In the American Heart Association (AHA) and European Resuscitation Council (ERC) 2010 guidelines for cardiopulmonary resuscitation (CPR), the importance of minimally interrupted chest compressions is emphasized.1,2 During basic life support, the rescuer should perform 2 quick breaths followed by 30 chest compressions and should repeat this cycle until an ambulance arrives and care is taken over by professionals. Each rescue breath should be given over 1 second with enough volume to make the patient’s chest rise, but rapid or forceful breaths should be avoided. The time taken to give 2 breaths should not exceed 5 seconds to allow a sufficient number of chest compressions to be delivered.1,2

Clinical Perspective on p 1590

Time spent on ventilations explains a significant part of the total duration of interruptions of chest compressions.3 The feasibility of the AHA and ERC guidelines recommendation that lay rescuers deliver 2 ventilations within 5 seconds was questioned after 2 manikin studies4,5 showed that lay rescuers and healthcare providers interrupted chest compressions for a much longer duration than recommended (16 and 10 seconds, respectively) to provide 2 ventilations. In a study of automated external defibrillator (AED) use by first responders, the duration of the pause for ventilation after the first and second compression cycles was 6.3 and 6.0 seconds, respectively.6 The long interruption time for ventilation in the first 2 studies4,5 is cited as a justification for compression-only CPR.7,8

This study aimed to determine whether the recommended short interruption for ventilations by trained lay rescuers can be achieved in practice and how interruptions for ventilations affect the number of delivered chest compressions and survival in a large cohort of contiguously collected cases of out-of-hospital cardiac arrests.

Methods

Settings

In the Netherlands, when a cardiac arrest is suspected, 2 ambulances equipped with a manual defibrillator are sent by the dispatcher. Besides the ambulance, the dispatcher sends firefighters or policemen (first

Background—The 2010 guidelines for cardiopulmonary resuscitation allow 5 seconds to give 2 breaths to deliver sufficient chest compressions and to keep perfusion pressure high. This study aims to determine whether the recommended short interruption for ventilations by trained lay rescuers and first responders can be achieved and to evaluate its consequence for chest compressions and survival.

Methods and Results—From a prospective data collection of out-of-hospital cardiac arrest, we used automatic external defibrillator recordings of cardiopulmonary resuscitation by rescuers who had received a standard European Resuscitation Council basic life support and automatic external defibrillator course. Ventilation periods and total compressions delivered per minute during each 2 minutes of cardiopulmonary resuscitation cycle were measured, and the chest compression fraction was calculated. Neurological intact survival to discharge was studied in relation to these factors and covariates. We included 199 automatic external defibrillator recordings. The median interruption time for 2 ventilations was 7 seconds (25th–75th percentile, 6–9 seconds). Of all rescuers, 21% took <5 seconds and 83% took <10 seconds for a ventilation period; 97%, 88%, and 63% of rescuers were able to deliver >60, >70, and >80 chest compressions per minute, respectively. The median chest compression fraction was 65% (25th–75th percentile, 59%–71%). Survival was 25% (49 of 199), not associated with long or short ventilation pauses when controlled for covariates.

Conclusions—The great majority of rescuers can give 2 rescue breaths in <10 seconds and deliver at least 70 compressions in a minute. Longer pauses for ventilations are not associated with worse outcome. Guidelines may allow longer pauses for ventilations with no detriment to survival. (Circulation. 2013;127:1585-1590.)

Key Words: cardiopulmonary resuscitation ◼ guideline ◼ heart arrest ◼ resuscitation ◼ ventilation
rescuers) equipped with an AED (LIFEPAK 500 or LIFEPAK 1000, Physio Control Inc, Redmond, WA). In the Netherlands, firefighters and policemen are dispatched as part of the organized response to cardiac arrest but are considered lay rescuers because their training includes only the standard ERC basic life support/AED courses for lay rescuers.

Besides the dispatched first responder, bystanders are also able to perform basic life support and to defibrillate with an onsite AED before the arrival of an ambulance. In the past, such lay rescuers had generally received a standard ERC basic life support and AED course. All rescuers were trained to perform CPR according to the 2005 guidelines, which included a compression/ventilation ratio of 30:2.

Data Source
The Amsterdam Resuscitation Study (ARREST) is an ongoing, prospective registry of all out-of-hospital cardiac arrests in the Dutch province of North Holland. All data are collected according to the Utstein recommendations. The Medical Ethics Review Board of the Academic Medical Center in Amsterdam approved the study and gave a waiver for the requirement of (written) informed consent. Details of the design of the data collection in the ARREST study are described elsewhere.

Study Design and Data Collection
The investigation was a prospective study of all persons who suffered out-of-hospital cardiac arrest, an AED was attached, and received CPR by trained lay rescuers in the period of September 2010 until March 2011 in the Dutch province North Holland.

Medical students collected all AED ECG recordings shortly after a cardiac arrest. These data were stored and analyzed with dedicated software specific for each type of AED.

For the purpose of this study, we included only AEDs for which the impedance recording (Physio Control LP500, LP1000, or LPCR+) or the displacement transducer (Zoll AED Plus, ZOLL Inc., Chelmsford, MA) allowed accurate determination of chest compressions.

Recordings were eligible for analysis if the AED had recorded at least the first complete compression-ventilation cycle from the notification of the data collection in the ARREST study are described elsewhere.

Data Analysis
All recordings were annotated for initiation and termination of a compression period. For our analysis, we selected the first and, when available, the last complete cycle of CPR of an AED recording to ensure that the possible effect of rescuer fatigue on ventilation duration and compressions was not overlooked in our analysis. The beginning of a cycle was defined as the moment the AED instructs the rescuer to start the resuscitation effort (marked “CPR prompt” in the recording). If the first identifiable compression was given before the notification of CPR prompt, that first compression was marked as the start of the compression period. The 2-minute interval ended with the last compression given after the AED instructed the rescuer to stop CPR (“stop CPR” in the recording; Figure 1).

The AED connect period consisted of 1 full cycle in 85 cases, 2 full cycles in 66 cases, and ≥3 cycles in 48 cases. Not all cycles in those with >1 cycle were analyzable; therefore, in 12 of those cases, only 1 cycle was included in the analysis.

A ventilation period was defined as a regular interruption in chest compressions during the CPR cycle for >3 seconds when impedance changes suggested ventilations and/or when the AED had given ventilation prompts. An interruption of chest compressions of <3 seconds was not considered a true attempt to ventilate.

The chest compression fraction was the proportion of the total resuscitation time without spontaneous circulation during which chest compressions were administered, averaged over the cycles analyzed in our study. We analyzed the duration of each ventilation and chest compression period, as well as the number of chest compressions and ventilations delivered during each 2-minute CPR cycle. We calculated the average duration of the ventilation period by adding the duration of all ventilation cycles in the first cycle and (when available) the last cycle and divided by the number of ventilation periods.

Follow-up
Survival to discharge was verified by contacting the hospital to which the patient had been transported. We retrieved data on neurological outcome at discharge from the hospital charts and estimated the cerebral performance category: 1=good cerebral performance, 2=moderate cerebral disability, 3=severe cerebral disability, 4=coma or vegetative state, and 5=death.

Statistical Analyses
Statistical analyses were performed with standard software (SPSS version 18.0 for Mac, SPSS Inc, Chicago, IL). Time intervals and other median values were expressed as medians (25th–75th percentiles). Baseline comparisons were analyzed by calculating the χ² statistic or 1-way ANOVA. The paired t test was used to determine statistical significance between the number of compressions between periods 1 and 2. The number of ventilations delivered by dispatched first responders and onsite rescuers was analyzed with the Mann-Whitney U test.

We examined the association between ventilation pause and survival. We measured the distribution of relevant baseline factors possibly associated with survival. These factors were age, sex, witnessed collapse, time interval from emergency call to attachment of Figure 1. Schematic time frame of 1 cycle of an electronic recording from an automatic external defibrillator (AED) showing the ECG (black line) and the impedance channel (green line) that reflects chest compressions. The 2 slower and shallower deflections during the ventilation pauses reflect the impedance change caused by 2 insufflations. The AED voice prompt “start CPR” (cardiopulmonary resuscitation) was marked as period 1 start (P1s). The first identifiable compression after the moment the compressions were started was marked C1, even if it occurred before P1s. Likewise, the beginning of a period of ventilation was marked V1. We finished a period with the last compression after the AED prompted “stop CPR” (P1e), and we marked the last compression of that cycle as V3, even if this occurred after the voice prompt to stop CPR.
an AED, ventricular fibrillation (VF) as the initial rhythm, and type of lay-rescuer. Comparisons of continuous variables were made with ANOVA; binary variables were compared with the \( \chi^2 \) statistic for trend. Survival according to the baseline factors was first analyzed with univariate logistic regression. Survival according to the interruption time for ventilation was further analyzed by logistic regression analysis with adjustments for baseline factors that had \( P<0.10 \) in univariate analyses. All statistical tests were 2 tailed, and a value of \( P<0.05 \) was considered to be statistically significant.

**Results**

In the study period, 336 patients with out-of-hospital cardiac arrest had an AED attached before the arrival of emergency medical service personnel; of these, 137 cases were excluded from the analysis and 199 recordings were included (Figure 2).

From 199 included recordings, 102 recordings consisted of an eligible first and last period, and 97 recordings consisted solely of a single period. Baseline and operative values of patients in the study population are shown in Table 1. AEDs were connected for median of 4 minutes (25th–75th percentile, 2–7 minutes).

**Compressions**

Rescuers gave on average 85 chest compressions in period 1 and 86 chest compressions during period 2 (\( P=0.188 \)). Of the rescuers, 97% were able to deliver >60 chest compressions per minute, 88% were able to deliver >70 compressions per minute, and 63% were able to deliver >80 chest compressions per minute (Table 2). In 81% of the cases, the mean compression rate was above the recommended minimum of 100 per minute, and in 23% of all cases, the compression rate was above the recommended maximum rate of 120 per minute. The median chest compression fraction was 65% (25th–75th percentile, 59%–71%). There was a significant trend between the ventilation time and the capability to deliver >60 chest compressions per minute (\( P=0.042 \)), >70 chest compressions per minute (\( P<0.001 \)), and >80 chest compressions per minute (\( P<0.001 \)).

**Ventilations**

The duration of interruptions to deliver 2 breaths is shown in Table 2. The median interruption time for 2 ventilations was 7 seconds (25th–75th percentile, 6–9 seconds). Overall, 17% of rescuers took on average of >10 seconds to provide 2 rescue breaths.

**Different Rescuers**

The median interruption times of the dispatched first responders (using LP1000 and LP500) and the onsite lay rescuers (using Zoll and LPCR+) were 7 seconds (25th–75th percentile, 5–9 seconds) and 8 seconds (25th–75th percentile, 7–10 seconds; \( P=0.059 \)), respectively. The dispatched first responders administered a median of 85 chest compressions per minute (25th–75th percentile, 78–93 chest compressions per minute) compared with 81 chest compressions per minute (25th–75th percentile, 72–91 chest compressions per minute) from the onsite lay rescuers (\( P=0.051 \)).

The lay rescuers using the LPCR+ provided on average 85 chest compressions per minute compared with 79 chest compressions per minute for users of the Zoll AED (\( P=0.076 \)). LPCR+ users provided 2 ventilations with a mean duration of 8 seconds compared with 7 seconds by the users of Zoll AED (\( P=0.41 \)).

The mean compression rate from rescuers using the LPCR+ was 115 chest compressions per minute. Rescuers using the Zoll AED Plus delivered chest compressions at a mean rate of 103 chest compressions per minute (\( P=0.018 \)).

**Rhythm During AED Connection**

The initial rhythm was VF in 100 of the 199 patients (50%). Only 9 of 100 VF patients remained in VF throughout the AED connection period, despite at least 1 defibrillation shock from the AED. Another 4 patients who had no VF as initial rhythm developed VF during the AED connection period.

**Survival**

Overall survival to discharge was 25% (49 of 199). The vast majority of the surviving patients had a cerebral performance category score \( \leq 2 \) (48 of 49, 98%). A significant trend for increased survival to discharge was seen with longer pauses for ventilation (\( P=0.007 \); Table 2). Table 3 show that baseline factors,

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**Figure 2.** Data flow and calculation of included cases. AED indicates automatic external defibrillator; CPR, cardiopulmonary resuscitation; and CV, compression/ventilation.

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**Table 1.** Baseline and Operative Values of Patients in the Study Population

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Study Population (n=199)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean±SD, y</td>
<td>66±15</td>
</tr>
<tr>
<td>Male sex, n (%)</td>
<td>138 (69)</td>
</tr>
<tr>
<td>Witnessed collapse, n (%)</td>
<td>146 (73)</td>
</tr>
<tr>
<td>VT/VF as initial rhythm, n (%)</td>
<td>100 (50)</td>
</tr>
<tr>
<td>Dispatched first responders/onsite rescuers, n</td>
<td>134/65</td>
</tr>
<tr>
<td>Delay from emergency call to AED attachment, min*</td>
<td>6:48 (4:28–9:04)</td>
</tr>
</tbody>
</table>

---

*Time interval is presented as median (25th–75th percentile).
including time from emergency call to attachment of the AED, VF as initial rhythm, and type of lay rescuer, were unevenly distributed between the ventilation groups. After adjustment for baseline factors, ventilation pause duration was not associated with significantly better or worse survival (Table 4). If analyzed for VF cases only, the results of the multivariable analysis were similar (data not shown). Post hoc secondary analyses using alternative grouping of ventilation duration (3–5, 6–9, 10) or only ventilation group variables of 3 to 12 and ≥13 seconds (data not shown) did not demonstrate quantitatively different results.

**Discussion**

The results of our study show that lay rescuers require a median ventilation time of 7 seconds (25th–75th percentile, 6–9 seconds) to complete 2 ventilation attempts. Only 21% are able to fully meet the ventilation guidelines of 2010. However, 97% of all rescuers provided chest compressions above the recommended minimum of 60 chest compressions in 1 minute, 88% of all administered >70 chest compressions in 1 minute, and 63% administered >80 chest compressions in 1 minute. Interruptions in chest compressions for rhythm analysis, rescue shocks, ventilations, or human error cause a rapid decrease in the aortic relaxation (diastolic) pressure and thereby cause a decrease in coronary and cerebral perfusion pressures.10,11 Earlier investigations demonstrated an association between the proportion of resuscitation time that chest compressions are administered and survival to hospital discharge after out-of-hospital cardiac arrest.10 Therefore, the AHA and ERC 2010 guidelines emphasized the importance of minimizing the time without chest compressions.1,2

The long interruption time for ventilations is cited as a justification for compression-only CPR to allow a sufficient number of chest compressions.6,7 We found that the time to provide the 2 ventilation breaths was even shorter in real life than it was in the studies with manikins4,5 and that the great majority of all rescuers provided chest compressions above the recommended minimum of 60 chest compressions in 1 minute. Raising the chest compression rate to at least 100 per minute in the 2010 guidelines could make the time for a ventilation pause even less critical. However, the intention was to not exceed a chest compression rate of >120 per minute. Nevertheless, in 23% of the cases, the chest compression rate was >120 per minute with potentially a small adverse influence on survival.12

**Predictors of Survival**

In our study, better survival was observed with longer ventilation times and the lowest chest compression fractions. This finding is not in agreement with the findings of other studies with

### Table 2. Ratio of Compressions and Ventilations Delivered

<table>
<thead>
<tr>
<th>Ventilation Duration, s</th>
<th>3–5</th>
<th>6–7</th>
<th>8–9</th>
<th>10–12</th>
<th>≥13</th>
<th>P Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cases, n (%)</td>
<td>42 (21)</td>
<td>58 (29)</td>
<td>50 (25)</td>
<td>28 (14)</td>
<td>21 (11)</td>
<td></td>
</tr>
<tr>
<td>Chest compression rate/min, median‡</td>
<td>107 (101–121)</td>
<td>105 (102–118)</td>
<td>113 (103–126)</td>
<td>111 (101–118)</td>
<td>106 (96–116)</td>
<td>0.18</td>
</tr>
<tr>
<td>Chest compression rate &gt;100/min, %</td>
<td>81</td>
<td>80</td>
<td>88</td>
<td>82</td>
<td>72</td>
<td>0.73</td>
</tr>
<tr>
<td>Chest compression rate &gt;120/min, %</td>
<td>26</td>
<td>19</td>
<td>34</td>
<td>14</td>
<td>14</td>
<td>0.39</td>
</tr>
<tr>
<td>Compressions/ventilations delivered, n/min‡</td>
<td>95/3</td>
<td>84/3</td>
<td>84/3</td>
<td>84/3</td>
<td>70/2</td>
<td></td>
</tr>
<tr>
<td>≥60 chest compressions delivered/min, %</td>
<td>98</td>
<td>98</td>
<td>100</td>
<td>97</td>
<td>86</td>
<td>0.042</td>
</tr>
<tr>
<td>≥70 chest compressions delivered/min, %</td>
<td>95</td>
<td>93</td>
<td>96</td>
<td>89</td>
<td>43</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>≥80 chest compressions delivered/min, %</td>
<td>93</td>
<td>66</td>
<td>72</td>
<td>54</td>
<td>19</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Chest compression fraction, median, %‡</td>
<td>74 (68–79)</td>
<td>66 (61–70)</td>
<td>62 (57–66)</td>
<td>63 (54–74)</td>
<td>57 (49–63)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Survival, % (n/N)</td>
<td>12 (5/42)</td>
<td>22 (13/58)</td>
<td>26 (13/50)</td>
<td>29 (8/28)</td>
<td>43 (9/21)</td>
<td>0.007</td>
</tr>
</tbody>
</table>

*P value for trend.
‡Chest compression fraction is presented as median (25th–75th percentile).
‡Numbers indicate the amount of compressions and single ventilations delivered in each minute.

### Table 3. Distribution of the Baseline Factors in the Ventilation Groups

<table>
<thead>
<tr>
<th>Ventilation Duration, s</th>
<th>3–5</th>
<th>6–7</th>
<th>8–9</th>
<th>10–12</th>
<th>&gt;13</th>
<th>P Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cases, n (%)</td>
<td>42 (21)</td>
<td>58 (29)</td>
<td>50 (25)</td>
<td>28 (14)</td>
<td>21 (11)</td>
<td></td>
</tr>
<tr>
<td>Patient age, mean±SD, y</td>
<td>66±19</td>
<td>66±15</td>
<td>65±14</td>
<td>65±15</td>
<td>65±15</td>
<td>0.99</td>
</tr>
<tr>
<td>Patient sex, male, n (%)</td>
<td>26 (62)</td>
<td>43 (74)</td>
<td>31 (62)</td>
<td>22 (79)</td>
<td>16 (76)</td>
<td>0.27</td>
</tr>
<tr>
<td>Witnessed collapse, n (%)</td>
<td>30 (71)</td>
<td>45 (78)</td>
<td>33 (66)</td>
<td>20 (71)</td>
<td>18 (86)</td>
<td>0.63</td>
</tr>
<tr>
<td>Dispatched first responder/onsite rescuers, n</td>
<td>38/4</td>
<td>42/16</td>
<td>37/13</td>
<td>16/12</td>
<td>11/10</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>VF as initial rhythm, n (%)</td>
<td>15 (36)</td>
<td>26 (45)</td>
<td>32 (64)</td>
<td>15 (54)</td>
<td>12 (58)</td>
<td>0.030</td>
</tr>
<tr>
<td>Time from emergency call to AED attachment, min‡</td>
<td>7:03 (6:16–9:01)</td>
<td>6:48 (5:16–9:29)</td>
<td>6:46 (4:23–9:37)</td>
<td>5:21 (1:44–8:38)</td>
<td>4:30 (1:03-7:18)</td>
<td>0.029</td>
</tr>
</tbody>
</table>

AED indicates automatic external defibrillator; and VF, ventricular fibrillation.
*P value for trend.
‡Time interval is presented in median in minutes (25th to 75th percentile).
long interruptions of chest compressions, mainly caused by pauses associated with defibrillation shocks.\textsuperscript{13,14} This paradox can be attributed to the fact that other baseline factors that are more important for predicting survival were unevenly distributed between the groups of ventilation duration. After adjustment for the baseline factors, the ventilation pause duration was not associated with significantly better or worse survival (Table 4). It is also possible that the suggested detrimental effect of perishock pauses does not apply to pauses for ventilation.

It must also be noted that in the study that found a significant relationship between lower chest compression fractions and survival, the relation was seen mainly in the patients with chest compression fractions <60% and as low as 20%.\textsuperscript{10} In our study, the lowest chest compression fractions were never below 60%; the great majority of rescuers even could deliver >60 chest compressions per minute.

### Are All Lay Rescuers the Same?

None of the lay rescuers in our study were part of emergency medical services, but police and firefighters may have had a more strict retraining schedule than other lay rescuers and may have been involved in >1 case of a true cardiac arrest. This matches our earlier observations that AEDs from dispatched first responders were used on average twice a year, whereas onsite AEDs are used on average once in 30 years.\textsuperscript{9} Although we indeed observed that onsite rescuers were more frequently represented in the longest ventilation groups, this finding did not reach statistical significance, and the difference in ventilation pauses was neither clinically nor statistically significant, nor was the number of delivered chest compressions per minute. There is therefore no suggestion that onsite lay rescuers with no or minimal past experience did worse than the dispatched first responders.

### What Is the Scientific Basis for the Current Recommendations in the 2010 Guidelines?

No direct scientific evidence supports or refutes the recommended maximal insufflation time of 5 seconds. There is evidence\textsuperscript{15,16} that supports the recommendation that the insufflation volume should not exceed 600 mL and that short insufflation times increase the risk of gastric dilatation.\textsuperscript{17,18} The recommended 5-second interruption time for 2 ventilations is the mathematical consequence of the intention to deliver at least 60 chest compressions per minute at a rate of 100 per minute, given a compression/ventilation ratio of 30:2. Our study shows that a chest compression fraction of >60%, compatible with good survival, is achieved in all ventilation groups except the longest.\textsuperscript{10} The importance of the minimal number of compressions delivered per minute is emphasized in a recent study in which the group of patients who received 75 to 100 compressions per minute had significantly more return of spontaneous circulation than those with fewer compressions delivered.\textsuperscript{12} Patients in all ventilation groups except the group with pauses ≥13 seconds received ≥70 compressions in 1 minute in the great majority of cases. Therefore, it appears that interruptions for ventilations are less critical for delivering sufficient compressions per minute than suggested by the current guidelines.

Longer insufflation periods proved compatible with excellent survival rates. There is no justification to recommend these very strict and short insufflation times, and it is possible to allow the recommended maximum time for ventilations to be at least 10 seconds without detriment to survival.

### Limitations

In most recordings, the impedance signal allowed identification of ventilation breaths, but in some cases, we could observe only the absence of compressions. In that situation, we are not certain that the pause in compressions, which we have defined as a ventilation period, was actually used to administer effective ventilations.

Information about the quality of the delivered chest compressions was absent in the recordings except in the Zoll AED recordings. This is an important factor because our results show that even with a relatively long interruption for ventilation, the number of administered chest compressions per minute remains acceptable.

Likewise, no information was available about the quality of the ventilations provided. The study of Odegaard et al\textsuperscript{19} demonstrated that there is an association between duration and quality of ventilation breaths. Only half of the ventilation attempts by lay rescuers on a manikin were successful. This could mean that rapid insufflations by rescuers who achieved very short interruptions of chest compressions do not have a positive effect on survival.

In general, lay rescuers follow the voice prompts of the AED. However, sometimes a more experienced lay rescuer would start chest compressions just before the voice prompt, and sometimes chest compressions were started just after the voice prompt. In both cases, we marked the first chest compression as the start of the cycle.
Conclusions
Trained lay rescuers are, most of the time, able to give 2 rescue breaths in <9 seconds and almost always give at least 60 compressions per minute. The chest compression fraction was >60% with all durations of breath except the longest. Survival was not directly adversely influenced by ventilation pauses >5 seconds, and outcome was determined by other factors. Lay rescuers with CPR training that includes chest compressions and ventilations are able to perform CPR better than previously believed. There is justification to increase the recommended maximum duration of a pause for ventilations to 10 seconds to match the reality of CPR by lay rescuers.

Acknowledgments
We thank Loes Bekkers, Paulien Homma, and Remy Stieglis for data management.

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The ARREST study is maintained by an unconditional grant from Physio Control Inc, Redmond, WA.

Disclosures
None.

References

CLINICAL PERSPECTIVE
Guidelines on cardiopulmonary resuscitation (CPR) recommend that pauses for ventilations do not exceed 5 seconds. Earlier investigations on manikins showed that lay rescuers and healthcare providers interrupted chest compressions for a much longer duration than recommended, believed to be detrimental to survival. In this study, we evaluated whether trained lay rescuers can follow the guidelines in practice and assessed how interruptions for ventilations affect the number of delivered chest compressions and survival of out-of-hospital cardiac arrest. We used 199 automatic external defibrillator recordings of CPR by lay rescuers, trained according to the 2005 guidelines for CPR that include a compression/ventilation ratio of 30:2. Impedance and transducer information from the automatic external defibrillators allowed accurate measurements of compression and ventilation parameters during each 2-minute CPR cycle. Trained lay rescuers delivered 2 rescue breaths in a median of 7 seconds (interquartile range, 6–9 seconds). They also delivered >70 compressions per minute in 88% of cases. Median chest compression fraction was 65% (25th to 75th percentile, 59%–71%). In only the 11% of cases when chest compressions were interrupted for ≥13 seconds, the number of delivered chest compressions was clearly inadequate, and the chest compression fraction was <60%. Overall survival was 25%, not negatively influenced by longer pauses for ventilation. These findings demonstrate that lay rescuers with CPR training that includes ventilations are able to perform CPR better than previously believed but cannot fully comply with the strict guidelines. Our findings justify an increase in the recommended maximum duration of a pause for ventilations to 10 seconds to match the reality of CPR by lay rescuers without an adverse effect on survival.
Duration of Ventilations During Cardiopulmonary Resuscitation by Lay Rescuers and First Responders: Relationship Between Delivering Chest Compressions and Outcomes
Stefanie G. Beesems, Lizzy Wijmans, Jan G.P. Tijssen and Rudolph W. Koster

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http://circ.ahajournals.org/content/127/15/1585

An erratum has been published regarding this article. Please see the attached page for:
/content/130/16/e146.full.pdf

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In the article by Beesems et al, “Duration of Ventilations During Cardiopulmonary Resuscitation by Lay Rescuers and First Responders,” which was published in the April 16, 2013 issue of the journal (*Circulation*, 2013;127:1585–1590), the symbols were missing from the Age row of Table 1 and the Patient age row of Table 3. Corrected versions of Table 1 and Table 3 have been provided below. In addition, the heading of Table 2 should have read “Ventilation Duration” instead of “Breath Duration.”

### Table 1. Baseline and Operative Values of Patients in the Study Population

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Study Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean±SD, y</td>
<td>66±15</td>
</tr>
<tr>
<td>Male sex, n (%)</td>
<td>138 (69)</td>
</tr>
<tr>
<td>Witnessed collapse, n (%)</td>
<td>146 (73)</td>
</tr>
<tr>
<td>VF/VT as initial rhythm, n (%)</td>
<td>100 (50)</td>
</tr>
<tr>
<td>Dispatched first responders/onsite rescuers, n</td>
<td>134/65</td>
</tr>
<tr>
<td>Delay from emergency call to AED attachment, min*</td>
<td>6:48 (4:28–9:04)</td>
</tr>
</tbody>
</table>

AED indicates automatic external defibrillator; VF, ventricular fibrillation; and VT, ventricular tachycardia.

*Time interval is presented as median (25th–75th percentile).

### Table 2. Ratio of Compressions and Ventilations Delivered

<table>
<thead>
<tr>
<th>Ventilation Duration, s</th>
<th>3–5</th>
<th>6–7</th>
<th>8–9</th>
<th>10–12</th>
<th>≥13</th>
<th>P Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cases, n (%)</td>
<td>42 (21)</td>
<td>58 (29)</td>
<td>50 (25)</td>
<td>28 (14)</td>
<td>21 (11)</td>
<td></td>
</tr>
<tr>
<td>Chest compression rate/min, median†</td>
<td>107 (101–121)</td>
<td>105 (102–118)</td>
<td>113 (103–126)</td>
<td>111 (101–118)</td>
<td>106 (96–116)</td>
<td>0.18</td>
</tr>
<tr>
<td>Chest compression rate &gt;100/min, %</td>
<td>81</td>
<td>80</td>
<td>88</td>
<td>82</td>
<td>72</td>
<td>0.73</td>
</tr>
<tr>
<td>Chest compression rate &gt;120/min, %</td>
<td>26</td>
<td>19</td>
<td>34</td>
<td>14</td>
<td>14</td>
<td>0.39</td>
</tr>
<tr>
<td>Compressions/ventilations delivered, n/min‡</td>
<td>95/3</td>
<td>84/3</td>
<td>84/3</td>
<td>84/3</td>
<td>70/2</td>
<td></td>
</tr>
<tr>
<td>≥60 chest compressions delivered/min, %</td>
<td>98</td>
<td>98</td>
<td>100</td>
<td>97</td>
<td>86</td>
<td>0.042</td>
</tr>
<tr>
<td>≥70 chest compressions delivered/min, %</td>
<td>95</td>
<td>93</td>
<td>96</td>
<td>89</td>
<td>43</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>≥80 chest compressions delivered/min, %</td>
<td>93</td>
<td>66</td>
<td>72</td>
<td>54</td>
<td>19</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Chest compression fraction, median, %†</td>
<td>74 (68–79)</td>
<td>66 (61–70)</td>
<td>62 (57–66)</td>
<td>63 (54–74)</td>
<td>57 (49–63)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Survival, % (n/N)</td>
<td>12 (5/42)</td>
<td>22 (13/58)</td>
<td>26 (13/50)</td>
<td>29 (8/28)</td>
<td>43 (9/21)</td>
<td>0.007</td>
</tr>
</tbody>
</table>

*P value for trend.
†Chest compression fraction is presented as median (25th–75th percentile).
‡Numbers indicate the amount of compressions and single ventilations delivered in each minute.
The current online version of the article has been corrected. The authors regret the error.

### Table 3. Distribution of the Baseline Factors in the Ventilation Groups

<table>
<thead>
<tr>
<th></th>
<th>3–5 (n, %)</th>
<th>6–7 (n, %)</th>
<th>8–9 (n, %)</th>
<th>10–12 (n, %)</th>
<th>&gt;13 (n, %)</th>
<th>P Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cases</td>
<td>42 (21)</td>
<td>58 (29)</td>
<td>50 (25)</td>
<td>28 (14)</td>
<td>21 (11)</td>
<td></td>
</tr>
<tr>
<td>Patient age, mean±SD, y</td>
<td>66±19</td>
<td>66±15</td>
<td>65±14</td>
<td>65±15</td>
<td>65±15</td>
<td>0.99</td>
</tr>
<tr>
<td>Patient sex, male, n (%)</td>
<td>26 (62)</td>
<td>43 (74)</td>
<td>31 (62)</td>
<td>22 (79)</td>
<td>16 (76)</td>
<td>0.27</td>
</tr>
<tr>
<td>Witnessed collapse, n (%)</td>
<td>30 (71)</td>
<td>45 (78)</td>
<td>33 (66)</td>
<td>20 (71)</td>
<td>18 (86)</td>
<td>0.63</td>
</tr>
<tr>
<td>Dispatched first responder/onsite rescuers, n</td>
<td>38/4</td>
<td>42/16</td>
<td>37/13</td>
<td>16/12</td>
<td>11/10</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>VF as initial rhythm, n (%)</td>
<td>15 (36)</td>
<td>26 (45)</td>
<td>32 (64)</td>
<td>15 (54)</td>
<td>12 (58)</td>
<td>0.030</td>
</tr>
<tr>
<td>Time from emergency call to AED attachment, min†</td>
<td>7:03 (6:16–9:01)</td>
<td>6:48 (5:16–9:29)</td>
<td>6:46 (4:23–9:37)</td>
<td>5:21 (1:44–8:38)</td>
<td>4:30 (1:03–7:18)</td>
<td>0.029</td>
</tr>
</tbody>
</table>

AED indicates automatic external defibrillator; and VF, ventricular fibrillation.

*P value for trend.
†Time interval is presented in median in minutes (25th to 75th percentile).