

## ORIGINAL ARTICLE

# Compression-Only CPR or Standard CPR in Out-of-Hospital Cardiac Arrest

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## ABSTRACT

**BACKGROUND**

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Emergency medical dispatchers give instructions on how to perform cardiopulmonary resuscitation (CPR) over the telephone to callers requesting help for a patient with suspected cardiac arrest, before the arrival of emergency medical services (EMS) personnel. A previous study indicated that instructions to perform CPR consisting of only chest compression result in a treatment efficacy that is similar or even superior to that associated with instructions given to perform standard CPR, which consists of both compression and ventilation. That study, however, was not powered to assess a possible difference in survival. The aim of this prospective, randomized study was to evaluate the possible superiority of compression-only CPR over standard CPR with respect to survival.

**METHODS**

Patients with suspected, witnessed, out-of-hospital cardiac arrest were randomly assigned to undergo either compression-only CPR or standard CPR. The primary end point was 30-day survival.

**RESULTS**

Data for the primary analysis were collected from February 2005 through January 2009 for a total of 1276 patients. Of these, 620 patients had been assigned to receive compression-only CPR and 656 patients had been assigned to receive standard CPR. The rate of 30-day survival was similar in the two groups: 8.7% (54 of 620 patients) in the group receiving compression-only CPR and 7.0% (46 of 656 patients) in the group receiving standard CPR (absolute difference for compression-only vs. standard CPR, 1.7 percentage points; 95% confidence interval, -1.2 to 4.6;  $P=0.29$ ).

**CONCLUSIONS**

This prospective, randomized study showed no significant difference with respect to survival at 30 days between instructions given by an emergency medical dispatcher, before the arrival of EMS personnel, for compression-only CPR and instructions for standard CPR in patients with suspected, witnessed, out-of-hospital cardiac arrest. (Funded by the Swedish Heart-Lung Foundation and others; Karolinska Clinical Trial Registration number, CT20080012.)

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EMERGENCY MEDICAL DISPATCH CENTERS are crucial in supporting and giving instructions to witnesses or bystanders who call for help for patients with cardiac arrest before the arrival of emergency medical services (EMS) personnel.<sup>1</sup> Telephone instructions given for cardiopulmonary resuscitation (CPR) seem to be given predominantly for CPR involving chest compression.<sup>2</sup>

Using an animal model, Berg and colleagues<sup>3</sup> found that compression-only CPR and standard CPR (i.e., CPR involving both compression and ventilation) have similar efficacy. In a clinical study in which dispatchers gave randomly assigned instructions to callers for aid to patients with cardiac arrest — to attempt resuscitation with the use of either compression-only CPR or standard CPR — survival rates were similar with the two CPR methods.<sup>2</sup> However, this lack of difference may have been due to an undersized study population. In a subgroup analysis, the rate of survival was significantly higher among patients with witnessed cardiac arrest receiving compression-only CPR than among those receiving standard CPR. Two retrospective registry studies have shown similar survival rates with compression-only CPR and standard CPR.<sup>4,5</sup>

We designed this prospective, randomized study to compare the efficacy (measured as the 30-day survival rate) of compression-only CPR and standard CPR, as performed on the basis of instructions from an emergency medical dispatcher, before the arrival of EMS personnel, in witnessed cases of out-of-hospital cardiac arrest.

## METHODS

### STUDY PROTOCOL AND DATA COLLECTION

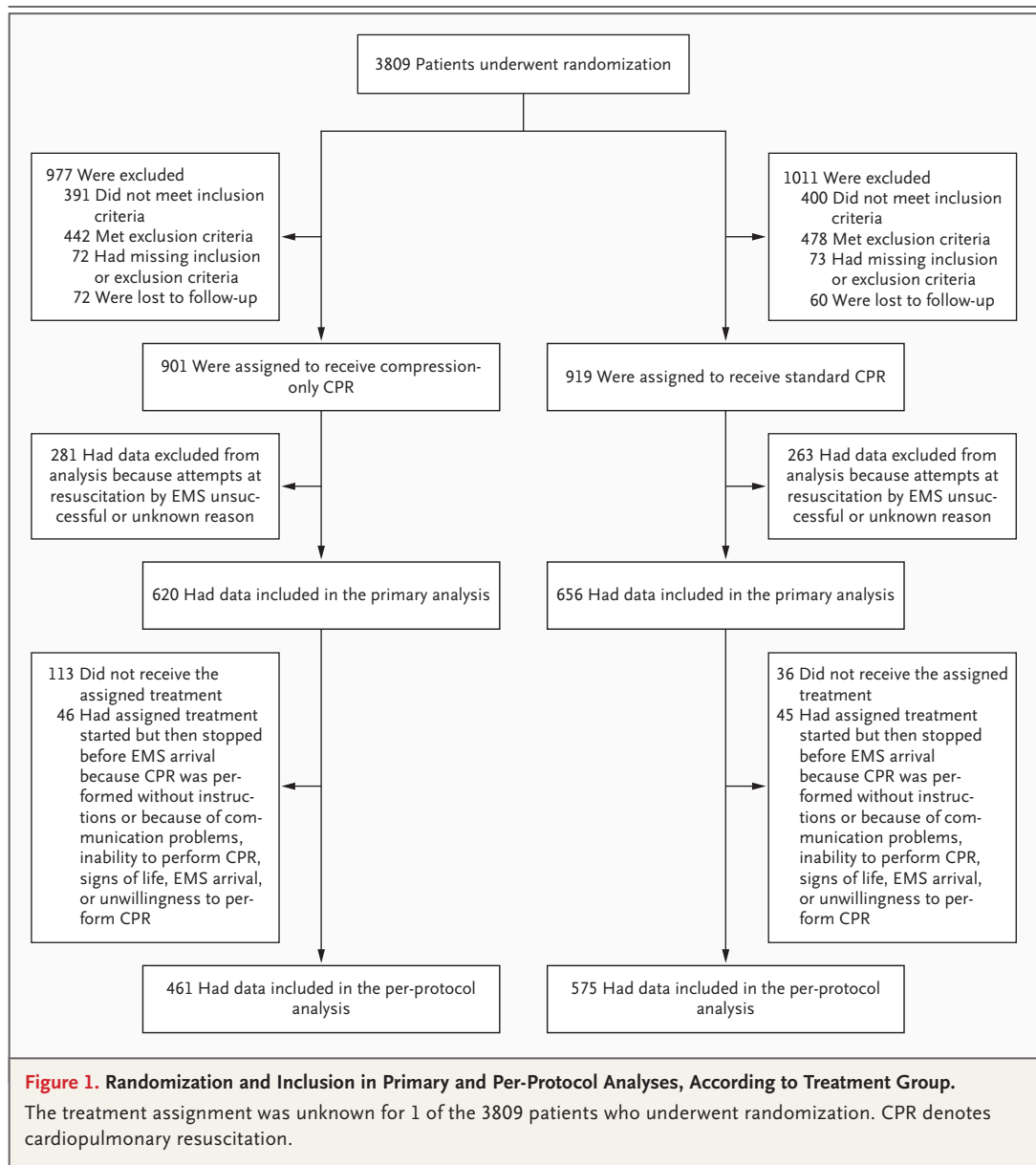
The study protocol was approved by the Regional Ethics Committee at Karolinska Institutet, Stockholm. The requirement for written informed consent was waived. The study was conducted in accordance with the protocol (available with the full text of this article at NEJM.org), which contains details about the methods and statistical analyses beyond those presented here.

Sweden has 9 million inhabitants, and its 18 Emergency Medical Dispatch Centers respond to about 10,000 calls daily. The Swedish Emergency Medical Dispatch Center system and strategies have been described elsewhere.<sup>6</sup>

In this study, dispatchers who received calls about suspected out-of-hospital cardiac arrest first determined whether randomization was warranted, by asking the caller whether the collapse had been witnessed (seen or heard), which was an inclusion criterion, as well as whether the patient was unconscious and was not breathing or not breathing normally. The dispatcher also ascertained that none of the following exclusion criteria were met: cardiac arrest caused by trauma, airway obstruction, drowning, or intoxication; patient's age under 8 years; and difficulty of the dispatcher in communicating with the caller. Furthermore, the dispatcher ascertained that no one at the scene had started CPR and that the caller did not already know how to perform CPR and was willing to be instructed to perform it.

If these conditions were met, the dispatcher gave the caller instructions for either compression-only CPR or standard CPR (mouth-to-mouth ventilation plus chest compression, consisting of 2 ventilations alternating with 15 compressions). The type of CPR on which the caller was instructed was determined on the basis of the next available data-collection sheet for each dispatcher, who removed a paper strip covering the treatment assignment on the sheet after determining that the inclusion criteria had been met. Data-collection sheets were distributed in blocks of 100 sheets, 50 for each treatment assignment. The order of sheets within each block was unique and was based on the random-number generator in SPSS software (version 18).

The dispatcher entered information about inclusion and exclusion criteria on the data-collection sheet and, after the call, noted whether CPR instructions had been given, and if so, instructions for which type of CPR. The dispatcher also recorded whether EMS personnel arrived at any point during the call and whether the arrival interrupted the giving of instructions. Dispatchers were given detailed written instructions to use for compression-only CPR and standard CPR, but they were permitted to diverge from the written instructions if they found it necessary. Our study started before the guidelines for CPR changed the recommendation from 2 ventilations alternating with 15 compressions to 30 compressions alternating with 2 ventilations. Our instructions of 2 ventilations alternating with 15 compressions were maintained throughout the study, since the



new guidelines did not address dispatcher-assisted CPR.

Data were collected from EMS records, and information about survival status was collected from national registers. No interrater reliability assessment was performed. However, 50% of the data-collection forms were double-checked and no relevant deviations were observed. In addition, we evaluated 100 recorded calls and reviewed the corresponding data-collection forms, finding no deviation of the information in each.

#### END POINTS

The primary end point was 30-day survival. The secondary end points were 1-day survival, defined as survival until midnight of the day of admission to the hospital, as well as the first detected cardiac rhythm and survival to discharge from the hospital.

#### STATISTICAL ANALYSIS

We estimated that a sample of 2213 patients in each treatment group would be needed to provide

**Table 1. Reasons for the Exclusion of 1988 Patients with Data Included in the Primary Analysis, According to Treatment Group.\***

Reason	Compression-Only CPR (N=977) <i>no. of patients/total no. (%)</i>	Standard CPR (N=1011) <i>no. of patients/total no. (%)</i>	P Value
Did not meet inclusion criteria			
Patient not unconscious	14/429 (3.3)	10/433 (2.3)	0.14
Patient not breathing or not breathing normally	46/429 (10.7)	45/433 (10.4)	0.92
Collapse not witnessed	369/429 (86.0)	378/433 (87.3)	0.74
Met exclusion criteria			
Patient <8 yr old	7/135 (5.2)	11/144 (7.6)	0.35
Arrest caused by airway obstruction	21/135 (15.6)	24/144 (16.7)	0.66
Arrest caused by intoxication	77/135 (57.0)	78/144 (54.2)	0.94
Arrest caused by trauma	30/135 (22.2)	31/144 (21.5)	0.90
Other			
Caller and patient in different locations	18/595 (3.0)	26/672 (3.9)	0.23
EMS arrived	20/595 (3.4)	22/672 (3.3)	0.76
Signs of life in patient	107/595 (18.0)	117/672 (17.4)	0.50
Communication problems between caller and dispatcher	61/595 (10.3)	61/672 (9.1)	1.00
CPR already started or caller knew how to perform CPR	178/595 (29.9)	197/672 (29.3)	0.33
Obvious signs of death in patient	17/595 (2.9)	22/672 (3.3)	0.42
Caller not able to perform CPR	116/595 (19.5)	129/672 (19.2)	0.41
Caller not willing to perform CPR	58/595 (9.7)	77/672 (11.5)	0.10
Unspecified	20/595 (3.4)	21/672 (3.1)	0.88

\* There may have been more than one reason for exclusion. CPR denotes cardiopulmonary resuscitation, and EMS emergency medical services.

a statistical power of 80% to detect an absolute difference of 2 percentage points in the 30-day survival rate between the two groups, assuming a rate of 5% with standard CPR and 7% with compression-only CPR, with a two-sided alpha value of 0.05.

Because CPR guidelines were altered during the study, giving compression-only CPR a more prominent role,<sup>7</sup> and because of the practical difficulties of running a study for more than 4 years, we decided that 1000 patients in each group was the largest number that would be realistic to include in our study. This revised sample size was estimated to provide a statistical power of 78% to detect an absolute difference of 3 percentage points in the 30-day survival rate between the two groups, assuming a rate of 5% with standard CPR and 8% with compression-only CPR, which was

considered sufficient to detect any clinically important difference in the survival rate. The calculations were performed in SamplePower 2.0 (SPSS).

Data were analyzed according to the randomized treatment assignments, for patients who fulfilled the inclusion and exclusion criteria (the intention-to-treat population in the primary analysis), as well as according to the treatment actually received (the per-protocol analysis). The chi-square test was used to compare compression-only CPR with standard CPR with regard to 30-day and 1-day survival rates (i.e., the primary and secondary end points). A two-tailed P value of less than 0.05 was considered to indicate statistical significance. We used logistic regression to adjust for possible confounders due to imbalances in the baseline characteristics between the two groups and to perform subgroup analyses to determine

**Table 2.** Baseline Characteristics of the Study Patients with Data Included in the Primary Analysis, According to Treatment Group.\*

Characteristic	Compression-Only CPR (N = 620)	Standard CPR (N = 656)
Mean age — yr	68	67
Age group — no. of patients (%)		
≤50 yr	58/592 (9.8)	75/626 (12.0)
>50–75 yr	343/592 (57.9)	360/626 (57.5)
>75 yr	191/592 (32.3)	191/626 (30.5)
Sex — no. of patients (%)		
Male	412/620 (66.5)	444/656 (67.7)
Female	208/620 (33.5)	212/656 (32.3)
Location of cardiac arrest — no. of patients (%)		
Home	442/581 (76.1)	461/609 (75.7)
Public place	54/581 (9.3)	51/609 (8.4)
Other	85/581 (14.6)	97/609 (15.9)
Mean interval between call and first EMS response interval — no. of patients (%)	10.2	10.3
≤5 min	132/573 (23.0)	129/595 (21.7)
6–8 min	150/573 (26.2)	175/595 (29.4)
9–15 min	193/573 (33.7)	198/595 (33.3)
>15 min	98/573 (17.1)	93/595 (15.6)
First cardiac rhythm — no. of patients (%)		
Ventricular fibrillation or tachycardia	188/550 (34.2)	212/581 (36.5)
Asystole	318/550 (57.8)	315/581 (54.2)
Pulseless electrical activity	44/550 (8.0)	54/581 (9.3)

\* CPR denotes cardiopulmonary resuscitation, and EMS emergency medical services.

whether the survival end points in each treatment group varied according to the baseline and end-point characteristics.

## RESULTS

### ENROLLMENT AND CHARACTERISTICS OF THE PATIENTS

Enrollment began in February 2005 and ended in January 2009, at which time there had been 3809 randomized cases of suspected out-of-hospital cardiac arrest. After exclusions, 1276 patients remained in the study (Fig. 1). Reasons for exclusion are listed in Table 1. Of the 1276 patients, 620 (48.6%) were randomly assigned to receive compression-only CPR, and 656 patients (51.4%) to receive standard CPR; 1036 patients (81.2%) were treated per protocol, and 149 (11.7%) did not re-

ceive the assigned treatment. A total of 113 of the 901 patients (12.5%) assigned to receive compression-only CPR were instead given standard CPR because the dispatchers incorrectly gave standard-CPR instructions. The two treatment groups were similar with respect to the baseline characteristics of the patients and the episodes of cardiac arrest (Table 2).

### PRIMARY AND SECONDARY OUTCOMES

The primary analysis showed a 30-day survival rate of 8.7% in the group receiving compression-only CPR and 7.0% in the group receiving standard CPR (absolute difference for compression-only vs. standard CPR, 1.7 percentage points; 95% confidence interval, −1.2 to 4.6;  $P=0.29$ ) (Table 3). A total of 24.0% of the patients receiving compression-only CPR survived for 1 day, as did 20.9% of those

**Table 3. Survival Outcomes in the Study Population, According to Treatment Group.\***

Outcome	Compression-Only CPR <i>no. of patients/total no. (%)</i>	Standard CPR	Two-Sided P Value	Difference (95% CI) <i>percentage points</i>
<b>Primary analysis</b>				
30-Day survival	54/620 (8.7)	46/656 (7.0)	0.26	1.7 (–1.2 to 4.6)
1-Day survival	147/613 (24.0)	136/652 (20.9)	0.18	3.1 (–1.5 to 7.7)
Survival to discharge from hospital	54/282 (19.1)	44/297 (14.8)	0.16	4.3 (–1.8 to 10.5)
<b>Per-protocol analysis</b>				
30-Day survival	39/461 (8.5)	43/575 (7.5)	0.56	1.0 (–2.3 to 4.3)
1-Day survival	115/457 (25.2)	123/571 (21.5)	0.17	3.6 (–1.6 to 8.8)
Survival to discharge from hospital	39/220 (17.7)	42/261 (16.1)	0.63	1.6 (–5.1 to 8.4)

\* Data from 1276 patients were included in the primary analysis, and data from 1036 were included in the per-protocol analysis. Data for survival to discharge were missing for many patients who died before day 30. CI denotes confidence interval, and CPR cardiopulmonary resuscitation.

receiving standard CPR. There were no significant differences between the two groups with respect to the other secondary end points.

#### SUBGROUP ANALYSES

The rates of the primary outcome of 30-day survival and the secondary outcome of 1-day survival did not differ significantly among the subgroups studied (Fig. 2A and 2B). Specifically, the rate of the primary end point did not vary significantly with age ( $P=0.50$ ), interval between call and first EMS response ( $P=0.95$ ), or first cardiac rhythm ( $P=0.99$ ). Adjustment for the baseline characteristics did not change the results.

There was no significant difference in the rates of survival between the two groups after data from patients under 18 years of age were excluded. Nor did the rates of survival differ significantly between the groups for patients who received treatment other than the treatment they had been randomly assigned to receive. Details of these subgroup comparisons, with respect to the primary and secondary end points, and comparisons of patients whose cardiac arrest was classified as uncertain and those with “true” cardiac arrest are provided in the Supplementary Appendix, available at NEJM.org.

#### LOSS TO FOLLOW-UP

Information on follow-up was unavailable for 132 of 1952 patients (6.8%), the main reason being loss of the corresponding EMS field reports, oc-

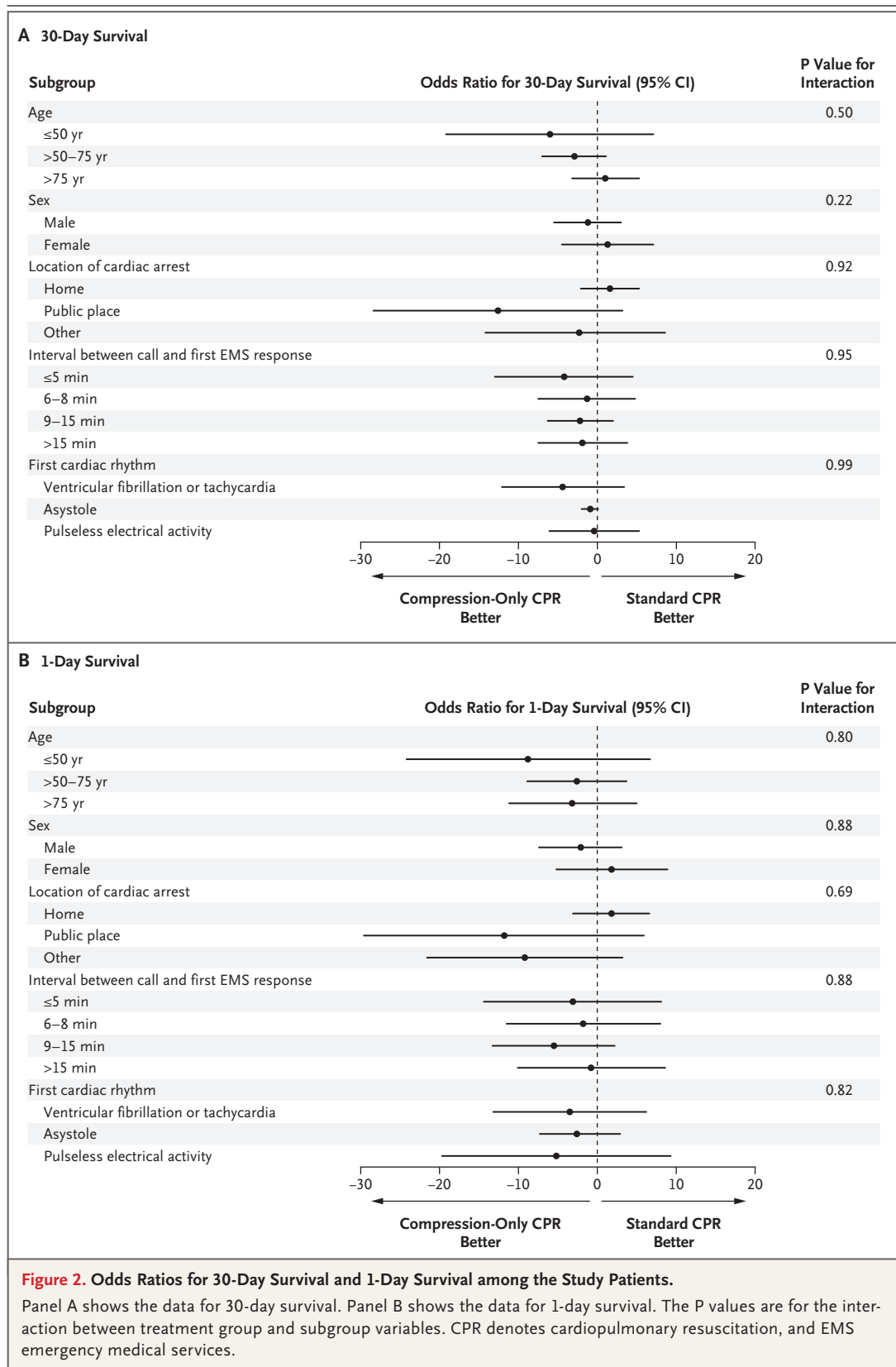
curing primarily in a small number of EMS districts. We therefore performed a subgroup analysis excluding districts where more than 18% of patients were lost to follow-up. No difference from the main results was found.

#### DISCUSSION

Our nationwide, randomized study of witnessed out-of-hospital cardiac arrest shows that giving instructions for compression-only CPR before the arrival of EMS personnel does not significantly improve the outcome of patients as compared with standard CPR. Neither the 1-day nor 30-day rates of survival differed significantly between the two groups. Furthermore, there was no significant difference in the rates of survival among various subgroups. The findings were similar irrespective of whether the data were analyzed according to the assigned treatment (the primary analysis) or the treatment received. Our results are in agreement with those from previously published retrospective registry studies.<sup>4,5,8</sup>

Previous studies in animals have shown no differences in survival or neurologic outcomes with standard CPR and compression-only CPR.<sup>3,9</sup> One investigation even showed adverse outcomes related to the interruption of chest compression in order to perform mouth-to-mouth ventilation.<sup>10</sup> Complete occlusion of the airways does not reduce the chances of survival if reasonable circulation is provided by chest compression.<sup>11</sup>





Compression-only CPR results in more compressions per minute than standard CPR and can be started more rapidly, but the quality of the compressions may be inferior, as reported in a study involving mannequins.<sup>12</sup>

According to American Heart Association (AHA) Guidelines for Emergency Cardiovascular Care, the 2 breaths after each set of 15 chest compression should have a duration of only 1.5 to 2 seconds per breath.<sup>13</sup> However, in a prospective, randomized study involving persons not trained in CPR, the total duration of the two ventilations was 16 seconds on average.<sup>14</sup> It is very difficult for a layperson to provide adequate ventilation.<sup>15</sup> Studies have shown that both laypersons and health workers hesitate to initiate CPR that includes mouth-to-mouth ventilation, for reasons of health and safety.<sup>16,17</sup> According to a recent observational cohort study, the more time the rescuers spend on chest compressions, the better the chances of survival.<sup>18</sup>

Our study population was similar to others with respect to age, sex, location of cardiac arrest, and findings on electrocardiography.<sup>19</sup> The average EMS response time in this study was longer than that in previous studies.<sup>2</sup> This may be explained by the inclusion of large rural areas in our study, which can increase the response time.

Like Hallstrom and colleagues,<sup>2</sup> we found that patients with witnessed out-of-hospital cardiac arrest who received compression-only CPR, as compared with standard CPR, performed by callers who received instructions from dispatchers had similar rates of survival. This result is further supported by the finding that the number of patients who were admitted to the hospital alive did not differ significantly between the two groups.

Our study has several limitations. First, 3809 patients were enrolled, but the final analysis included data from only one third of these patients (approximately 600 patients in each of the two groups). Thus, one limitation of the study is that many patients who underwent randomization were subsequently excluded from the analysis, according to the predefined inclusion and exclusion criteria. Because the analysis was based on fewer patients than the number originally planned, there was a high risk of a type II error. We initially calculated that 2213 patients were needed in each group to detect a small absolute improvement (by 2 percentage points) in the 30-day survival rate with 80% power (with a 20% risk of type II er-

ror), and a sample of 1000 patients seemed realistic to detect an absolute difference of 3 percentage points with 78% power. Thus, although our study did not show a significant difference in the 30-day survival rate (estimated absolute difference, 1.7 percentage points), our results are in agreement with the findings of Hallstrom and colleagues<sup>2</sup> and Berg and colleagues,<sup>3</sup> who reported that there might be a small benefit of compression-only CPR.

Second, the dispatchers did not follow the randomization instructions in a small proportion of cases. The reason for this protocol violation is probably that some dispatchers had a prejudice against compression-only CPR and a preference for standard CPR. Also, some callers showed a preference for a CPR technique other than that specified by randomization.

Third, during the course of the study, the AHA and the European Resuscitation Council changed their CPR guidelines, giving greater emphasis to the quality and quantity of chest compressions. We did not implement these guidelines, because they were not reflected in the Swedish national guidelines until January 2007, 2 years after our study was initiated. Furthermore, these new guidelines did not include dispatcher-instructed CPR.<sup>20,21</sup>

Finally, our finding that compression-only CPR is not significantly better than standard CPR does not apply to cardiac arrest caused by trauma, respiratory failure, or intoxication or to children under the age of 8 years or patients in whom bystanders perform CPR without instructions from dispatchers.

In conclusion, our prospective, randomized study, which focused on patients with witnessed, out-of-hospital, primary cardiac arrest, showed no significant difference in survival when dispatchers gave instructions to callers to perform compression-only CPR, as compared with standard CPR, before the arrival of EMS personnel. Overall, this study lends further support to the hypothesis that compression-only CPR, which is easier to learn and to perform, should be considered the preferred method for CPR performed by bystanders in patients with cardiac arrest.

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Disclosure forms provided by the authors are available with the full text of this article at NEJM.org.

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