Duration of Ventilations during Cardiopulmonary Resuscitation by Lay-Rescuers and First Responders: Relationship between Delivering Chest Compressions and Outcomes

Running title: Beesems et al.; Interruptions of chest compressions

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Journal Subject Code: Treatment:[25] CPR and emergency cardiac care
Abstract:

**Background**—The Guidelines 2010 for cardiopulmonary resuscitation (CPR) allow 5 seconds to give two breaths to deliver sufficient chest compressions and keep perfusion pressure high. This study aims to determine if the recommended short interruption for ventilations by trained lay-rescuers and first responders can be achieved and 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 (AED) recordings of CPR by rescuers who had received a standard ERC Basic Life Support and AED course. Ventilation periods, total compressions delivered per minute during each 2 minutes CPR cycle were measured and chest compression fraction (CCF) calculated. Neurologic intact survival to discharge was studied in relation to these factors and covariates. We included 199 AED recordings. The median (25th – 75th percentile) interruption time for two ventilations was 7 seconds (6-9). Of all rescuers, 21% took <5 seconds, 83% took <10 seconds for a ventilation period; 97%, 88% and 63% of rescuers were able to deliver respectively >60, >70 and >80 chest compressions per minute. The median CCF (25th - 75th percentile) was 65% (59-71%). Survival was 49/199 (25%), not associated with long or short ventilation pauses when controlled for covariates.

**Conclusions**—The great majority of rescuers can give two rescue breaths in less than 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 without detriment to survival.

**Keywords:** cardiopulmonary resuscitation, heart arrest, ventilation, chest compression resuscitation, guideline
Introduction

In the American Heart Association (AHA) and European Resuscitation Council (ERC) Guidelines 2010 (G2010) for cardiopulmonary resuscitation (CPR) the importance of minimally interrupted chest compressions is emphasized.\textsuperscript{1,2} During Basic Life Support (BLS), the rescuer should perform ‘two quick breaths’, followed by 30 chest compressions and 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 victim’s chest rise, but to avoid rapid or forceful breaths. The time taken to give two breaths should not be more than 5 seconds to allow for a sufficient number of chest compressions delivered.\textsuperscript{1,2} Time spent on ventilations explains a significant part of the total duration of interruptions of chest compressions.\textsuperscript{3} The feasibility of the AHA and ERC guidelines recommendation that lay-rescuers deliver two ventilations within five seconds was questioned after two manikin studies\textsuperscript{4,5} showed that lay-rescuers and healthcare providers interrupted chest compressions for a much longer duration than recommended (16 seconds and 10 seconds, respectively) to provide two ventilations. In a study of Automated External Defibrillator (AED) use by first-responders, the duration of the pause for ventilation after respectively the first and second compression cycle was 6.3 seconds and 6.0 seconds.\textsuperscript{6} The long interruption time for ventilation in the first studies\textsuperscript{4,5} is cited as a justification for ‘compression-only CPR’.\textsuperscript{7,8}

This study aimed to determine if 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 (OHCA).
Methods

Settings

In the Netherlands, when a cardiac arrest is suspected, two ambulances equipped with a manual defibrillator, are sent out by the dispatcher. Besides the ambulance, the dispatcher sends out firefighters or policemen (first-responder) 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 as their training only includes the standard ERC BLS/AED courses for lay-rescuers.

Besides the dispatched first-responder, bystanders are also able to perform BLS and defibrillate with an onsite AED prior to arrival of an ambulance. Such lay-rescuers had generally received a standard ERC BLS and AED course in the past. All rescuers were trained to perform CPR according to the G2005 which included a compression:ventilation (C:V) ratio of 30:2.

Data Source

The Amsterdam Resuscitation Study (ARREST) is an ongoing, prospective registry of all OHCAs 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, 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.9

Study design and data collection

The investigation was a prospective study of all persons who suffered OHCA, to whom 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 of which the impedance recording allowed accurate determination of chest compressions (Physio Control LP500, LP1000 or LPCR+) or from the displacement transducer (Zoll AED Plus, ZOLL Inc., Chelmsford, MA).

Recordings were eligible for analysis if the AED had recorded, at least, the first complete compression-ventilation cycle from the notification of ‘start CPR’ to ‘Stop CPR’ by the voice-prompt of the AED, before the AED was disconnected by EMS. We excluded ECGs with a C:V ratio other than 30:2 and ECGs that were not analyzable because of technical deficiencies.

We differentiated the dispatched first-responders from the other lay-rescuers by the AED used. LP1000 and LP500 were solely used by dispatched first responders and LPCR+ and the Zoll AED Plus solely by non-dispatched onsite rescuers.

**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 in order to assure that the possible effect of fatigue of the rescuer 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 with the resuscitation-effort (marked with ‘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 ends with the last compression that was given after the AED instructs the rescuer to stop CPR (‘stop-CPR’ in the recording) (Figure 1).

The AED connect period consisted of 1 full cycle in 85 cases, two full cycles in 66 cases.
and 3 or more cycles in 48 cases. Not all cycles in those with more than one 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 more than 3 seconds where impedance changes suggested ventilations and/or when the AED had given ventilation prompts. An interruption of chest compressions less than 3 seconds was not considered a true attempt to ventilate.

The chest compression fraction (CCF) was the proportion of the total resuscitation time without spontaneous circulation during which chest compressions were administered, averaged over the cycles that were 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 minutes 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 estimating the Cerebral Performance Category (CPC): good cerebral performance (1); moderate cerebral disability (2); severe cerebral disability (3); coma or vegetative state (4); and death (5).

**Statistical analyses**

Statistical analyses were performed with standard software (SPSS, version 18.0 for Mac, Chicago, IL). Time intervals and other median values were expressed as median (25th – 75th percentiles). Baseline comparisons were analyzed by calculating the chi-square statistic or the one-way ANOVA. The paired t-test was used to determine statistical significance between the
number of compressions between period 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, gender, witnessed collapse, time interval from emergency call to attachment of an AED, ventricular fibrillation (VF) as initial rhythm and type of lay-rescuer. Comparisons of continuous variables were made with ANOVA; binary variables were compared with the chi-square 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 \( p \)-value of \(<0.05\) was considered to be statistically significant.

**Results**

In the study period, 336 cases of OHCA had an AED attached before arrival of EMS personnel of which 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 solely consisted of a single period. Baseline and operative values of patients in the study population are shown in Table 1. AEDs were connected for median (25th - 75th percentile) 4 (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% to deliver >70 compressions per minute and 63% 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 CCF (25th - 75th percentile) was 65% (59-71%). There was a significant trend between the ventilation-time and the capability to deliver over 60 chest compressions per minute (p=0.042), over 70 chest compressions per minute (p<0.001) and over 80 chest compressions per minute (p<0.001).

**Ventilations**

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

**Different rescuers**

The median (25th - 75th percentile) interruption time of the dispatched first responders (using LP1000 and LP500) and of the onsite lay-rescuers (using Zoll and LPCR+) was 7 seconds (5-9) and 8 seconds (7-10) (p=0.059), respectively. The dispatched first responders administered median 85 chest compressions per minute (78-93 chest compressions per minute) compared to 81 chest compressions per minute (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 to 79 chest compressions per minute to users of the Zoll-AED (p=0.076). LPCR+ users provided 2 ventilations with a mean duration of 8 seconds compared to 7 seconds by the Zoll-AED (p=0.41).
The mean compression-rate from rescuers with the LPCR+ was 115 chest compressions per minute and rescuers with the Zoll AED Plus delivered chest-compressions with a mean rate of 103 chest compressions per minute (p=0.018).

**Rhythm during AED connection**

The initial rhythm was VF in 100/199 (50%) of the patients. Only 9 of 100 VF patients remained in VF throughout the AED connection period, despite at least one 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 49/199 (25%). The vast majority of the surviving patients had a CPC score ≤2 (48/49; 98%). A significant trend of increased survival to discharge was seen with longer pauses for ventilation (p=0.007) (Table 2). Table 3 show that baseline factors including time interval 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 the baseline factors, ventilation pause duration was not associated with significantly better or worse survival (Table 4). If analyzed for VF cases only, the result of the multivariable analysis was similar (data not shown). Post hoc secondary analyses using alternative grouping of ventilation duration (3-5, 6-9, ≥10) or only ventilation group variables 3-12 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 (25th - 75th percentile) ventilation time of 7 seconds (6-9) to complete two 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 one minute, 88% of all administered over 70 chest compressions in one minute and 63% of all administered over 80 chest compressions in one minute.

Interruptions in chest compressions, for rhythm analysis and 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. Early investigations demonstrated an association between the proportion of resuscitation time that chest compressions are administered and survival to hospital discharge after OHCA. Therefore, the AHA and ERC Guidelines of 2010 emphasized the importance of minimizing the time without chest compressions.

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

Predictors of survival

In our study, better survival was observed with longer ventilation times and with lowest chest compression fractions. This is against the findings of other studies with 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, more important for predicting survival, were unevenly distributed between the groups of ventilation duration. After adjustment for the baseline factors, 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 the study that found a significant relationship between lower chest compression fractions and survival, saw that relation mainly in the patients with chest compression fractions below 60\% and as low as 20\%.\textsuperscript{10} In our study, the lowest chest compression fractions were never below 60\%, while the great majority of rescuers even then could deliver >60 chest compressions per minute.

\textbf{Are all lay-rescuers the same?}

None of the lay-rescuers in our study were part of EMS, but police and firefighters may have had a more strict retraining schedule than other lay-rescuers and may have been involved in more than one case of a true cardiac arrest. This matches with our earlier observations that AEDs from dispatched first responders were used on average twice a year, while onsite AEDs are used on average once in 30 years.\textsuperscript{9} While we indeed observed that onsite rescuers were more frequently represented in the longest ventilation groups, it did not reach statistical significance and the difference in ventilation pauses were 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.

\textbf{What is the scientific basis for the current recommendations in the Guidelines 2010?}

There is no direct scientific evidence that supports or refutes the recommended maximal
insufflation time of 5 seconds. There is evidence that supports the recommendation that the insufflation volume should not exceed 600 ml\textsuperscript{15,16} and that short insufflation times increase the risk of gastric dilatation\textsuperscript{17,18}. The recommended 5 seconds interruption time for two ventilations is the mathematical consequence of the intention to deliver at least 60 chest compressions per minute at a rate of 100/minute, given a C:V ratio of 30:2. Our study shows that a CCF of >60%, compatible with good survival, is achieved in all ventilation groups except the longest.\textsuperscript{10} The importance that a minimal number of compressions is delivered per minute is emphasized in a recent study, in which the group of patients that received 75-100 compressions per minute had significantly more ROSC than those with less compressions delivered.\textsuperscript{12} Patients in all ventilation groups except the group with pauses ≥13 seconds received 70 compressions or more in one minute in the great majority of cases. It appears therefore, that interruption 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 only observe the absence of compressions. In that situation we have no certainty 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, there was no information 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 may start chest compressions just before the voice prompt, 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 two rescue breaths in less than 9 seconds and give almost always at least 60 compressions per minute. The CCF was >60% with all durations of breaths except the longest. Survival was not directly adversely influenced by ventilation pauses longer than 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.
Acknowledgements: We thank Loes Bekkers, Paulien Homma and Remy Stieglis for data management.

Funding Sources: The ARREST study is maintained by an unconditional grant of Physio Control Inc, Redmond, WA, USA.

Conflict of Interest Disclosures: None.

References:


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, y*</td>
<td>66±15</td>
</tr>
<tr>
<td>Male gender, 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</td>
<td>134/65</td>
</tr>
<tr>
<td>Delay emergency call – AED attached (min)†</td>
<td>6:48 (4:28-9:04)</td>
</tr>
</tbody>
</table>

*Plus minus values are means±SD
†Time intervals are presented in median (25th-75th percentile).
Table 2. Ratio of compressions and ventilations delivered.

<table>
<thead>
<tr>
<th>Breath 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>Number of 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>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 (%)</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 (%)</td>
<td>26</td>
<td>19</td>
<td>34</td>
<td>14</td>
<td>14</td>
<td>0.39</td>
</tr>
<tr>
<td>C/V delivered/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; †Numbers indicate the amount of compressions (C) and single ventilations (V) delivered in each minute. ‡Time intervals are presented as median (25th - 75th percentile).

Table 3. The distribution of the baseline factors in the ventilation groups.

<table>
<thead>
<tr>
<th>Ventilation duration (s)</th>
<th>3</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>12</th>
<th>≥13</th>
<th>p-value *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of cases (%)</td>
<td>42 (21)</td>
<td>58 (29)</td>
<td>50 (25)</td>
<td>28 (14)</td>
<td>21 (11)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patient age, years†</td>
<td>66±19</td>
<td>66±15</td>
<td>65±14</td>
<td>65±15</td>
<td>65±15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.99</td>
</tr>
<tr>
<td>Patient gender male, n (%)</td>
<td>26 (62)</td>
<td>43 (74)</td>
<td>31 (62)</td>
<td>22 (79)</td>
<td>16 (76)</td>
<td></td>
<td></td>
<td></td>
<td></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></td>
<td></td>
<td></td>
<td></td>
<td>0.63</td>
</tr>
<tr>
<td>Dispatched first responder/onsite rescuers</td>
<td>38/4</td>
<td>42/16</td>
<td>37/13</td>
<td>16/12</td>
<td>11/10</td>
<td></td>
<td></td>
<td></td>
<td></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></td>
<td></td>
<td></td>
<td></td>
<td>0.030</td>
</tr>
<tr>
<td>Time interval emergency call – AED attached (min)‡</td>
<td>7:03</td>
<td>6:48</td>
<td>6:46</td>
<td>5:21</td>
<td>4:30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.029</td>
</tr>
</tbody>
</table>

*P-value for trend; †Plus minus values are means±SD; ‡Time intervals are presented in median in minutes (25th to 75th percentile). VF denotes ventricular fibrillation.
Table 4. Survival analyses.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Univariable analysis</th>
<th>Multivariable analysis</th>
<th>P-value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR (95% CI)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ventilation duration 3-5</td>
<td>Reference</td>
<td>Reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ventilation duration 6-7</td>
<td>2.14 (0.70-6.55)</td>
<td>1.62 (0.43-6.10)</td>
<td>0.183</td>
<td>0.48</td>
</tr>
<tr>
<td>Ventilation duration 8-9</td>
<td>2.60 (0.84-8.03)</td>
<td>1.02 (0.27-3.78)</td>
<td>0.097</td>
<td>0.98</td>
</tr>
<tr>
<td>Ventilation duration 10-12</td>
<td>2.96 (0.85-10.3)</td>
<td>1.30 (0.29-5.97)</td>
<td>0.087</td>
<td>0.73</td>
</tr>
<tr>
<td>Ventilation duration ≥13</td>
<td>5.55 (1.55-19.8)</td>
<td>2.38 (0.46-12.1)</td>
<td>0.008</td>
<td>0.30</td>
</tr>
<tr>
<td>Time interval emergency call – AED attached*</td>
<td>0.82 (0.74-0.90)</td>
<td>&lt;0.001</td>
<td>0.81 (0.71-0.92)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Dispatched first responder/ onsite rescuers</td>
<td>0.29 (0.14-0.58)</td>
<td>&lt;0.001</td>
<td>0.67 (0.27-1.64)</td>
<td>0.38</td>
</tr>
<tr>
<td>VF as initial rhythm</td>
<td>26.2 (7.77-88.22)</td>
<td>&lt;0.001</td>
<td>32.6 (8.86-120.1)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

OR, odds ratio for survival; CI, confidence interval.
*time per minute

Figure Legends:

**Figure 1.** Schematic timeframe of one cycle of an electronic recording from an AED showing the electrocardiogram (black line) and the impedance channel (green line) that reflects chest compressions. The two slower and more shallow deflections during the ventilation pauses reflect the impedance change caused by two insufflations. The AED voiceprompt ‘start CPR’ was marked as period 1 start (P1s). The first identifyable compression after the moment the compressions were started was marked as ‘C1’, even if this occurred before P1s. Likewise, the beginning of a period of ventilation was marked as ‘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.

**Figure 2.** Data flow and calculation of included cases.
Figure 1
Resuscitation effort with use of a LP1000, LP500, LPCRP+ or Zoll-AED
N=336

Less than one full cycle in an AED recording
N=93

1 or 2 analyzable periods
N=243

Technical shortcomings of the recording
N=31

Analyzable recordings
N=212

CV-ratio 15:2 or ‘compression-only CPR’
N=13

Included for analysis
N=199

Figure 2
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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