

A COMPARISON OF ACTIVE COMPRESSION–DECOMPRESSION CARDIOPULMONARY RESUSCITATION WITH STANDARD CARDIOPULMONARY RESUSCITATION FOR CARDIAC ARRESTS OCCURRING IN THE HOSPITAL

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Abstract Background. Recent studies have demonstrated improved cardiopulmonary circulation during cardiac arrest with the use of a hand-held suction device (Ambu CardioPump) to perform active compression–decompression cardiopulmonary resuscitation (CPR). The purpose of this study was to compare active compression–decompression with standard CPR during cardiac arrests in hospitalized patients.

Methods. All patients over the age of 18 years who had a witnessed cardiac arrest while hospitalized at our center were enrolled in this trial; they were randomly assigned according to their medical-record numbers to receive either active compression–decompression or standard CPR. The study end points were the rates of initial resuscitation, survival at 24 hours, hospital discharge, and neurologic outcome. Compressions were performed according to the recommendations of the American Heart Association (80 to 100 compressions per minute; depth of compression, 3.8 to 5.1 cm [1.5 to 2 in.]; and 50 percent of the cycle spent in compression).

Results. Sixty-two patients (45 men and 17 women) with a mean age ($\pm$ SE) of 68 ± 2 years were entered into the trial. Sixty-two percent of the patients who underwent active compression–decompression were initially resuscitated, as compared with 30 percent of the patients who received standard CPR ($P<0.03$); 45 percent of the patients who underwent active compression–decompression survived for at least 24 hours, as compared with 9 percent of patients who underwent standard CPR ($P<0.004$). Two of the 62 study patients survived to hospital discharge; both were randomly assigned to receive active compression–decompression. Neurologic outcome, as measured by the Glasgow coma score, was better with active compression–decompression (8.0 ± 1.3) than with standard CPR (3.5 ± 0.3 ; $P<0.02$).

Conclusions. In this preliminary study, we found that, as compared with standard CPR, active compression–decompression CPR improved the rate of initial resuscitation, survival at 24 hours, and neurologic outcome after in-hospital cardiac arrest. Larger trials will be required to assess the potential benefit in terms of long-term survival. (N Engl J Med 1993;329:1918-21.)

ACTIVE compression–decompression cardiopulmonary resuscitation (CPR) is a novel method of resuscitation in which the passive relaxation phase of CPR is converted into an active phase by means of a hand-held suction device (Ambu CardioPump, Ambu International, Copenhagen, Denmark). Active compression–decompression CPR has been demonstrated to improve cardiopulmonary circulation in both animals and human subjects.^{1,2} More recently, in a study using radiolabeled microspheres, it has been shown to improve cerebral and myocardial perfusion in animals.³ Subsequent trials in cases of witnessed cardiac arrest in humans (a bystander model of CPR) have demonstrated improved coronary perfusion pressure with active compression–decompression as compared with standard CPR.⁴ However, the effects of this technique on the rate of initial resuscitation, survival at 24 hours, and neurologic outcome have not been evaluated. Therefore, we undertook this prospective study to compare active

compression–decompression with standard CPR in cases of cardiac arrest occurring in a tertiary care medical center.

METHODS

This study was approved by the North Shore University Hospital-Cornell University Medical College institutional review board for compassionate use (without informed consent) during cardiac arrest. The eligible subjects were all hospitalized patients over the age of 18 years who had nontraumatic, witnessed cardiac arrests. The exclusion criteria included respiratory arrest without hemodynamic collapse, inability to achieve prompt endotracheal intubation within the first 15 minutes after the arrest, and do-not-resuscitate orders. All patients were randomly assigned by means of their medical-record numbers to receive a single type of CPR throughout their hospitalizations; patients with even numbers were assigned to active compression–decompression CPR and those with odd numbers to standard CPR. Compressions were performed according to the recommendations of the American Heart Association (80 to 100 compressions per minute; depth of compression, 3.8 to 5.1 cm [1.5 to 2 in.]; and 50 percent of the cycle spent in the compression phase). Figure 1 shows the Ambu CardioPump that was used for active compression–decompression. Compressions were performed at a pressure of 29.5 to 50.0 kg (65 to 110 lb), equivalent to a compression depth of 3.8 to 5.1 cm, depending on the stiffness of the chest, and were not interrupted for ventilation.^{5,6} The cardiac-arrest team

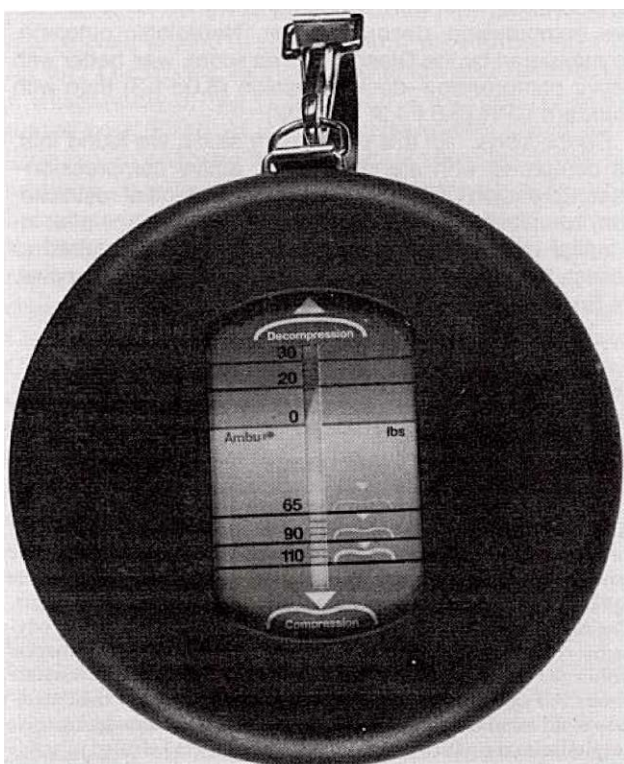
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Dr. Todd J. Cohen is a coinventor of the technique of active compression–decompression cardiopulmonary resuscitation. All rights to this invention belong to the University of California (where this technique was developed and later licensed to Ambu International, Copenhagen, Denmark). The University of California has applied for a patent on this device (patent pending), and university policy provides for a percentage of royalties to go to the inventors.



A



B

Figure 1. The Device Used in Active Compression–Decompression CPR.

The device consists of a suction cup, a piston, and a horizontal handle (Panel A). The radius of the suction cup is 6.5 cm, and the overall height of the device is 13.5 cm. The top of the device (Panel B) consists of a gauge, calibrated in pounds (or kilograms) to achieve compressions of a force equivalent to that recommended by the American Heart Association. The circular undercut grip prevents wrist strain, and the gauge helps ensure the correct CPR technique. A hook strap is attached to the device and helps to fasten it to crash carts and emergency-resuscitation equipment. Active compression–decompression CPR is performed by placing the device in a midsternal position with 80 to 100 compressions per minute, each with a depth of 3.8 to 5.1 cm (1.5 to 2 in.), and with 50 percent of the cycle spent in the compression phase. The compression phase is similar to that of standard CPR. The decompression phase is performed to bring the chest to a fully expanded position without losing contact with it (producing approximately -9.1 kg [-20 lb] of pressure),

consisted of a senior resident (team leader) and two junior residents in internal medicine (all three trained in advanced cardiac life support) and an anesthesiologist to assist with endotracheal intubation. Bag ventilation was performed with 100 percent delivered oxygen. The role of the team leader was to ensure consistency in the location, rate, and depth of CPR compressions as well as advanced cardiac life support during both CPR techniques. Active compression–decompression CPR was performed by members of the arrest team who were specifically trained in this technique. The study was conducted in the medical intensive care unit, the coronary care unit, the cardiac-catheterization laboratory, and the medical wards at North Shore University Hospital–Cornell University Medical College. The end points for the study were the rate of successful initial resuscitation, defined as return of pulse and systolic blood pressure (above 90 mm Hg) for at least 1 hour, survival at 24 hours, discharge from the hospital, and neurologic outcome as assessed by means of the Glasgow coma score (in which 3 is the worst score and 15 the best score) approximately 24 hours after resuscitation.^{7,8}

Statistical Analysis

The outcomes of the initial resuscitation attempts, survival at 24 hours, and hospital discharge in the groups assigned to active compression–decompression and standard CPR were analyzed and compared with use of chi-square analysis, with Yates' correction.^{9,10} Before this study began, we performed a power calculation that determined that a sample of 20 patients per group was necessary, on the basis of the following assumptions: an initial rate of resuscitation and 24-hour survival of 30 percent in the standard-CPR group; demonstration of an absolute difference of 40 percent (from 30 percent to 70 percent) in the active-compression–decompression group; a two-sided alpha level of 0.05; and a beta error of 0.20. The primary analysis of resuscitation rates was limited to the first cardiac arrest in each of the patients assigned to each group. A secondary analysis evaluated the eventual outcomes in each group. The neurologic outcomes of patients who received standard and active compression–decompression CPR were compared with the use of an independent-samples t-test. A two-tailed P value of less than 0.05 was considered to indicate statistical significance. All other data are presented as means $\pm$ SE.

RESULTS

Sixty-two patients (45 men and 17 women) with a mean age of 68 ± 2 years were entered into the trial between October 15, 1992, and April 16, 1993. Twenty-nine patients (47 percent) were randomly assigned to active compression–decompression CPR and 33 patients (53 percent) to standard CPR. The CardioPump adhered to all patients regardless of the shape of the chest. Overall, this cohort represented an extremely ill population, in which at least 60 percent of the patients had a preexisting terminal illness. Tables 1 and 2 list the clinical diagnoses, initial arrest rhythms, and base-line clinical characteristics of the two groups, which were similar. Several patients in

each group had more than one clinical diagnosis. The mechanisms of arrest included electromechanical dissociation (defined as a cardiac rhythm without a palpable pulse) in 27 patients, asystole in 14 patients, and refractory ventricular tachycardia or ventricular fibrillation in 21 patients.

Table 1. Clinical Diagnoses and Initial Arrest Rhythms of the Patients Assigned to Active Compression-Decompression (ACD) and Standard CPR.

CATEGORY	ACD (N = 68)	STANDARD (N = 73)
Diagnosis*		
Metastatic carcinoma or hematologic cancer	8	9
End-stage congestive heart failure	6	8
Sepsis	8	10
Myocardial infarction (cardiogenic shock)	8	5
Chronic renal failure	2	2
Cirrhosis	1	1
AIDS	0	2
Acute renal failure	1	0
Unknown	3	3
Cerebrovascular accident	2	0
Rhythm		
Asystole	6	8
Electromechanical dissociation	14	13
Ventricular tachycardia or fibrillation	9	12

*Several patients had more than one clinical diagnosis. AIDS denote the acquired immunodeficiency syndrome

Table 2. Base-Line Clinical Characteristics of the Patients Assigned to Active Compression-Decompression (ACD) or Standard CPR.

CHARACTERISTIC	ACD (N = 29)	STANDARD (N = 33)
	mean $\pm$ SE	
Age (yr)	68 $\pm$ 3	69 $\pm$ 3
Duration of CPR (min)	28 $\pm$ 4	31 $\pm$ 3
Time of initiation of CPR (min)	0.8 $\pm$ 0.3	0.5 $\pm$ 0.2
pH	7.26 $\pm$ 0.04	7.24 $\pm$ 0.04
PCO ₂ (mm Hg)	41 $\pm$ 4	45 $\pm$ 7
PO ₂ (mm Hg)	108 $\pm$ 21	99 $\pm$ 15
Serum sodium (mmol/liter)	136 $\pm$ 2	137 $\pm$ 2
Serum potassium (mmol/liter)	5.1 $\pm$ 0.4	5.0 $\pm$ 0.3
Serum chloride (mmol/liter)	102 $\pm$ 2	103 $\pm$ 2
Serum carbon dioxide (mmol/liter)	18 $\pm$ 2	16 $\pm$ 1
Blood urea nitrogen (mg/dl)	64 $\pm$ 11	53 $\pm$ 9
Serum creatinine (mg/dl)	2.7 $\pm$ 0.4	2.6 $\pm$ 0.3
White cells ($\times 10^9$ /liter)	15.2 $\pm$ 3.5	15.2 $\pm$ 2.7
Hemoglobin (g/dl)	11.7 $\pm$ 0.6	10.2 $\pm$ 0.5

*PCO₂ denotes partial pressure of carbon dioxide, and PO₂ partial pressure of oxygen

Eighteen of the 29 patients assigned to active compression-decompression (62 percent) were initially resuscitated, as compared with 10 of the 33 patients assigned to standard CPR (30 percent; $P < 0.03$). Thirteen of the 29 patients assigned to active compression-decompression (45 percent) survived for at least 24 hours, as compared with 3 of the 33 assigned to standard CPR (9

percent; $P < 0.004$). Two of the 29 patients who underwent active compression-decompression (7 percent) survived to hospital discharge, as compared with none of the 33 assigned to standard CPR (P not significant). Eleven of the 28 patients who survived the initial resuscitation (6 assigned to active compression-decompression, and 5 to standard CPR) were subsequently given do-not-resuscitate status by their attending physicians and did not undergo further attempts at resuscitation (with techniques of either basic or advanced cardiac life support) when a subsequent cardiac arrest occurred. Neurologic evaluation with use of the Glasgow coma score revealed a mean value of 8.0 ± 1.3 for patients assigned to active compression-decompression and 3.5 ± 0.3 for those assigned to standard CPR ($P < 0.02$). Of the patients who survived for at least 24 hours, 8 of the 13 who underwent active compression-decompression awoke and were able to speak, whereas none of the survivors who underwent standard CPR regained consciousness. Table 3 summarizes the primary results of this trial.

Chest films were obtained for 24 of 28 patients after initial successful resuscitation. There was no evidence of rib fracture or thoracic trauma in the active compression-decompression group (15 patients), and only one rib fracture in the standard-CPR group (9 patients). An autopsy was requested after almost every fatal cardiac arrest. Six patients underwent comprehensive thoracic postmortem examinations (two in the active-compression-decompression group and four in the standard-CPR group); there was no evidence of rib fracture or thoracic trauma due to either of these methods.

DISCUSSION

This study demonstrates improved rates of initial resuscitation, 24-hour survival, and neurologic outcome with active compression-decompression CPR as compared with standard CPR. The rates of initial resuscitation and 24-hour survival with standard CPR in this study are similar to those reported in previous studies.¹¹⁻¹³ Overall, a high percentage of patients in this study (at least 60 percent) had a preexisting terminal illness. Subsequently, 11 of the 28 patients who survived the initial resuscitation (39 percent) were given do-not-resuscitate status by their attending physicians (despite hemodynamic and neurologic recovery). This complicated the assessment of the effect of active compression-decompression on survival to hospital discharge. This preliminary study was terminated by the Food and Drug Administrations on April 16, 1993, in favor of a multicenter trial that is planned in the future to determine whether this technique improves long-term survival.

Since Kouwenhoven et al. described the technique of CPR by closed-chest cardiac massage,¹⁴ several investigators have attempted to develop methods to enhance both cardiopulmonary circulation and survival. These techniques include military antishock trousers,¹⁵ high-impulse CPR,^{16,17} the mechanical Thumper (Michigan Instruments, Grand Rapids, Mich.),¹⁸ interposed-abdominal-counterpulsation CPR,^{19,20} and the

circumferential pneumatic vest.^{21,22} However, none of these methods have gained wide acceptance. Recent data on both interposed-abdominal-counterpulsation and vest CPR suggest a benefit from their use; however, both methods have important limitations.^{16-19,22} Interposed-abdominal-counterpulsation CPR requires at least two operators and a third operator to perform ventilation. The vest is a highly complex device that requires expensive equipment (estimated cost, \$8,000 to \$10,000) and substantial time to set up. The device we studied is small and hand-held; it weighs only 0.7 kg (1.5 lb) and is inexpensive (estimated cost, \$200). It is easy to use and its use is intuitive for anyone who has performed standard CPR. In addition, it is portable, requires no set-up time, and has a gauge that assists in the proper performance of the technique. To date, no complications have been reported with this device, and specifically, no increased incidence of rib fractures has been observed. On the basis of the limited efficacy of standard CPR and data on the use of active compression-decompression in animals and humans that have demonstrated improvement in cardiopulmonary circulation, ventilation, cerebral and myocardial perfusion, rates of initial resuscitation, 24-hour survival, and neurologic recovery, we believe that this may be a more effective method of CPR for patients with non-traumatic cardiac arrest.¹⁻⁴

Table 3. Outcomes of Patients Assigned to Active Compression-Decompression (ACD) or Standard CPR.

OUTCOME	ACD (N = 29)	STANDARD (N = 33)	P VALUE*
Resuscitation – no. (%)	18 (62)	10 (30)	<0.03
Survival for ≥ 24 hr – no. (%)	13(45)	3 (9)	<0.004
Hospital discharge – no. (%)	2(7)	0	NS
Glasgow coma score**	8.0±1.3	3.5±0.3	<0.02

*NS denotes not significant.

**Plus-minus values are means±SE.

The mechanism of the improvement in cardiopulmonary circulation produced by active compression-decompression CPR remains speculative. Transesophageal echocardiography has demonstrated enhanced diastolic filling during active chest decompressions.^{2,23} It may be that greater chest expansion results in a greater decrease in intrathoracic pressure, thereby increasing venous return and augmenting cardiac output.^{2,23,24} The technique is probably more effective than standard CPR because of its ability to augment ventilation and myocardial and cerebral perfusion.^{2,3}

On the basis of our preliminary study, we conclude that active compression-decompression is a simple and easy-to-perform technique for CPR that improves the rate of initial resuscitation, survival at 24 hours, and neurologic outcome after cardiac arrest, as compared with standard CPR. Further research is necessary to determine whether active compression-decompression CPR is associated with a long-term improvement in survival.

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