ORIGINAL ARTICLE

Cardiopulmonary Resuscitation in Prone Position: A Simplified Method for Outpatients

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Background: The efficacy of cardiopulmonary resuscitation (CPR) is vital for saving lives of victims with sudden cardiac arrest. In 1960, Kuowenhoven and colleagues proposed the method that has become standard for CPR. Despite vast input of resources for public education and training of this procedure, its success rate outside hospitals remains poor to dismal. During CPR, restoration of respiration is as important as circulation. But opening the airway and giving effective mouth-to-mouth respiration is difficult for lay people to learn. Furthermore, most bystanders are reluctant to do mouth-to-mouth respiration because of the risk of infection. Therefore, the general population needs a more simplified CPR method for outpatients. The practice of CPR in the prone position, first proposed by McNeil in 1989, has not been adopted, despite the fact that it meets the desirable requirements of ideal resuscitation: simultaneous restoration of circulation and respiration with a very simple maneuver.

Methods: Part 1 (circulation test): Eleven patients who expired in the intensive care unit (ICU), with arterial lines attached, received standard pre-cordial cardiac massage, and the generated blood pressure (BP) was recorded. They were then turned to the prone position, with the head turned to one side. We compressed the patient's thoracic spine with the same force used in standard CPR (rhythm of approximately 60 per minute each time when the back bounces back), and the BP was also recorded. Part 2 (ventilation test): Ten healthy volunteers (5 doctors and 5 nurses) were enlisted for respiratory assessment during compression on the back. With the nose clipped and spontaneous breathing held, the volunteer's exhaled tidal volume upon compression was measured with a spirometer.

Results: Standard external cardiac massage of the cadavers generated BPs of 55 ± 20/13 ± 7 mmHg; however, external compression on the back of the cadavers generated higher BP of 79 ± 20/17 ± 10 mmHg (p = 0.028, Wilcoxon signed-rank analysis). External compression on the back of the volunteers generated mean tidal volumes of 399 ± 110 mL.

Conclusion: Our study revealed that prone CPR provides good respiratory and circulatory support at the same time. It is easy to perform and it may be a good alternative way for bystanders to perform CPR in public surroundings. We recommend that more investigators do further studies on this topic. [*J Chin Med Assoc* 2006;69(5):202–206]

Key Words: cardiopulmonary resuscitation, prone position

Introduction

The effectiveness of cardiopulmonary resuscitation (CPR) before arrival at hospital is a vital factor in saving victims of sudden cardiac arrest. The combination of mechanical ventilation, external pre-cordial compression, and electrical defibrillation introduced by Kuowenhoven et al[1] in 1960 has become the standard method for the past 40 years. However, the success rate for CPR outside hospitals remains poor to dismal, despite a vast input of resources for its training.[2–4] Attempts have been made to simplify the technique of CPR. The idea of

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CPR in the prone position (prone CPR) was first mentioned by McNeil in 1989,[2] and reinforced by Stewart in 2002.[5] Prone CPR seems to meet the desirable requirements of ideal resuscitation for outpatients, but it has not been adopted as the standard method. There are few clinical studies on prone CPR.[6,7] More clinical data are necessary to draw support for this ideal CPR procedure. Since 1999, we started to collect data on expired patients in the intensive care unit (ICU) for clinical study of prone CPR.

Methods

With the permission of the families, 11 patients who expired in the ICU (Table 1), who had arterial lines attached to physiologic monitors, were included in this study. They received standard pre-cordial cardiac massage for 1 minute, and the BP tracings were recorded. They then were turned to the prone position with the head turned to one side. Similar to standard pre-cordial cardiac massage, a nurse was asked to compress the patient's thoracic spine regularly at a rate of about 60 per minute for 1 minute (each time when the back bounced back), and the generated blood pressure (BP) tracing was recorded. Patients who were severely dehydrated or hypovolemic, such as those who died of head injury and sepsis, were excluded from this study.

Five doctors (including some of the authors) and 5 nurses also volunteered. They were asked to bite tightly on a mouthpiece that was connected to a spirometer (Haloscale, Ferraris Medical, Holland, NY, USA), while in the prone position with the head turned to one side. With a nose clip applied, they were asked to hold their spontaneous breathing while a nurse was performing the same massage on their back for 1 minute. The subject's exhaled tidal volume upon compression on the back was measured and recorded (Table 2).

Results

By external compression on the back of the 11 cadavers whose mean body weight was 65.4 ± 9.0 kg, the mean systolic BP generated was 79.4 ± 20.3 mmHg and diastolic pressure was 16.7 ± 10.3 mmHg. The average rate of back compression was 60 per minute. By pre-cordial compression on 8/11 cadavers, the mean systolic BP generated was 55.4 ± 20.3 mmHg and diastolic pressure was 13.0 ± 6.7 mmHg. Wilcoxon signed-rank test of these data yielded a statistically significant p value of 0.028 (Table 1). By external compression on the back of the volunteers whose mean body weight was 63.3 ± 14.7 kg, the mean tidal volume recorded was 399 ± 110 mL (Table 2). Representative arterial BP tracing generated from pre-cordial and back compression are shown in Figure 1.

Table 1. Blood pressure measurements in expired patients with supine and prone CPR

Case No.	Gender	Age	BW, kg	Diagnosis	Procedure	BP, supine mmHg	BP, prone mmHg
1	M	58	60	CAD	CABG × 3	N/A*	110/20
2	M	68	62	CAD + RHD	CABG + AVR	N/A*	70/20
3	F	58	51	RHD	MVR	N/A*	90/20
4	M	60	65	DCMP	Nil	80/25	110/40
5	M	57	67	CAD + ICMP	CABG, HTx	60/10	78/10
6	M	78	75	Ao dissection with rupture	Arch replacement	90/20	90/20
7	M	49	78	CAD, AMI	HTx	55/5	90/10
8	M	57	80	CAD with RV rupture	CABG + RV repair	41/15	66/5
9	M	50	64	DCMP	Nil	39/7	52/4
10	M	75	57	SBE	CABG + AVR	43/11	62/24
11	M	39	60	ICMP	Nil	35/11	55/11
Mean ± SD		59 ± 11	65 ± 9			(55 ± 20)/(13 ± 7)	(79 ± 20)†/(17 ± 10)

AMI = acute myocardial infarction; Ao = aorta; AVR = aortic valve replacement; BW = body weight; CABG = coronary artery bypass grafting; CAD = coronary artery disease; DCMP = dilated cardiomyopathy; HTx = heat transplantation; MVR = mitral valve replacement; RHD = rheumatic heart disease; RV = right ventricle; SBE = subacute bacterial endocarditis.

**Blood pressure in supine position was not recorded in the first 3 cases.*

†Statistically significant (Wilcoxon signed-rank test, p = 0.028)

Table 2. Tidal volume measurements in volunteers

Volunteer No.	Gender	Age	Body weight, kg	Tidal volume, mL
1	M	53	84	550
2	M	38	77	400
3	M	45	75	450
4	M	52	80	600
5	M	32	65	400
6	F	35	51	275
7	F	32	51	300
8	F	28	44	300
9	F	25	56	400
10	F	23	50	310
Mean ± SD		36 ± 11	63 ± 15	399 ± 110

M = male; F = female.

Discussion

Successful CPR for victims of cardiac arrest outside the hospital remains very difficult. According to a report by Brison et al,[3] the overall survival rate was only 2.5% for a consecutive sample of 1,510 primary cardiac arrest patients in 5 Ontario communities, although the average ambulance response time for witnessed cases was 7.8 minutes.

Most of the general public is not familiar with the standard CPR procedure introduced by Kuowenhoven et al.[1] A recent survey showed that 84% of 6th-year medical students in Japan might not perform standard CPR properly.[8] Great effort has been exerted around the world to teach lay people to perform standard CPR, but the results remain unsatisfactory.[2–4]

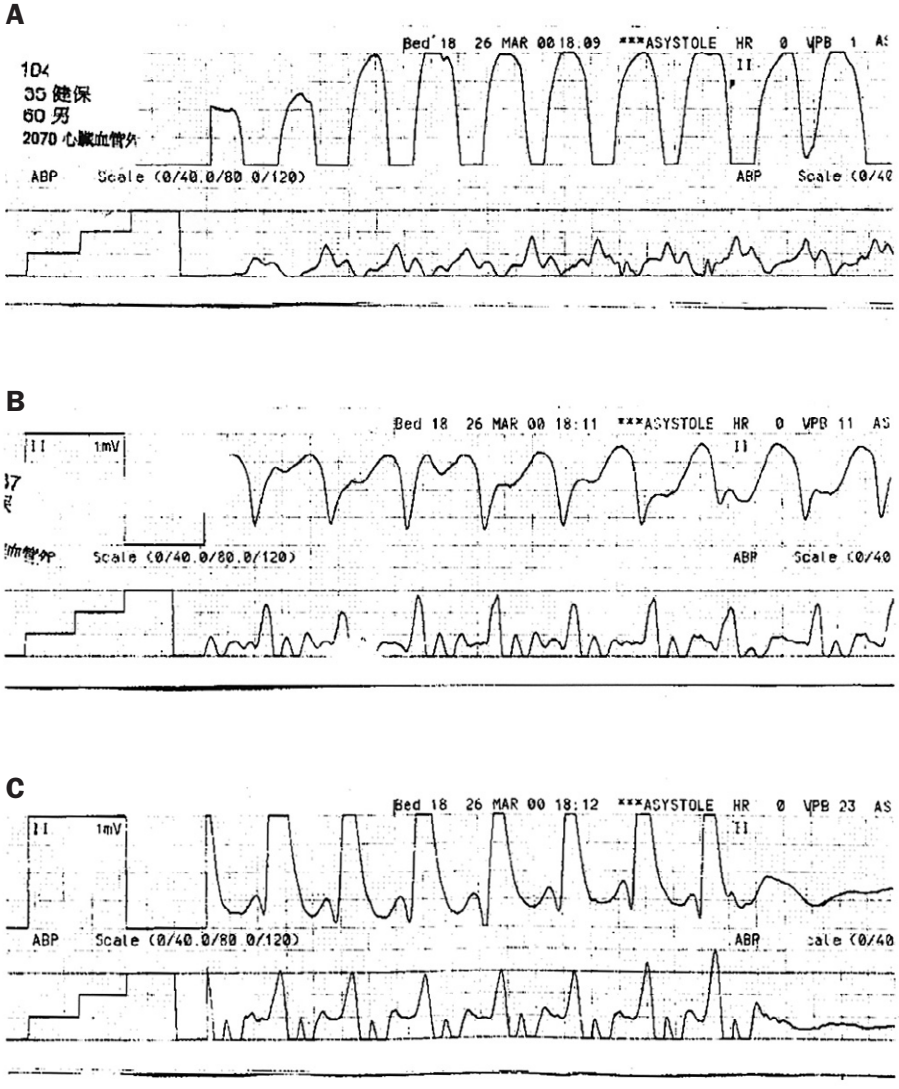

Figure 1. A representative arterial blood pressure tracing during chest compression for a 60-year-old male who died of dilated cardiomyopathy on March 26, 2000. The upper tracing is EKG and the lower radial arterial blood pressure (scale: 0/40, 0/80, and 0/120 mmHg). (A) Cardiac massage from the anterior chest wall (standard CPR method). (B) Cardiac massage from the back (thoracic spine), gentle force. (C) Cardiac massage from the back (thoracic spine), more forceful.

While caring for critical patients in the ICU, we have observed that many were still conscious and alert despite a systolic BP of 60 mmHg. It is believed that ischemic injury of the kidney, liver, and lungs may occur during prolonged hypotension, but the brain is protected by reactive vasodilatation. Therefore, it is not direly urgent to generate a high BP during CPR. Our data suggested that the BP generated with back compression is no less than that generated from pre-cordial compression. Both provided suboptimal, but probably adequate, BP for patients if they can arrive at a hospital without much delay.

Pre-cordial cardiac massage is also difficult for lay people to learn. Most people cannot remember which point of the sternum to compress and how much force to apply. Excessive force of compression during pre-cordial massage may cause rib fracture and is hazardous to the heart. This is especially important, because most bystanders cannot differentiate cardiac arrest from other conditions such as shock, bradycardia, or stroke in which pre-cordial cardiac massage is unnecessary or even harmful. Back compression homogeneously shortens the distance between the sternum and the spine and is, thus, less likely to cause rib fracture and injury to the heart.

During CPR, effective ventilation is as important as restoration of blood circulation, and in conventional CPR, the airway must be cleared first. Unfortunately, with the lack of powered suction in public surroundings, it is difficult for bystanders to clear the victim's airway. Besides, if the victim is unconscious, his tongue may fall back to the larynx and cause airway obstruction while lying in the supine position. Air can be forced into the lungs only when the mandible is held upwards to open the airway during mouth-to-mouth artificial breathing, which is difficult for lay people to learn and can only be performed by trained and experienced rescuers. In most instances, bystanders in public surroundings cannot perform mouth-to-mouth artificial breathing correctly. Thus, it is only when endotracheal intubation is available that standard CPR can be performed effectively. In the prone position, the tongue falls by gravity and the airway opens spontaneously. No endotracheal intubation is needed during prone CPR.

Does prone CPR provide adequate ventilation? At the beginning, we tried to measure the tidal volume during back compression in cadavers, but found that they were not good candidates. The reason is that most of them died of multiorgan failure and had severe pulmonary complication before death, which is dissimilar to victims outside the hospital. However, conscious volunteers are ideal for the ventilation test. Our volunteers included 5 doctors and 5 nurses. They were asked to hold a spontaneous breath during back compression. The tidal volume thus generated was surprisingly good and was similar to normal breathing. With regular back compression, the respiratory rate was approximately 60 per minute, which might cause hyperventilation, but this might compensate for metabolic acidosis during cardiac arrest.

Vomiting and aspiration pneumonia are serious complications of standard CPR. Stomach content frequently regurgitates and goes into the airway if the patient is in the supine position. CPR in the prone position may prevent these complications.

Some other alternative methods of CPR, including vest CPR,[9] interposed abdominal compression,[10] and active chest compression-decompression[11,12] have been introduced, but these methods remain difficult for lay people to learn.

The importance of public-access defibrillators has been stressed, and automated external defibrillators (AED) have been placed in targeted public places, such as airports, shopping centers, and casinos in affluent countries.[13] The survival rate, however, is not any better, as reported in several studies.[4] In most instances, bystanders were reluctant to apply immediate CPR to prehospital victims. We believe that it is most important to restore the victim's respiratory and circulatory functions before arrival at the hospital, and defibrillation may even be harmful to the victim if not done properly.

Successful CPR in the prone position during intracranial or spinal cord surgery has been reported in the literature.[14] The maneuver, however, is different from this proposed prone CPR. In those cases, the patient was intubated and was placed in the prone position. The ongoing surgery, thus, made changing of the patient's position impossible. Surgeons place their hands under the sternum to perform the reversed pre-cordial compression. We believe that back compression is easier and may have the same effect.

McNeil listed desirable requirements of an ideal method of CPR as:

1. Can be performed by 1 rescuer as effectively as by 2;
2. Does not require mouth-to-mouth contact;
3. Does not cause gastric distension;
4. Relieves gastric distension;
5. Avoids the danger of aspiration of vomitus if regurgitation occurs;
6. Avoids the necessity for maneuvers to open the airway;
7. Assists ventilation and circulation with the same maneuver;

8. Can relieve upper airway obstruction by simulating a modified Heimlich maneuver, using the same maneuver as is being used for ventilation and circulatory assist;
9. Should require less than 30 minutes to learn;
10. The simplicity of the method should promote easy retention of skills;
11. If commenced in less than 4 minutes from the time of cardiac arrest, it should maintain a circulation that has been oxygenated sufficiently to allow advanced life support methods to have a reasonable chance of success by resuscitation, if available within 8 minutes from the time of arrest.[2]

Prone CPR has not attracted the attention of program directors who are advocating and promoting CPR by the public, no doubt because they believe the back compression would not be effective to generate adequate BP. From our study, prone CPR seems to meet all the criteria of the ideal method of CPR. In addition, because of the simplicity of this method, the cost of teaching may be much less than expected.

How should lay people be taught to perform prone CPR? It is very simple!

Step 1: Place the patient in the prone position.

Step 2: Bend either one of the forearms and put it underneath the forehead or just turn the head to one side if you do not remember how to bend and place the forearms.

Step 3: Compress the mid-portion of the thoracic spine with 2 hands of regular force and rhythm (each time when the chest wall bounces back) until arrival at hospital.

In conclusion, prone CPR not only may provide good respiratory and circulatory support, but also is easy for people to perform. It may also have fewer complications of rib fracture, heart injury, and aspiration pneumonia. It is probably a good alternative to conventional CPR for bystanders to perform effective CPR in public surroundings. We hope this paper may attract more investigators to do further studies on this topic.

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