

## A COMPARISON OF STANDARD CARDIOPULMONARY RESUSCITATION AND ACTIVE COMPRESSION-DECOMPRESSION RESUSCITATION FOR OUT-OF-HOSPITAL CARDIAC ARREST

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### ABSTRACT

**Background** We previously observed that short-term survival after out-of-hospital cardiac arrest was greater with active compression-decompression cardiopulmonary resuscitation (CPR) than with standard CPR. In the current study, we assessed the effects of the active compression-decompression method on one-year survival.

**Methods** Patients who had cardiac arrest in the Paris metropolitan area or in Thionville, France, more than 80 percent of whom had asystole, were assigned to receive either standard CPR (377 patients) or active compression-decompression CPR (373 patients) according to whether their arrest occurred on an even or odd day of the month, respectively. The primary end point was survival at one year. The rate of survival to hospital discharge without neurologic impairment and the neurologic outcome were secondary end points.

**Results** Both the rate of hospital discharge without neurologic impairment (6 percent vs. 2 percent,  $P=0.01$ ) and the one-year survival rate (5 percent vs. 2 percent,  $P=0.03$ ) were significantly higher among patients who received active compression-decompression CPR than among those who received standard CPR. All patients who survived to one year had cardiac arrests that were witnessed. Nine of 17 one-year survivors in the active compression-decompression group and 2 of 7 in the standard group, respectively, initially had asystole or pulseless electrical activity. In 12 of the 17 survivors who had received active compression-decompression CPR, neurologic status returned to base line, as compared with 3 of 7 survivors who had received standard CPR ( $P=0.34$ ).

**Conclusions** Active compression-decompression CPR performed during advanced life support significantly improved long-term survival rates among patients who had cardiac arrest outside the hospital. (N Engl J Med 1999;341:569-75.)

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**D**ESPITE the widespread use of standard cardiopulmonary resuscitation (CPR), sudden death from cardiac causes outside the hospital remains the leading cause of death among adults in developed countries worldwide. To improve the efficacy of CPR, a method of active compression-decompression resuscitation was developed.<sup>1-12</sup> With this method, the use of a hand-held suction device during active chest-wall decom-

pression decreases intrathoracic pressure, thereby enhancing venous blood return. Then, during compression, more blood is propelled out of the thorax. Consequently, active compression-decompression CPR provides greater perfusion of vital organs than does standard CPR.<sup>1,2</sup>

The promising results of initial clinical studies<sup>3,4</sup> led to the evaluation of active compression-decompression CPR in a large number of clinical trials.<sup>5-12</sup> Although some failed to demonstrate significant benefit with this new technique,<sup>5-10</sup> other studies found that short-term survival improved significantly with active compression-decompression CPR as compared with standard CPR.<sup>11,12</sup> The primary purpose of the current study was to determine whether one-year survival and neurologic outcome would also be significantly improved with the use of active compression-decompression CPR when this technique is used during advanced life support. This study is a continuation of an evaluation performed from November 1993 to January 1995, in which we compared the effects of active compression-decompression CPR with standard CPR on short-term survival among patients with out-of-hospital cardiac arrest.<sup>12</sup>

### METHODS

#### Study Design

We assessed one-year survival in all patients who had cardiac arrest and received CPR in the Paris metropolitan area or Thionville, France, from November 1993 to May 1995. The study was approved by the Consultative Council for the Protection of Persons Volunteering for Biomedical Research of the Unité de Formation et de Recherche Lariboisière Saint-Louis, Paris. The two-tiered organization of the French emergency medical system has

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previously been described.<sup>12,13</sup> Fifteen mobile intensive care units located throughout Paris and Thionville participated in this multicenter study. These units serve approximately 2.5 million residents. Patients at least 18 years of age were treated during advanced life support with active compression–decompression CPR if their cardiac arrests occurred on odd days of the month and with standard CPR if the arrests occurred on even days.

We followed the Utstein guidelines for reporting out-of-hospital cardiac arrests.<sup>14</sup> According to practice guidelines, we excluded patients with cardiac arrest that was presumed to be irreversible, as indicated by clinical characteristics including rigid body tone, pale color, low temperature, and the presence of presacral edema; those with do-not-resuscitate orders or known terminal illness<sup>14</sup>; and those in whom a spontaneous palpable carotid or femoral pulse was restored with basic life support alone. As in previous studies, patients for whom the time from cardiac arrest to basic CPR exceeded 30 minutes were also excluded.<sup>12,15,16</sup>

### End Points

The primary end point was survival at one year. Survival to hospital discharge without neurologic impairment and neurologic outcome were secondary end points. Intervals between events were recorded from the time of collapse until admission to the intensive care unit.<sup>14</sup> The outcomes of patients and complications related to the method of CPR were recorded by one of us. This physician also supervised the collection of follow-up data for each patient after hospital discharge by regular telephone contact with the patient or the patient's general practitioner. Follow-up information gathered included general status and neurologic outcome, assessed according to Glasgow–Pittsburgh cerebral-performance categories.<sup>14</sup> On this scale, a cerebral performance score of 1 indicates full neurologic recovery, whereas a score of 5 indicates profound neurologic impairment. Neurologic status one year after cardiac arrest was compared with neurologic function before arrest by questioning the family or the general practitioner.

### Basic and Advanced Life Support

During basic life support, either standard CPR or active compression–decompression CPR was performed by rescue and ambulance personnel from various emergency-medical-service organizations.<sup>12,13</sup> All basic-life-support personnel were trained twice and tested monthly in the performance of both standard CPR and active compression–decompression CPR so that they could assist during advanced life support. During the study, not all of the more than 200 basic-life-support teams in Paris and Thionville were equipped with an active compression–decompression device. Consequently, we did not randomly assign the method of CPR used during basic life support in this study.

All 15 participating mobile intensive care units were equipped to perform either type of CPR for advanced life support. Physicians in these mobile units were trained and tested every three months during the study period. Standard CPR was always performed according to the recommendations of the American Heart Association and the European Resuscitation Council.<sup>17,18</sup> Active compression–decompression CPR was performed with a CardioPump (Ambu International, Glostrup, Denmark) according to published recommendations.<sup>19,20</sup> To prevent fatigue, the rescuer performing CPR by either technique was instructed to rest after three minutes, and another rescuer continued the resuscitation effort.

On arrival, physicians of the mobile intensive care units intubated patients and initiated ventilation with a portable pneumatic ventilator (Airox, BioMS, Pau, France). All resuscitation efforts with either method of CPR were performed only at the scene of the cardiac arrest and not in a moving vehicle. Patients were transported to the hospital only if they were successfully resuscitated at the scene.

### Statistical Analysis

On the basis of a review of data from our earlier study<sup>12</sup> and data from previous studies in France that found that the propor-

tion of patients surviving one year after standard CPR and advanced life support was close to 2 percent,<sup>21</sup> the sample size for each group was fixed at 375 patients, the number required for the study to have 80 percent power to detect an absolute difference of 4 percent between groups in the proportion of patients surviving after one year. In our previous study in Paris, we found that short-term survival was greater with active compression–decompression CPR than with standard CPR.<sup>12</sup> In the current study, we extended that investigation and enrolled additional patients to meet the requirement for 375 patients in each group.

The data were analyzed according to the intention-to-treat principle. Since all the patients were studied for one year, the proportions of patients who survived in the two groups were compared with use of the chi-square test. When conditions of validity for the chi-square test were not fulfilled, Fisher's exact test was used and exact confidence intervals calculated. Continuous variables were compared with use of Student's *t*-test or with use of the Mann–Whitney distribution-free test in the case of nongaussian distribution. All tests were performed with biomedical Data Package software (University of California, Los Angeles) or StatXact software (Cytel, Cambridge, Mass.).

## RESULTS

A total of 1083 calls to emergency medical systems for assistance with cardiac arrests were recorded during the 19-month study period. Of the 1083 patients, 333 did not receive advanced life support and were excluded from enrollment. The excluded patients were well matched between the group that received standard CPR and the group that received active compression–decompression CPR, in the following ways. Basic life support was not provided to 111 patients who had irreversible arrest and to 9 patients who had do-not-resuscitate orders; advanced life support was not provided to 91 patients who had a terminal illness and to 114 patients for whom the time from collapse to initiation of basic CPR was known to be greater than 30 minutes; and 8 patients recovered after basic life support alone. The remaining 750 patients were treated with advanced life support.

Among the 750 patients were 47 who were erroneously treated with a CPR technique that did not correspond to the assignment strategy according to odd and even days: 27 patients received standard CPR instead of active compression–decompression CPR, and 20 patients received active compression–decompression CPR instead of standard CPR. The intention-to-treat analysis included 377 patients who were assigned to standard CPR and advanced life support and 373 who were assigned to active compression–decompression CPR and advanced life support. The base-line characteristics of the patients in the two study groups were similar (Table 1). The two groups were similar with regard to age, suspected cause of cardiac arrest, type of CPR during basic life support, and dose of epinephrine per minute. CPR was performed by a bystander for fewer than 10 percent of patients in each group.

A comparison of clinical outcomes after CPR with each technique is shown in Table 2. Survival at one year was significantly greater among patients who received active compression–decompression CPR than

**TABLE 1.** BASE-LINE CHARACTERISTICS OF PATIENTS ASSIGNED TO STANDARD CPR OR ACTIVE COMPRESSION-DECOMPRESSION CPR FOR ADVANCED LIFE SUPPORT.\*

VARIABLE	STANDARD CPR (N=377)	ACTIVE COMPRESSION-DECOMPRESSION CPR (N=373)
Male sex — %	67	69
Age — yr	59±18	58±18
Site of cardiac arrest — %		
Home	63	69
Street	14	9
Public place	13	11
Workplace	3	3
Outpatient setting	6	6
Cardiac disease suspected — %	64	64
Initial cardiac rhythm — %		
Asystole	83	81
Ventricular fibrillation or ventricular tachycardia	11	14
Other rhythms or pulseless electrical activity	6	6
Cardiac arrest witnessed — no. (%)	275 (73)	279 (75)
CPR performed by bystander — no. (%)	29 (8)	28 (8)
Type of CPR for basic life support — no. (%)		
None	68 (18)	86 (23)
Standard	127 (34)	133 (36)
Active compression-decompression	171 (45)	148 (40)
Interval after collapse — min		
To CPR for basic life support	8.9±6.9	9.5±7.9
To CPR for advanced life support	19.9±11.7	21.1±11.6
To return of spontaneous circulation	33.1±16.5	36.2±17.5
To discontinuation of unsuccessful CPR	57.2±18.5	57.6±20.9
Duration of CPR for advanced life support — min	30.3±19.7	28.1±16.9
Total amount of epinephrine administered — mg	14.3±11.7	14.3±12.5

\*Plus-minus values are means ±SD. Because of rounding, not all percentages total 100. For some variables, data were not available for all patients.

among those who received standard CPR (5 percent [17 patients] vs. 2 percent [7 patients], respectively; odds ratio for survival, 2.5; 95 percent confidence interval, 1.03 to 6.16;  $P=0.03$ ). For all outcome measures, the lower limit of the confidence interval was greater than 1, indicating the benefit of active compression-decompression CPR. No patients were lost to follow-up. All one-year survivors in both groups had a cardiac arrest that was witnessed.

Neurologic outcomes (according to Glasgow-Pittsburgh cerebral-performance categories)<sup>14</sup> were similar in the two groups: the mean ( $\pm$ SD) score was  $1.3\pm0.5$  in the active compression-decompression group and  $1.5\pm0.5$  in the standard-CPR group ( $P=0.39$ ). Neurologic status returned to base line in 12 of 17 one-year survivors in the active compression-decompression group (71 percent), as compared with 3 of 7 (43 percent) in the standard-CPR group ( $P=0.34$ ). We observed that 9 of 17 one-year survivors in the active compression-decompression group (53 percent) and 2 of 7 in the standard-CPR group (29 percent) initially had asystole or pulseless electrical activity (Table 3). Thus, 9 of 218 patients whose cardiac arrest was witnessed and who initially had a rhythm of asystole or electromechanical dissociation (4 percent) were still alive one year after active compression-decompression CPR, as compared with 2 of 215 (1 percent) one year after standard CPR (odds ratio for survival, 4.5; 95 percent confidence interval, 1.0 to 21.5). By contrast, 8 of 41 patients with a witnessed arrest and an initial rhythm of ventricular fibrillation (20 percent) survived for at least one year in the active compression-decompression group, as compared with 5 of 37 patients (14 percent) in the standard-CPR group (odds ratio, 1.6; 95 percent confidence interval, 0.5 to 5.2).

**TABLE 2.** SHORT-TERM AND LONG-TERM OUTCOMES AMONG PATIENTS ASSIGNED TO STANDARD CPR OR ACTIVE COMPRESSION-DECOMPRESSION CPR FOR ADVANCED LIFE SUPPORT.

OUTCOME	STANDARD CPR (N=377)	ACTIVE COMPRESSION-DECOMPRESSION CPR (N=373)	ODDS RATIO (95% CI)*
	no. (%)		
Return of spontaneous circulation	111 (29)	146 (39)	1.5 (1.1–2.1)
Survival at 1 hr	88 (23)	117 (31)	1.5 (1.1–2.1)
Admission to intensive care unit	85 (23)	109 (29)	1.4 (1.02–1.97)
Survival at 24 hr	51 (14)	85 (23)	1.9 (1.3–2.8)
Survival at 7 days	20 (5)	38 (10)	2.0 (1.2–3.6)
Hospital discharge without neurologic impairment	7 (2)	21 (6)	3.2 (1.3–7.5)†
Survival at 1 yr	7 (2)	17 (5)	2.5 (1.03–6.16)

\*Odds ratios are the odds of the outcome in question in the group that received active compression-decompression CPR as compared with the odds in the standard-CPR group. CI denotes confidence interval.

† $P=0.01$ .

**TABLE 3.** CHARACTERISTICS OF PATIENTS WHO SURVIVED ONE YEAR AFTER STANDARD CPR OR ACTIVE COMPRESSION-DECOMPRESSION CPR FOR ADVANCED LIFE SUPPORT.\*

VARIABLE	STANDARD CPR (N=7)	ACTIVE COMPRESSION-DECOMPRESSION CPR (N=17)	P VALUE
Time from collapse to CPR for advanced life support — min	2.1±3.7	14.1±10.9	0.01
Duration of CPR for advanced life support — min	22.3±16.8	9.5±7.3	<0.01
Collapse witnessed by advanced-life-support personnel — no. (%)	4 (57)	2 (12)	
Initial cardiac rhythm — no. (%)			
Asystole	2 (29)	8 (47)	
Ventricular fibrillation or ventricular tachycardia	5 (71)	8 (47)	
Other rhythms or pulseless electrical activity	0	1 (6)	
CPR performed by bystander — no. (%)			
None	1 (14)	9 (53)	
By witness	1 (14)	1 (6)	
By emergency-medical-service personnel	1 (14)	5 (29)	
By advanced-life-support personnel	4 (57)	2 (12)	
Glasgow-Pittsburgh cerebral-performance category — no.			
1			
Before arrest	6	16	
At 1 yr	2	11	
2			
Before arrest	1	1	
At 1 yr	5	6	
3			
Before arrest	0	0	
At 1 yr	0	0	
4			
Before arrest	0	0	
At 1 yr	0	0	
5			
Before arrest	0	0	
At 1 yr	0	0	

\*Plus-minus values are means ±SD.

Additional characteristics of patients who survived for one year in each of the two groups are shown in Table 3. The duration of CPR during advanced life support was significantly shorter among the 17 one-year survivors who received active compression-decompression CPR (9.5±7.3 minutes) than among the 7 one-year survivors who received standard CPR (22.3±16.8 minutes, P<0.01), even though the advanced-life-support team took significantly less time to arrive for each of the 7 survivors in the standard-CPR group (2.1±3.7 minutes, vs. 14.1±10.9 minutes in the active compression-decompression group; P=0.01). In 4 of the 7 surviving patients in the standard-CPR group and 2 of the 17 surviving patients in the active compression-decompression group, cardiac ar-

**TABLE 4.** COMPLICATIONS AMONG PATIENTS ASSIGNED TO STANDARD CPR OR ACTIVE COMPRESSION-DECOMPRESSION CPR FOR ADVANCED LIFE SUPPORT.

COMPLICATION	STANDARD CPR (N=377)	ACTIVE COMPRESSION-DECOMPRESSION CPR (N=373)	P VALUE
	no. (%)		
Ecchymosis at the sternal contact point	30 (8)	158 (42)	<0.001
Rib fracture	57 (15)	50 (13)	0.28
Pulmonary hemorrhage	7 (2)	17 (5)	0.05
Sternal dislodgment	5 (1)	11 (3)	0.16
Gastric laceration	0	1 (<1)	0.33

**TABLE 5.** OUTCOMES OF PATIENTS WHOSE CARDIAC ARREST WAS WITNESSED AND WHO WERE ASSIGNED TO STANDARD CPR OR ACTIVE COMPRESSION-DECOMPRESSION CPR FOR BOTH BASIC AND ADVANCED LIFE SUPPORT.

OUTCOME	STANDARD CPR FOR BASIC AND ADVANCED LIFE SUPPORT (N=99)	ACTIVE COMPRESSION-DECOMPRESSION CPR FOR BASIC AND ADVANCED LIFE SUPPORT (N=120)
	no. (%)	
Return of spontaneous circulation	26 (26)	65 (54)
Survival at 1 hr	19 (19)	55 (46)
Admission to intensive care unit	17 (17)	53 (44)
Survival at 24 hr	13 (13)	38 (32)
Hospital discharge without neurologic impairment	1 (1)	10 (8)
Survival at 1 yr	1 (1)	9 (8)

rest was witnessed by the advanced-life-support team. The use of CPR by a bystander was not found to affect one-year survival in this study (Table 3). Except for the occurrence of ecchymoses, complication rates were also similar in the two groups (Table 4).

A subgroup analysis included patients whose cardiac arrest was witnessed and who received only standard CPR or only active compression-decompression CPR during both basic and advanced life support (Table 5). Patients who received standard CPR during both phases of life support had a one-year survival rate of 1 percent, as compared with an 8 percent one-year survival rate among those who received active compression-decompression CPR during basic and advanced life support. Because the

number of patients in these two subgroups was small, this difference was not statistically significant.

### DISCUSSION

We found that with the use of active compression-decompression CPR during advanced life support, the rate of survival at one year was more than twice the survival rate with standard CPR. The majority of patients who benefited from the active compression-decompression technique had an initial rhythm of asystole. Although the results with the use of standard CPR in Paris were similar to those previously observed in large metropolitan areas in other developed countries,<sup>5,11,22</sup> the one-year survival rates associated with the use of active compression-decompression CPR in our study were higher than the hospital-discharge rates associated with standard CPR in many metropolitan areas that have well-trained emergency personnel.<sup>21-24</sup>

All the one-year survivors in both groups in this study had a cardiac arrest that was witnessed. As compared with long-term survivors in the standard-CPR group, long-term survivors who received active compression-decompression CPR during advanced life support had a shorter duration of CPR during this phase before the return of spontaneous circulation, even though the mobile intensive care unit arrived significantly later. Moreover, an important feature of our study population was that more than 80 percent of the patients in each group had asystole when the cardiac rhythm was first recorded. Taken together, the results suggest that in patients who have out-of-hospital arrest, it may be particularly important to “prime the pump” with active compression-decompression CPR to restore sufficient metabolic support for cardiac contractility.

The percentage of patients with an initial rhythm of asystole was higher in our study than in other studies of active compression-decompression CPR.<sup>5-11</sup> This may be because electrocardiographic monitoring is initiated by the advanced-life-support team on arrival, usually about 20 minutes after the cardiac arrest. Although asystole is thought to be a rhythm with a very poor prognosis, especially as compared with ventricular fibrillation, and although it was present in the majority of our patients, our overall rates of resuscitation were similar to those for studies in other large cities with efficient emergency systems where more patients were initially found to have ventricular fibrillation rather than asystole.<sup>5,7,10-12</sup>

The use of active compression-decompression CPR, as compared with standard CPR, has led to improved short-term outcomes in several clinical trials.<sup>11,12,25,26</sup> However, the outcomes observed worldwide with active compression-decompression CPR have been inconsistent.<sup>3-12,25,26</sup> Probably the most important reason for this inconsistency relates to training. In some studies, the rescue personnel were in-

troduced to active compression-decompression CPR just one or two months before the clinical studies were initiated.<sup>5,7,9,10</sup> By contrast, the emergency medical teams in the current study had used or had been familiar with this technique for more than two years before the study began. Moreover, training of all the personnel in both active compression-decompression CPR and standard CPR was frequent and rigorous and focused on use of the gauge on the suction device for monitoring compression and especially decompression. This approach has been shown to be essential for proper performance of the new CPR technique.<sup>19,20</sup> In at least one large trial that had negative results, use of the gauge was not thought to be important.<sup>5</sup> However, in support of training and use of the gauge are the results of a recent multicenter trial in France and Belgium that compared treatment with high and low doses of epinephrine in more than 3000 patients who had out-of-hospital cardiac arrest.<sup>26</sup> Active compression-decompression CPR was rigorously taught at sites equipped to administer this type of CPR, and nearly 1000 patients received active compression-decompression CPR. Among patients who received low doses of epinephrine, hospital-discharge rates were 50 percent higher in the subgroup that received active compression-decompression CPR than in the subgroup that received standard CPR ( $P < 0.05$ ).

Where and for how long CPR is performed is another factor that is critical to effective resuscitation. Active compression-decompression CPR requires more effort than standard CPR.<sup>5,7,10,27</sup> Recognizing this, the rescue personnel in the current study took three-minute turns to prevent fatigue while performing CPR. Moreover, in all cases CPR was performed at the scene of the arrest and not in a moving vehicle. Others have shown that standard CPR and especially active compression-decompression CPR are much more difficult to perform in a moving vehicle than under stationary conditions.<sup>28</sup> Unlike other clinical trials of the active compression-decompression technique, in which CPR was often performed in a moving vehicle,<sup>5,7,10</sup> in the current study we were able to maintain high-quality performance of both CPR techniques throughout the resuscitation effort.

In the recent French trials of CPR, a physician was present at the scene of cardiac arrest to administer and guide advanced life support.<sup>12,26</sup> In studies in the United States, Canada, and Britain, physicians were not routinely present in the field.<sup>5-8,10,11</sup> In addition, in France, CPR was performed for at least 30 minutes after the arrival of the mobile intensive care unit, regardless of the patient's initial cardiac rhythm. Prolonging CPR may be particularly important for patients found in asystole. In the current study, many patients required more than 20 minutes of CPR before they were successfully resuscitated. In other studies, patients in asystole received 10 to 15 minutes of

CPR, and often, if they were not revived, all further rescue efforts were terminated.<sup>5-7,10,11</sup>

Finally, another difference between the current study and some other studies relates to sample size. The number of participants in each group in this study was calculated to ensure sufficient power to detect an expected difference in long-term end points, according to the results of an initial investigation.<sup>12</sup> All the principal end points in other studies were short-term outcomes, and some of those studies did not have sufficient statistical power to reveal differences between the two methods of CPR in terms of hospital-discharge rates or longer-term survival.<sup>3-6,8,9,11</sup> In one study,<sup>11</sup> the 95 percent confidence interval of the odds ratio for hospital discharge included the value of 3.2 found for the odds ratio in the current study.

One of the limitations of the current study was that investigators could not be blinded to the method of CPR used in each group. Although the baseline characteristics of the patients were similar in the two groups, it is possible that bias on the part of the rescue personnel played a part in the technique used and hence in the outcomes. However, in our previous study, the duration of the resuscitation effort for patients who did not recover was the same for both CPR techniques.<sup>12</sup> Moreover, the fact that many rescue personnel had been performing the new technique for a 19-month period decreased the possibility of bias. In any case, it is clear from a review of our previous experience that both short- and long-term survival rates have never been higher in France.

The results of this study show that the performance of active compression-decompression CPR, as compared with standard CPR, by advanced-life-support personnel increased the one-year survival rates of patients who had out-of-hospital cardiac arrest, but overall mortality was still very high. It will be essential to improve many of the interventions both before and after the patient's arrival at the hospital in order to maximize survival after cardiac arrest. Though not a panacea, active compression-decompression CPR increases the patient's chance of short- and long-term survival. Its use should be encouraged once sufficient numbers of rescue personnel have been trained to perform this new technique.

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#### APPENDIX

Other members of the French Active Compression-Decompression Cardiopulmonary Resuscitation Study Group were J.-P. Cantineau, M.D., and

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## CORRECTION

**Active Compression–Decompression  
Cardiopulmonary Resuscitation**

*To the Editor:* As an investigator in four initial studies of active compression–decompression cardiopulmonary resuscitation (CPR), including a large randomized trial,<sup>1</sup> I would like to comment on the report by Plaisance et al. (Aug. 19 issue).<sup>2</sup> All studies of active compression–decompression CPR are seriously flawed by their complete lack of blinding. My own experience with the active compression–decompression device has demonstrated its powerful effect on participants' efforts. Imagine the additional effect when an unblinded intervention is not a pharmacologic or electrical therapy, but a mechanical device, the efficacy of which depends on the vigor and technique of its use.

Additional opportunities for error arise when, as in the study by Plaisance et al., unblinded investigators both supervise the use of the device and directly manage the resuscitation that determines its success. If the chance of survival increases, the quality of neurologic outcome becomes crucial, but scoring is reliable only when blinded investigators with proved interrater reliability directly examine patients with use of validated instruments.<sup>3</sup> In the study by Plaisance et al., subjective outcomes were obtained from third parties (proved unreliable in previous research) by unblinded investigators, and the reproducibility of ratings was not tested.

The sophisticated, intensive resuscitation resources of the Service d'Aide Médicale Urgente are the diametric opposite of most of the world's emergency medical services. In the current study, 25 percent of one-year survivors had an arrest that was witnessed by advanced-life-support personnel (and apparently another 25 percent had an arrest that was witnessed by basic-life-support personnel). These are small, atypical subpopulations, different from those with the citizen-witnessed arrests studied in most CPR research, and should be analyzed separately in the Utstein model.

I admire the investigators' hard work, but it is well known that we researchers (like all humans) are strongly motivated to find better treatments. The less rigorous a study's methods, the greater the likelihood that it will yield positive results.<sup>4</sup> Even when investigators are blinded, failure to implement blinding as rigorously as possible increases the odds of a positive result by 40 percent.<sup>5</sup> There were so many opportunities for positive-outcome bias in this investigation (and previous investigations) of active compression–decompression CPR that it would be surprising statistically if some studies did not report efficacy.

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*To the Editor:* In the study by Plaisance et al. on the use of active compression–decompression resuscitation in France, approximately 10 percent of witnessed arrests involved CPR by a bystander. The importance of this observation is diminished by the authors' statement, "The use of CPR by a bystander was not found to affect one-year survival in this study." However, this statement is confusing, since Table 3 of their article implies that for 14 of the 24 long-term survivors, CPR was performed by a bystander. Since 14 of the 57 who received bystander-initiated CPR survived, as compared with only 10 survivors among the other 693, this difference corresponds to an odds ratio of 22 in favor of bystander-initiated CPR. Recognizing that other factors may be pertinent (for instance, bystanders providing CPR may be more familiar with available emergency medical resources, resulting in earlier introduction of advanced-life-support protocols), this odds ratio makes the benefits of active compression–decompression resuscitation (odds ratio for survival, 2.5) seem minor in comparison and suggests that efforts to increase the extremely low rate of bystander-initiated CPR are well justified.

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*To the Editor:* Plaisance et al. report the results of a randomized trial that showed improved survival with the use of active compression–decompression resuscitation as opposed to conventional heart massage for persons with out-of-hospital cardiac arrest. I am surprised that allocation of the experimental treatment on alternate days (odd days) continues to be accepted by authoritative journals as randomized — that is, without any pattern.

Moreover, and more important, their conclusion is based on an increase in long-term survival by a factor of less than three (5 percent, vs. 2 percent with standard CPR) in a population with cardiac arrest with a remarkably high incidence of asystole as the first monitored rhythm. Five years ago, a doubling of the rate of good outcomes as a result of external pacing in a smaller but similar population was not considered a result substantial enough to alter current guidelines.<sup>1</sup> The obvious question — whether emergency medical systems that have already achieved far better outcomes without the active compression–decompression device than the French emergency medical system have achieved with it, should nevertheless adopt this technique — remains unanswered.

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Dr. Plaisance replies:

*To the Editor:* Dr. Callahan is aware of the hemodynamic data from studies in animals and in humans in support of active compression–decompression CPR. Unlike his prehospital field experience, in which use of the gauge was not emphasized and the device was not widely used before its efficacy was evaluated, we had the benefit in Paris of knowing with a high degree of certainty that active compression–decompression was being performed correctly, since it had been introduced into the Paris emergency medical system two years before the study began. Although the limitations of performing a new technique in an unblinded manner are important, issues related to proper training, use of the gauge, and widespread implementation of a technique before it is compared with the widely accepted standard are most likely more important. There are probably many opportunities for positive-outcome bias in research, but there are also opportunities for negative-outcome bias, as stated by Nolan et al.<sup>1</sup> Finally, the survivors in the standard-CPR group, not the active compression–decompression group, had a very high percentage of arrests witnessed by advanced-life-support personnel.

As noted by Dr. Bubb, few patients in Paris receive CPR from a bystander. This is an unfortunate situation but may slowly be improving, as noted in the conclusion of our article. Nonetheless, the standard-CPR group and the active compression–decompression group were similar with regard to the number of patients who received bystander CPR, but the outcomes were clearly better in the active compression–decompression group.

In response to Dr. Martens: we did not randomize by patient number because of the logistic problem that would be involved in trying to

coordinate all the rescue units at any point in time. Our low randomization errors support our approach.

In view of a meaningful improvement in outcome when this technique is performed by well-trained personnel, we continue to support, as do other investigators,<sup>2,3,4</sup> more widespread use of this technique.

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*Editor's note:* The following disclosure statement was omitted from the article entitled "A Comparison of Standard Cardiopulmonary Resuscitation and Active Compression–Decompression Resuscitation for Out-of-Hospital Cardiac Arrest," by Plaisance et al. "Dr. Lurie is a co-inventor of the CardioPump, the device used to perform active compression–decompression cardiopulmonary resuscitation, and is entitled to potential royalties from the sale of the device." We regret the omission.

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