The efficacy of alternative cardiopulmomonary resuscitation methods when compared to standard cardiopulmonary resuscitation: a simulation study
另類心肺復甦法與標準心肺復甦法功效上的比較：一個模擬研究

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Objective: There are limited data comparing the alternative cardiopulmomonary resuscitation (CPR) methods (over the head CPR, straddle CPR and one hand CPR) to standard CPR performed by emergency medical technicians (EMTs). Therefore we investigated the efficacy of the alternative CPRs compared to that of standard CPR performed by EMTs in simulated cardiac arrest scenarios. ***Methods:*** Thirty EMTs of intermediate level participated in this study. The performance of CPR was defined as the average depth, the total number of chest compressions, and the rate of compressions. EMTs performed three minutes of standard CPR and of alternative CPR on standard simulation mannequins with recording devices. Recorded performance was measured and compared between subgroups by the type of CPR, gender of EMTs and gender with various methods of CPR using ANOVA and t test statistics. ***Results:*** The average depth of compressions was 42.3±5.8, 42.6±4.7, 43.5±3.7, 33.8±6.6 mm (mean±standard deviation) respectively in standard CPR, over the head CPR, straddle CPR and one hand CPR. The total number of chest compression was 330.4±38.1, 334.8±70.2, 334.0±34.9, 312.1±53.5 in 3 minutes. The rate of compressions was found to be 111.5±10.3, 113.8±11.6, 110.5±11.2, 110.7±11.8 times per minute. The comparison of the performance qualities for the four types of CPR showed that the compression depth was significantly lower in one-hand CPR (p<0.000). No EMT gender difference in the quality of performance of total CPR was noted. ***Conclusions:*** The efficacy of alternative CPRs are shown to be similar to that of standard CPR in a compression-only simulation cardiac arrest model. (Hong Kong j.emerg.med. 2012;19:242-248)

目的：只有有限的數據比較另類心肺復甦（CPR）法（過頭式CPR、跨越式CPR和單手式CPR）和由急症醫學技術員（EMT）施行的標準CPR。因此，我們在一個模擬心臟驟停的情況下，作了由EMT施行的另類CPR和標準CPR在功效上的對比研究。**方法：**30位中級程度的EMT參與了這項研究。CPR的表現以平均按壓深度，胸腔按壓總次數，和按壓速率作為定義。EMT在附有記錄設備的標準模擬假人上，分別施行標準CPR和另類CPR各3分鐘。被記錄下來的表現經過計量後，以方差分析和t檢驗統計法對CPR類型和EMT性別亞群進行對比。**結果：**標準CPR、過頭式CPR、跨越式CPR和單手式CPR的平均按壓深度分別為42.3±5.8，42.6±4.7，43.5±3.7，33.8±6.6毫米（平均值±標準差）。3分鐘胸腔按壓總次數為330.4±38.1，334.8±70.2，334.0±34.9，312.1±53.5次。每分鐘的按壓速率為111.5±10.3，

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113.8±11.6 ， 110.5±11.2 ， 110.7±11.8 次。對四種類型 CPR 表現的比較顯示，單手式 CPR 的按壓深度明顯較低（p<0.000）。EMT 的性別差異在 CPR 總次數上沒有差別。**結論：**以純按壓方式於模擬心臟驟停模型上施行的另類 CPR，在功效上與標準 CPR 類似。

Keywords: Ambulance, cardiac compression, confined space, emergency medical technician

關鍵詞：救護車、心臟按壓、密閉空間、急症醫學技術員

Introduction

Once a cardiac arrest occurs, any witnesses as well as emergency medical service providers should conduct cardiopulmonary resuscitation (CPR) during this prehospital setting to increase the survival rate of the patient.[1,2] Standard methods of performing CPR, at the prehospital settings, are advocated in most situations, including when emergency medical technicians (EMTs) are conducting the CPR. Since cardiac arrests may occur in confined spaces, such as in a bathroom, in a vehicle or in other venues, modified chest compressions may have their roles.[3]

It is especially difficult to maintain a quality CPR performance at the prehospital setting in a moving ambulance.[4] This is due to various limitations, such as the number of EMTs sitting at the back of the ambulance, the ambulance space, and the ambulance speed.[5,6] In Korea, one driver and one EMT-I-level EMT are onboard, and in most cases, only the EMT conducts the CPR. Thus, it is very difficult to conduct the standard 30:2 compression:ventilation CPR. In such cases, it may be a further challenge to maintain chest compressions of high quality. As noted in the current concept of Cardiocerebral Resuscitation (CCR)[7] and the 2010 guidelines for CPR published by International Liaison Committee on Resuscitation,[8] only chest compression is recommended to be conducted if a comprehensive chest compression with a cycle of 30:2 is not possible to be conducted due to limiting factors. The aforementioned recommendation of compression-only CPR may also be applicable in a moving ambulance. Extending this concern, the authors conducted a simulation to investigate the efficacy of various CPR methods that may be used with respect to the limitations as a result of a moving ambulance.

Methods

Thirty EMTs who had taken a course on prehospital CPR training were selected as the subjects of this study. They were intermediate-level EMTs from Gyunggi-Do province who have had field experiences in emergency medical services (EMS) for at least one year (mean, 4.5 years and range, 1-12 years). The qualifications for the intermediate-level EMTs included a three or four-year-course university degree and a relevant training certification. The study was conducted in the basic life support practice room of the Gyunggi-Do Fire Service Academy.

The study goals were explained to the subjects. The Institutional Review Board approved the study plans including subject selection, conduction of a simulation study using a mannequin, data collection, and analysis of results. All the subjects were trained for 30 minutes on the appropriate location, depth, rate, release, and minimisation of CPR interruption, and on the appropriate methods of conducting alternative CPRs.

The study was a randomised crossover study in which the method of the CPR was randomised in the individual participant by drawing lots. The depth and precision of CPRs were shown visually, and the CPR stations were connected to a device that enabled performance recording both electronically and in hard copy (Laerdal Skill reporting system™). To minimise possible bias which may be introduced by mannequin use and the variations of each subject, and to get comfortable with using the mannequin, the subjects were asked to practice CPR for 10 minutes while watching a video on the monitor connected to the mannequin before the start of the study. Under the simulated conditions in which a non-rebreather mask without assisted ventilation was placed on the mannequin with 15 L/minute of oxygen,[9] the subjects were instructed to conduct chest compressions immediately without checking for consciousness, requesting assistance, or activating EMS.

For each method, chest compressions were conducted for three minutes. For standard CPR, the subjects were instructed to kneel down at the lateral side of the mannequin and compress the chest at the centre of the nipple glands, as directed in the 2010 guidelines for CPR published by International Liaison Committee on Resuscitation.[8] For over-the-head CPR (Figure 1), the subjects were instructed to kneel down at the head of the mannequin, which should be positioned between their knees and thighs, and compress the chest centre with the centre of body facing towards the legs of the mannequins.[10] For straddle CPR (Figure 2), the subjects were instructed to kneel at the thighs of the mannequin for straddling, and compress the centre of the chest with the subjects facing the head of the mannequin.[3] For one-hand CPR (Figure 3), the subjects were instructed to compress the chest of the mannequin with one hand and to support themselves with their other hand at the same time. When the subjects were instructed to begin the CPR, the authors activated the timer, the log button of the monitor and the storage device. Once the study began, the monitor was placed away from the vision of the subjects, and thus not permitting the subjects to watch the monitor. For each CPR, a 3-minute chest compression was conducted, followed by a 10-minute rest.

Using an equation for a crossover design to test a 10% difference in the compression depth with 80% power and a significance level of 0.05, at least 25 subjects were required. According to the CPR method (standard CPR, over-the-head CPR, straddle CPR, and one-hand CPR), the depth, total number, and number/minute of chest compressions were collected via the Laerdal Skill reporting system™ device that was connected to the mannequin. Using SPSS 15.0 for Windows, an ANOVA test and a t-test were conducted to analyse continuous data, such as the depth, total number, and number/minute of chest compressions. The significance level of the test was <0.05.

Figure 1. Over-the-head cardiopulmonary resuscitation (CPR). The CPR providers kneel down at the head of the mannequin and compress the chest facing towards the legs of the mannequin.

Figure 2. Straddle cardiopulmonary resuscitation (CPR). The CPR providers kneel at the thighs of the mannequin for straddling and compress the chest facing the head of the mannequin.

Figure 3. One-hand cardiopulmonary resuscitation (CPR). The CPR providers compress the chest of the mannequin with one hand and support themselves with the other hand at the same time.

Results

The ambulance-working period, age, height, and weight of all the 30 subjects (14 male and 16 female) in mean and range were 4.5 years (1-12 years), 31 years (26-43 years), 166.1 cm (153-182 cm), and 61.9 kg (45-85 kg), respectively.

As to the quality of all CPRs, the mean compression depth, total number of compressions, and number of compressions per minute were 41.4±6.0 mm (mean± standard deviation or SD), 326.4±52.6 compressions, and 110.3±12.2 compressions/minute, respectively. For standard CPR, over-the-head CPR, straddle CPR, and one-hand CPR, the results in mean±SD were respectively compression depths: 42.3±5.8 mm, 42.6±4.7 mm, 43.5±3.7 mm, 33.8±6.6 mm; total numbers of compressions: 330.4±38.1, 334.8±70.2, 334.0±34.9, 312.1±53.5; and numbers of compressions per minute: 111.5±10.3, 113.8±11.6, 110.5±11.2, 110.7±11.8 (Table 1). The comparison of these performance qualities across the four types of CPR showed that the only statistically difference was that compression depth was significantly lower in one-hand CPR ($p<0.000$). No EMT gender differences in the quality of performance of total CPR was noted (Table 2). Within each CPR type, no EMT gender difference in the quality of CPR performance was found as well. For one-hand CPR, however, the compression depth was lower, although found to be not significant, among the female subjects than among the male subjects (Table 3).

Discussion

The prehospital EMS systems differ across countries and across regions within a country. Not surprisingly, when cardiac arrest occurs, the patient management may vary among them.[11] In Europe, physicians are onboard mobile ambulances and may provide extensive interventions and treatments to cardiac arrest patients.[12] In the U.S., paramedics who are supervised with indirect medical oversight conduct CPR on patients until the return of spontaneous circulation (ROSC).[13] If ROSC is not achieved within a time period, then

Table 1. Overall performance of CPR methods

	Standard CPR	Over the head CPR	Straddle CPR	One hand CPR	Overall	P* value
Average compression† depth	42.3±5.8 (40.4-44.6)	42.6±4.7 (40.9-44.3)	43.5± 3.7 (42.1-44.8)	33.8±6.6 (35.4-40.1)	41.4± 6.0 (40.3-42.4)	<0.00
Total number of chest compression†	330.4±38.1 (316.9-343.9)	334.8±70.2 (309.9-359.7)	334.0±34.9 (312.8-346.6)	312.1±53.5 (293.1-331.1)	326.4±52.6 (316.8-335.9)	0.310
Average rate of chest compression†	111.5±10.3 (107.9-115.2)	113.8±11.6 (109.7-117.9)	110.5±11.2 (106.5-114.6)	110.7±11.8 (108.6-112.7)	110.3±12.2 0 (109.1-112.5)	0.240

CPR: cardiopulmonary resuscitation
*P value by ANOVA; †Date shown as mean±standard deviation (and confidence interval of mean)

Table 2. Overall performance of CPR methods by sex

	Male	Female	P* value
	MeanïSD	MeanïSD	
Average depth	42.3±4.5	40.5±6.6	0.10
Total number of chest compression*	326.6±30.7	326.4±64.9	0.97
Average rate of chest compression*	110.1±8.1	110.6±14.6	0.83

CPR: cardiopulmonary resuscitation; SD: standard deviation
*P value by t test

Table 3. The performance of standard CPR and alternative CPR methods by sex

		Male	Female	P* value
		MeanïSD	**MeanïSD**	
Standard CPR*	Average depth*	43.7±496	41.0±6.4	0.23
	Total number of chest compression*	316.4± 42.2	340.2±36.4	0.11
	Average number of chest compression*	110.7± 7.9	112.8±12.3	0.64
Over the head CPR*	Average depth*	42.6±3.6	42.4±5.5	0.99
	Total number of chest compression*	335.9±20.6	285.5±90.396	0.79
	Average rate of chest compression*	111.9±6.9	114±14.0	0.61
Straddle CPR*	Average depth*	43.8±3.1	43.6±3.8	0.88
	Total number of chest compression*	327.4±29.3	336.1±39.8	0.52
	Average rate of chest compression*	108.8±9.9	111.2±12.7	0.60
One hand CPR*	Average depth*	39.9±4.95	35.7±7.3	0.08
	Total number of chest compression*	326.9±28.7	300.8±64.3	0.37
	Average rate of chest compression*	109.6±8.6	104.6±15.8	0.47

CPR: cardiopulmonary resuscitation; SD: standard deviation
*P value by t test

CPR may be discontinued (termination of resuscitation) and the patient is considered deceased.[14]

In Korea, EMS is considered to be an administrative-type service. Its first goal is the immediate transfer of the patients in cardiac arrest to the emergency department of a nearest hospital. Unlike that in the U.S., CPR in Korea is conducted for a very short time, approximately four to five minutes at the scene where the victim has collapsed; then the patient is transferred to the emergency department of a hospital regardless of whether or not ROSC was attained. The resuscitation is continued in the hospital.

Reports from various studies have indicated difficulty in maintaining quality CPR performances in a moving ambulance.[3,4,15,16] In addition, although termination of resuscitation may be announced at the site of the arrest, CPR is still conducted on approximately half of cardiac arrest patients during their transfer to the hospital in the U.S..[17] Thus, the management and performance of quality CPR in the transporting ambulance remains a challenging problem.

Various factors can affect the quality of CPR performance in a moving ambulance. Factors include driving conditions, such as the speed, acceleration and deceleration of the vehicle, road conditions, limited space in the ambulance, types of patient gurneys, number of emergency service providers, and finally, the type of CPR used by the medical providers.[3,5,6,18,19] To assess for improvements in the quality of the CPR in a moving ambulance, a study was recently conducted using a mechanical-device-assisted CPR. However, its clinical evidence at the prehospital phase is still insufficient.[20-22] Furthermore, it may be difficult to install mechanical-device-assisted CPR machines in all ambulances due to limited budgets and the lack of training.

Straddle CPR, as an alternative method, has shown to be effective in delivering chest compressions on a stretcher during the transport to the hospital.[23] In addition, since the safety of emergency medical service providers in a moving vehicle is paramount,[24] alternative CPR methods of various body positions depending on the situation should be considered in confined spaces and under special circumstances, particularly in a moving ambulance.

Prior to the start of this study, a survey was conducted on EMS providers to identify currently used methods other than the standard CPR. The EMS responded that one-hand CPR was performed in about 70% of the time during patient transfers and that the standard CPR method was difficult to perform due to the gurney obstructing the placement of their knees. One-hand CPR is used due to the need to maintain providers' balance on curving roads or during rapid acceleration and deceleration. The results of our study showed that along with straddle and over-the-head CPRs, no differences in the CPR depth and CPR rate were found between one-hand CPR and standard CPR for the male EMS providers. This suggests that one-hand CPR should be considered as an alternative method to standard CPR when there is a difficulty in maintaining balance.

Our study has a few of limitations. Firstly, since this is a simulation study involving mannequins placed on the ground, real-time characteristics of patients and the varying sites of the arrest were not reflected. A future simulation study that reflects certain realistic circumstances, such as in a moving ambulance or a randomised non-simulation study that is conducted by an EMS system may be required. Secondly, a compression-only CPR not including airway and respiration evaluation and treatments, such as bag-valve mask ventilation and advanced airway insertion is not commonly performed presently.

Conclusion

The efficacy of alternative CPRs are shown to be similar to that of standard CPR in a compression-only simulation cardiac arrest model. Alternative CPRs may be considered in confined areas or when the quality of standard CPR is difficult to maintain, such as in a moving ambulance. Further studies that examine these alternative CPR methods in realistic scenarios and incorporate them to advanced cardiac life support should be undertaken.

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