated in minutes. Data was analyzed in SPSS using ANOVA and Friedman test.

Results: The mean age of the rescuers was 30.6±6.8 years. Based on Kruskal-Wallis test results, common, continuous, and alternate techniques were in descending order of fatigue level, and the common, alternate, and continuous techniques were in descending order of number of massages. In addition, according to ANOVA, the highest $ETCO_2$ levels were observed in the alternate, continuous, and common techniques, respectively; the difference between the techniques was significant ($P<0.001$).

Implications for practice: The use of alternate counting technique reduces rescuer fatigue, elevates $ETCO_2$ during resuscitation, and makes approximating the number of massages to the number advised by the American Heart Association possible.

Keywords: Chest compression counting technique, CPR quality, Rescuer fatigue

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Introduction

Cardiac arrest is one of the major problems affecting general health among thousands of individuals who annually lose their lives because of this problem (1). This situation is still one of the most dangerous conditions that requires immediate and deliberate action for survival and prevention of irreversible damages to the vital systems of the body (2). The quality of cardiopulmonary resuscitation (CPR) is a major criterion for determining survival rate, such that the survival rate increases two-three times by improving cerebral and cardiac blood flow in patients (3-5).

The results of some studies suggested that the quality of care provided during resuscitation efforts is not in accordance with the international standards (1). Despite the great efforts devoted to improving the quality of resuscitation in the past 50 years, the results of former studies indicated the need for further action (1). Variability in the quality of CPR leads to discrepancy in outcomes. Therefore, the basic factors affecting CPR, including the number of massages, depth of massage, compression to ventilation ratio (C:V), and chest recoil, should be considered to increase the quality of CPR (6).

According to the 2010 resuscitation guidelines, all rescuers should provide chest compression for cardiac arrest patients (7). Cardiac massage is the core of CPR and desirable quality of CPR is dependent on it (8). Given the importance of massage, guidelines recommend minimizing interruption during massage and even using only chest compression CPR technique to increase massage time and ratio of cardiac massage to total time of CPR, resulting in increased return of spontaneous circulation (ROSC), high survival rates, and early hospital discharge. The 2010 American Heart Association (AHA) guidelines suggested changes in the order of steps from A-B-C (airway, breathing, chest compressions) to C-A-B (chest compressions, airway, breathing), which shows the importance of chest compression as it provides adequate blood flow to maintain the brain and heart (9).

Over the past 50 years, it has been repeatedly recommended to increase the number of chest compressions to raise the ratio of chest compression time to total time of resuscitation. In addition, the 2015 guideline determined a maximum of 120 massages per minute to avoid reduced quality of massage, especially suitable compression depth. It should be noted that by increasing the number of compressions, the compression depth is reduced and the number of inappropriate compressions is increased (10). Studies demonstrated that increased or decreased number of massages could affect compression depth, such that compression depth reduces to less than 4 cm in 80 compressions per minute and to 3.5 cm in 160 compressions per minute. As a result, it is recommended to avoid excessive number of compressions, which leads to insufficient compression depth (11).

Studies also indicated that excessive increase in the number of compressions leads to a significant reduction in the number of correct compressions, and ultimately, decrease in quality of CPR by causing fatigue in rescuers (11-13). One of the factors that resuscitation instructions emphasize on is monitoring the end-tidal carbon dioxide ($ETCO_2$) during CPR. Measurement of $ETCO_2$ concentration is an easy and non-invasive technique to measure blood flow during CPR and its increase could reflect the quality of CPR and ROSC (14). $ETCO_2$ could also indicate insufficient pressure of chest compression caused by rescuer fatigue resulting in undesirable cardiac output (15).

Although various studies were conducted on the appropriate number of cardiac massage and it has been repeatedly mentioned in CPR guidelines, there are no recommendations on the proper number and counting techniques. To the best of our knowledge, only one study has investigated and focused on different techniques of counting. Zhan lei et al. conducted a mannequin-based study assuming that 1-10 counting technique requires less energy from rescuers by using monosyllabic numbers compared to the 1-30 counting technique; thus, it causes less fatigue. The results of that study demonstrated less rescuer fatigue and higher quality of resuscitation (16). Given that the study of Zhan et al. was the only study found by researchers on this issue and that study was a mannequin-based simulation of CPR event, we aimed to investigate three techniques of compression counting, including common (without counting), alternate (1-10), and continuous (1-100) techniques, in advanced CPR under real hospital conditions.

Methods

This clinical trial was conducted on three groups of rescuers (n=30), as members of resuscitation team, and patients requiring CPR at research and treatment center of Ghaem Teaching Hospital in Mashhad, Iran, 2015. The rescuers used the three chest compression counting techniques of common, alternate, and continuous. According to the equation of calculating the mean, standard deviation, and quality index in the study of Zhan lei et al. (16), the sample size was determined 30 for each group. In the three groups of continuous, alternate, and common chest compression counting, 7, 7, and 9 subjects (totally 23 cases) were excluded, respectively, based on the exclusion criteria, including non-adherence to four cycles of two-minute CPR and underlying pulmonary embolism disease. Overall, 90 CPR events were evaluated.

Group 1: standard division: S1=4.09; mean, X1=31.10
Group 2: standard division: S2=3.09; mean, X2=22.15

The inclusion criteria for the rescuers were consent to participate in the study, a BSc degree or higher (in nursing or anesthesia), at least six months of employment in the resuscitation team, and participating in a briefing session before the initiation of the intervention. The resuscitation events were included if the patients had advanced airway obstruction. The exclusion criteria were unwillingness of rescuers to continue participating in the study, not performing the four complete cycles of two-minute CPR (compression and respiration) during the study, not employing one of the three techniques, failure to perform resuscitation in accordance with the AHA protocol, and diseases such as pulmonary embolism. This study was conducted with approval of Ethics Committee of Mashhad University of Medical Sciences, providing an introduction letter to Ghaem educational, research, and treatment center, and obtaining informed consent from the patients' companions.

In this study, the inclusion and exclusion criteria forms, a demographic form, resuscitation assessment checklist, fatigue form, capnograph device, and stopwatch were utilized. The professors of the Faculty of Nursing and Midwifery at Mashhad University of Medical Sciences confirmed the content validity of the forms. Validity of the visual analog scale to evaluate fatigue (VASF) was confirmed by different studies (17). Validity of capnography was approved in a study by Pourghaznein et al. in 2013. The use of capnography device was recommended by the latest international resuscitation guidelines to monitor the quality of resuscitation process (18). Its validity is automatically evaluated at the beginning of each rebooting.

Each rescuer first performed the common technique of compression counting (without counting), and then randomly performed the other two compression techniques. These two techniques were allocated randomly with sortition. To avoid the effect of training of the other two techniques on the common technique, this technique was chosen as the top priority sampling.

Each rescuer conducted all the three counting techniques. Rescuers did not count the compressions in the common technique, and the researcher counted the number of compressions in two minutes. In the alternate compression counting technique, rescuer started counting compression from 1 to 10, and then counting started again from 1, the researcher counted the total number of compressions. In the continuous compression counting technique, counting and re-counting began from No. 1; the researcher counted the total number of compressions. Before the presence of rescuers to the patient's bedside, counting technique was reminded to them and in each CPR event, only one counting technique was used.

With the occurrence of cardiac arrest and announcing the code 99, the CPR team started resuscitation efforts. Capnography sensor (side stream technique) was connected to the endotracheal tube, and end-tidal CO_2 appeared on the monitor of the capnography device as quantitative data (numerical) and graphics, which were visible only to the researcher.

One counting technique performed by two rescuers was evaluated in every CPR event. The first person performed chest compression for two minutes. By the end of the two minutes, the second person immediately continued chest compression for two minutes. Then, the first and second persons again performed chest compression for two minutes, respectively. A total of 8 minutes of chest compression was studied in each CPR.

Fatigue scores were measured before compression, at the first and second two minutes, and at the end of CPR. The $ETCO_2$ level and the number of chest compressions were evaluated by the end of each cycle of CPR. The researcher read the mean $ETCO_2$ on the monitor of the capnography device and recorded it in the CPR checklist. The researchers counted the number of compressions every two minutes using the stopwatch and recorded it in the CPR assessment checklist. At all events, the fixed number of 10 breaths per minute was given to the patient.

After collecting and coding data and ensuring the accuracy of data entry, characteristics of the samples were described by using descriptive statistics such as frequency, mean, and standard deviation. Normality of distribution of the quantitative variables was assessed using Kolmogorov-Smirnov and Shapiro-Wilk tests. Given the non-normality of the distribution of the number of chest compressions, Friedman test was used to compare this variable in the three techniques, using SPSS version 16. All the statistical tests were performed with 95% confidence interval at significance level of 0.05.

Results

The mean age of the rescuers was 30.6±6.8 years (age range: 24-43 years). The rescuers consisted of 26.7% (n=8) females and 73.3% (n=22) males. The mean age of the patients in the three counting techniques was 71.8±13.5 years. These patients included 58.9% (n=53) females (Table 1).

Kruskal-Wallis test showed that rescuer fatigue in the three counting techniques at the start of resuscitation was not significantly different (P=0.17), but a significant difference was noted at the end of the first two minutes, at the end of the second two minutes, and the mean of four minutes (P=0.001). Thus, the common, continuous, and alternate techniques were in descending order of rescuer fatigue scores (Table 2).

Table 1. Characteristics of the patients and rescuers studied for the three counting techniques

Variables		Counting techniques			
		Without counting	Continuous	Alternate	Results
Age of patients (mean±SD)		73.8±14.5	70.7±13.1	71.0±13.1	P=0.43
Gender of patients	Male N(%)	9(30.0)	12(40.0)	16(53.3)	P=0.18
	Female N(%)	21(70.0)	18(60.0)	14(46.7)	
Heart rhythm number (percent)	VT	3(10.0)	1(3.3)	1(3.3)	P=0.10
	VF	1(3.3)	3(10.0)	2(6.7)	
	PEA*	0(0.0)	0(0.0)	3(10.0)	
	Asystole	26(86.7)	26(86.7)	27(90.0)	
Need to shock number(%)	Yes	26(86.7)	26(86.7)	27(90.0)	P=1.00
	No	4(13.3)	4(13.3)	3 (10.0)	
Cardiopulmonary resuscitation (CPR) frequency number(%)	First time	27(90.0)	29(96.6)	29(96.6)	P=0.16
	Second time	2(6.6)	1(3.4)	1(3.4)	
	Third time	1(3.4)	0(0.0)	0(0.0)	
	Four and more	0(0.0)	0(0.0)	0(0.0)	
Age of rescuers (mean±SD)		30.6±6.8			
Height (cm) (mean±SD)		171.4±8.1			
Weight (kg) (mean±SD)		71.1±11.7			
Gender of rescuers number (%)	Male N(%)	22(73.3)			
Gender rescuers number (%)	Female N(%)	8(26.7)			
Work experience in CPR team number(%)	Six months	12(40.0)			
	One to two years	4(13.3)			
	More than two years	14(46.7)			

* Pulseless Electrical Activity

Table 2. Mean of rescuer fatigue level in various stages of assessment for the three counting techniques

	One to ten technique	One to a hundred technique	Without counting technique	Kruskal-Wallis test result
	Mean±SD	Mean±SD	Mean±SD	
Start resuscitation	0.8±0.6	1.2±0.7	0.7±0.7	P=0.17
End of the first two minutes	3.8±0.9	5.1±1.1	2.1±0.8	P=0.001
End of the second two minutes	7.2±1.2	6.7±1.1	3.7±1.0	P=0.001
Mean four minutes	11.0±2.0	11.8±1.4	5.8±1.2	P=0.001
Friedman test result	P=0.001	P=0.001	P=0.001	

Table 3. Comparison of the mean number of massages for the three studied techniques

	One to ten technique	One to a hundred technique	Without counting technique	Kruskal-Wallis test result
	Mean±SD	Mean±SD	Mean±SD	
The first two minutes (Number of massages per minute)	124.3±5.0	97.5±5.5	110.3±4.6	P=0.001
The second two minutes (number of massages per minute)	119.6±5.0	88.5±6.1	105.6±4.0	P=0.001
Difference between the first and second minutes (number of massage per minute)	4.7±5.5	9.0±7.3	4.7±4.8	P=0.001
Mean four minutes(number of massages per minute)	122.0±26.1	93.0±30.8	108.0±27.8	P=0.001
Friedman test result	P=0.001	P=0.001	P=0.001	

Table 4. Mean of end-tidal CO_2 for the three studied techniques

	One to ten technique	One to a hundred technique	Without counting technique	ANOVA test result
	Mean±SD	Mean±SD	Mean±SD	
The first two minutes	10.3±1.3	12.2±2.1	9.4±1.5	P=0.001
The second two minutes	8.7±1.3	9.5±1.9	6.1±2.1	P=0.001
Difference between the first and second minutes	1.6±1.5	2.7±2.4	3.3±2.5	P=0.001
Mean four minutes	10.4±1.4	11.7±2.0	9.7±1.8	P=0.001
ANOVA test result	P=0.001	P=0.001	P=0.001	

By the end of the first two minutes, Mann-Whitney U test reflected that the fatigue scores in the continuous technique were higher compared to the common technique (P=0.001). By the end of the first and second two minutes, the fatigue score in the common technique was higher than the alternate technique (P=0.001). Meanwhile, by the end of the first and second two minutes, the fatigue scores in the continuous technique group were higher than those in the alternate technique group (P=0.001).
Mann-Whitney U test showed that the number of massages in the second two minutes was less than the first two minutes in the three counting techniques (P=0.001). Kruskal-Wallis test proved that the number of massages per minute in the common counting technique group was higher than the other two groups in the first and second two minutes and total four minutes (P=0.001) (Table 3).
ANOVA test results showed that end-tidal CO_2 levels in all the three techniques was significantly different in the first and second two minutes (P=0.001). This means that in the second two minutes, the $ETCO_2$ score was lower than that in the first two minutes. The $ETCO_2$ level in the alternate counting technique (1-10) was higher than the other two counting techniques (Table 4).

Discussion

The results showed that the fatigue scores in an ascending order were related to the alternate (one to ten), common, and continuous counting (one to a hundred) techniques, respectively. Zou et al. (2015) conducted a study to evaluate the speed of cardiac massage on fatigue of rescuers. In this study, fatigue was defined, when 5 consecutive massage depths could not be achieved according to standard. Fatigue occurred at the speed of 140 in second 78, at the speed of 120 in second 106, and at the speed of 100 in second 96. By increasing massage speed higher than 120/min, rescuer fatigue occurs earlier (19). In that study, the mean number of massages in the common counting technique was higher than the other two counting techniques. The rescuer fatigue level elevated by increasing the number of massages. Probably the increase in fatigue in the common technique compared to the other two techniques is related to the number of massages. The results of that study are consistent with ours.
Lei et al. (2009) in a mannequin-based study evaluated the effects of two different chest compression counting techniques on CPR quality. Their results showed that 1-10 counting technique (3 times repetitions) was associated with less fatigue and longer time to reach the peak heart rate compared to 1-30 counting technique (16). The results of that study are in line with the current findings.

In this study, it was predicted that the monosyllabic counting technique is easier than polysyllabic ones and can save the physical capacity of rescuer as compared to the polysyllabic technique. Our findings are in agreement with these predictions. In the present study, the common counting technique was associated with the highest fatigue level, which indicates that further increase in the number of massages from the recommended number by resuscitation guidelines exacerbates fatigue.

Studies also demonstrate that a significant reduction in correct massage over time occurs because of rescuer fatigue that is effective on quality of cardiopulmonary resuscitation. Increased speed and number of massage can lead to reduce the cardiopulmonary resuscitation efficiency and rescuers fatigue. Although an increase in the number of massage can improve the survival rate of patients, but it can affect the workload and rescuer fatigue and ultimately cardiopulmonary resuscitation quality. The common counting technique has the highest number of chest compressions, but it has the lowest resuscitation quality. In counting technique of one to ten, which the number of massage is according to the resuscitation guideline, we had the highest resuscitation quality.

The results showed that the highest number of massage is related to without counting, 1-10 counting, and 1-100 counting techniques, respectively. By doing chest compressions via counting technique, we achieve the range of massage recommended by resuscitation guidelines that would have the highest quality of resuscitation. In the common counting technique, the number of chest compressions was higher than those proposed by resuscitation guidelines, which is associated with increased rescuer fatigue and decreased $ETCO_2$ level compared to the other two techniques. It can be concluded that 1-10 counting technique is associated with the most appropriate number of chest compressions according to the resuscitation guidelines and the highest quality resuscitation compared to the other two techniques.

Kern et al. (1992) conducted a study entitled 'the number of chest compressions during resuscitation at bedside'. They showed that the use of auditory prompts improves the speed of rescuer massage (120 times per minute) (20). That study was similar to the present one in terms of investigating the number of chest compressions, and its results are consistent with the present study in relation to the number of chest compressions in accordance with the resuscitation guidelines.

Zhan lei et al. (2009) in a study evaluated the effects of two different counting techniques of chest compressions on the CPR quality on mannequins. They reported that the total number of compressions had no significant difference in two studied techniques (16). In the present study, the number of massage in three counting techniques was significantly different from each other; thus, the results of this study are inconsistent with those of the present study in terms of the number of massage. This discrepancy in results might be due to studying mannequins, a 30-minute break between the two techniques, and the limited sample size.

By doing chest compression via counting technique, we can obtain the range of massage recommended by resuscitation guidelines that would have the highest quality of resuscitation. In the common counting technique, the number of chest compressions was higher than the number of massage proposed by resuscitation guidelines, which is associated with increased rescuer fatigue and decreased $ETCO_2$ levels compared to the other two techniques. It can be concluded that through 1-10 counting technique provides the most appropriate number of chest compressions according to the resuscitation guidelines and the highest quality resuscitation compared to the other two techniques.

The results showed that the highest $ETCO_2$ levels were respectively related to 1-10 counting, 1-100 counting, and common techniques. Given that $ETCO_2$ is a sign of cardiac output during resuscitation (an index of effectiveness of chest compression and rescuers fatigue), 1-10 counting technique in the present study showed the highest $ETCO_2$ level, the least fatigue, and the most effective number of massage, indicating the superiority of this technique to the other two techniques.

Chen Jin et al. (2014) conducted a study entitled clinical evaluation of autochest compression device during cardiac arrest outside the hospital. The results of that study demonstrated superiority of using the device (automated Auto Pulse) to manual CPR in terms of improved cerebral blood flow and increased $ETCO_2$ level (21). The advantage of device is further regulation, higher number of massage, maintaining massage depth and the absence of fatigue, compared with manual CPR, which affects the $ETCO_2$ level. Given that the device influences qualitative indicators of resuscitation and 1-10 counting technique improves the quality indicators of number of massage and rescuer fatigue, the results of that study are indirectly consistent with the present study.

Implications for Practice

The use of alternate counting technique (1-10) compared to continuous counting (1-100) and common techniques (without counting) in chest compression is more consistent in terms of the number of chest compressions emphasized by the 2015 AHA guideline. It also reduces rescuer fatigue and increases $ETCO_2$ during CPR. Therefore, the use of alternate counting technique (1-10) in patients with heart failure can promote cardiac resuscitation quality and reduce fatigue rescuers.

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Conflicts of Interest

The authors declare no conflict of interest.

References

1. Sutton RM, Nadkarni V, Abella BS. “Putting it all together” to improve resuscitation quality. Emerg Med Clin North Am. 2012;30(1):105-22.
2. Salari A, Mohammad Nejad E, Vanaki Z, Ahmadi F. Effect of in-hospital cardiopulmonary cerebral resuscitation management on resuscitation outcomes. J Crit Care Nurs. 2011;4(1):12-22.
3. Abella BS, Sandbo N, Vassilatos P, Alvarado JP, O’Hearn N, Wigder HN, et al. Chest compression rates during cardiopulmonary resuscitation are suboptimal: a prospective study during in-hospital cardiac arrest. Circulation. 2005;111(4):428-34.
4. Dine CJ, Gersh RE, Leary M, Riegel BJ, Bellini LM, Abella BS. Improving cardiopulmonary resuscitation quality and resuscitation training by combining audiovisual feedback and debriefing. Crit Care Med. 2008;36(10):2817-22.
5. Fried DA, Leary M, Smith DA, Sutton RM, Niles D, Herzberg DL, et al. The prevalence of chest compression leaning during in-hospital cardiopulmonary resuscitation. Resuscitation. 2011;82(8):1019-24.
6. Hassan N, Brooks SC, Beed M, Howes D, Douma M. Improving chest compressions following cardiac arrest: pushing ahead. J Anesth Clin Res. 2014;5(390):2.
7. Jiang C, Jiang S, Zhao Y, Xu B, Zhou XL. Dominant hand position improves the quality of external chest compression: a manikin study based on 2010 CPR guidelines. J Emerg Med. 2015;48(4):436-44.
8. Rajab TK, Pozner CN, Conrad C, Cohn LH, Schmitto JD. Technique for chest compressions in adult CPR. World J Emerg Surg. 2011;6:41.
9. Field RA, Soar J, Davies RP, Akhtar N, Perkins GD. The impact of chest compression rates on quality of chest compressions–a manikin study. Resuscitation. 2012;83(3):360-4.
10. Vaillancourt C, Everson-Stewart S, Christenson J, Andrusiek D, Powell J, Nichol G, et al. The impact of increased chest compression fraction on return of spontaneous circulation for out-of-hospital cardiac arrest patients not in ventricular fibrillation. Resuscitation. 2011;82(12):1501-7.
11. Hong MY, Tsou JY, Tsao PC, Chang CJ, Hsu HC, Chan TY, et al. Push-fast recommendation on performing CPR causes excessive chest compression rates, a manikin model. Am J Emerg Med. 2014;32(12):1455-9.

12. Avramidis D, Sakellariou D, Stroumboulis P, Stathopoulou X, Gabrielatos G, Manolis AS. Reducing barriers for implementation of immediate CPR with chest compressions alone. Hosp Chron. 2008;3(1):9-12.
13. Ochoa FJ, Ramalle-Gomara E, Lisa V, Saralegui I. The effect of rescuer fatigue on the quality of chest compressions. Resuscitation. 1998;37(3):149-52.
14. Levin PD, Pizov R. End-tidal carbon dioxide and outcome of out-of-hospital cardiac arrest. N Engl J Med. 1997;337(23):1694-5.
15. Kolar M, Križmarić M, Klemen P, Grmec Š. Partial pressure of end-tidal carbon dioxide successful predicts cardiopulmonary resuscitation in the field: a prospective observational study. Crit Care. 2008;12(5):R115.
16. Lei Z, Qing H, Min Y. The effect of two different counting methods on the quality of CPR on a manikin--a randomized controlled trial. Resuscitation. 2009;80(6):685-8.
17. Brunier G, Graydon J. A comparison of two methods of measuring fatigue in patients on chronic haemodialysis: visual analogue vs Likert scale. Int J Nurs Stud. 1996;33(3):338-48.
18. American Heart Association. Highlights of the 2015 American Heart Association guidelines update for CPR and ECC. Dallas, USA: American Heart Association; 2015.
19. Zou Y, Shi W, Zhu Y, Tao R, Jiang Y, Li S, et al. Rate at 120/min provides qualified chest compression during cardiopulmonary resuscitation. Am J Emerg Med. 2015;33(4):535-8.
20. Kern KB, Sanders AB, Raife J, Milander MM, Otto CW, Ewy GA. A study of chest compression rates during cardiopulmonary resuscitation in humans: the importance of rate-directed chest compressions. Arch Intern Med. 1992;152(1):145-9.
21. Gao C, Chen Y, Peng H, Chen Y, Zhuang Y, Zhou S. Clinical evaluation of the AutoPulse automated chest compression device for out-of-hospital cardiac arrest in the northern district of Shanghai, China. Arch Med Sci. 2016;12(3):563-70.