Circulation Cause Recurrence of Ventricular Fibrillation after the First Successful Conversion by Defibrillation in Out-of-Hospital Cardiac Arrest

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Running Title: Berdowski; Chest Compressions Cause Refibrillation

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Abstract

**Background**-Unlike Resuscitation Guidelines (GL) 2000, GL2005 advise resuming cardiopulmonary resuscitation (CPR) immediately after defibrillation. We hypothesized that immediate CPR resumption promotes earlier recurrence of ventricular fibrillation (VF).

**Methods and Results**-This study used data of a prospective per-patient randomized controlled trial. Automated External Defibrillators (AEDs) used by first responders were randomized to either a) perform post-shock analysis and prompt rescuers to a pulse check – GL2000, or b) resume CPR immediately after defibrillation – GL2005. Continuous recordings of ECG and impedance signals were collected from all patients with an out-of-hospital cardiac arrest to whom a randomized AED was applied. We included patients with VF as their initial rhythm in whom CPR onset could be determined from the ECG and impedance signals. Time intervals are presented as median (Q1-to-Q3).

Of 361 patients, 136 met the inclusion criteria: 68 were randomized to GL2000 and 68 to GL2005. Rescuers resumed CPR 30 (21-to-39) and 8 (7-to-9) seconds, respectively, after the first shock that successfully terminated VF ($P<0.001$); VF recurred after 40 (21-to-76) and 21 (10-to-80) seconds respectively ($P=0.001$). The time interval between start of CPR and VF recurrence was 6 (0-to-67) and 8 (3-to-61) seconds respectively ($P=0.88$). The hazard ratio for VF recurrence in the first 2 seconds of CPR was 15.5 (95% confidence interval, 5.63-57.7) compared to prior to CPR resumption. After more than 8 seconds of CPR, the hazard of VF recurrence was similar to prior to CPR resumption.

**Conclusions**-Early CPR resumption after defibrillation causes early VF recurrence.

**Clinical Trial Registration Information**-URL: http://www.controlled-trials.com; trial number ISRCTN72257677.

**Keywords:** cardiopulmonary resuscitation, defibrillation, electrocardiography, fibrillation, resuscitation.
Background

Ventricular fibrillation (VF) is common in patients with out-of-hospital cardiac arrest (OHCA), varying from 18% to 63% of all cases.\(^1\)\(^,\)\(^2\) About half of these patients have VF recurrence within the first two minutes after successful VF conversion,\(^3\) 74% of the patients have VF recurrence sometime during pre-hospital care.\(^4\) The number of VF recurrences during the resuscitation period is negatively associated with survival.\(^5\)

A recent animal study found a clear relation between initiation of chest compressions and the recurrence of VF.\(^6\) The current Guidelines for cardiopulmonary resuscitation issued in 2005 advise immediately resuming cardiopulmonary resuscitation (CPR) for two consecutive minutes after a defibrillation shock in order to minimize CPR interruption.\(^7\)\(^,\)\(^8\) Guidelines for cardiopulmonary resuscitation issued in 2000 advised performing post-shock rhythm analysis and checking for signs of life, thus delaying resumption of CPR for about half a minute.\(^9\)\(^,\)\(^10\)

The purpose of our study was to investigate the relation between CPR resumption after the first successful VF conversion and the recurrence of VF. We hypothesize that 1) chest compressions stimulate recurrence of VF and 2) patients who are resuscitated according to the Resuscitation Guidelines 2005 and receive immediate CPR after a shock refibrillate earlier in comparison to patients who are resuscitated according to the Resuscitation Guidelines 2000 and receive delayed CPR.

Methods

Setting

The Amsterdam Resuscitation Studies (ARREST) research group prospectively collects data of all resuscitation efforts in the Dutch province North Holland, covering approximately 2671
km² and a population of 2.4 million people. The area includes both urban and rural communities. In case of a medical emergency, people dial the national emergency number, where the operator transfers the call to the regional ambulance dispatch center. When suspecting a cardiac arrest, the ambulance dispatcher sends out two ambulances of a single tier. Also, the dispatcher sends out a first responder - firefighters, policemen or a general practitioner, equipped with an AED (LIFEPAK 500/ LIFEPAK 1000, Physio Control, Redmond, WA). All ambulance personnel are equipped with a manual defibrillator (LIFEPAK 12, Physio Control, Redmond, WA) and qualified to perform Advanced Life Support (ALS) according to the guidelines of the European Resuscitation Council.11

The ARREST 8 trial (http://www.controlled-trials.com; trial number ISRCTN72257677) investigates whether maximizing CPR during AED usage improves outcome. All first responder AEDs are individually randomized to two modes of resuscitation therapy (Table 1). In the first mode, the AED is programmed according to Guidelines 2000, where the AED analyzes outcome after a shock, prompts to check for a pulse and to give CPR for one minute until the next rhythm analysis. In the second mode, the AED is programmed according to Guidelines 2005, where the AED prompts to immediately start CPR and continue for two minutes after a single shock. In addition, these AEDs prompt for 15 seconds of pre-shock CPR. AEDs are reprogrammed after each application of the device according to a pre-specified randomization list. Therefore, AED users are blinded to the AED protocol until the AED is powered on, but are not blinded during AED usage.

The primary outcome of ARREST 8 is survival until admission to a hospital. The Medical Ethics Committee of the Academic Medical Center in Amsterdam approved this study and gave a waiver for the requirement of informed consent prior to randomization; all surviving patients gave written consent for usage of the data. The ARREST 8 trial started June 7, 2006
and recruitment is currently ongoing. The planned enrollment is 198 patients with VF as initial rhythm in each arm of the study.

Data Collection

All data concerning the resuscitation were prospectively collected according to the Utstein recommendations. Study personnel visited the site of the AED shortly after the cardiac arrest and downloaded the electronic data recorded by the AED. Paramedics sent the electronic data recorded by their defibrillator to the data center by modem immediately after the resuscitation effort. These data were merged, stored and analyzed with dedicated software (Code Stat Reviewer 7.0, Physio Control, Redmond, WA, USA).

Design of Current Analysis

The current analysis focused on the mechanism and timing of VF recurrence in relation to CPR and uses data from the ARREST 8 trial available at September 1, 2008. Patients were included in this analysis if their initial rhythm was VF. We excluded patients to whom an incorrectly programmed AED had been attached, patients to whom an onsite AED had been attached prior to the AED of the first responder, patients with missing or incomplete ECG recordings and patients who were already dead on arrival. A patient was defined dead on arrival if the patient showed obvious clinical signs of death (i.e. rigor mortis, marbling or livor mortis). The moment of the first successful VF conversion was defined as termination of VF for 5 seconds after the shock irrespective of the subsequent rhythm and was read from the AED ECG. The start of CPR after the shock was visible through the impedance signal of the recording. If the start of CPR after the shock could not be determined from the impedance signal recorded by the AED, the patient was also excluded from the analysis.
The electrical outcome of the study was recurrence of VF after the first successful VF conversion. Two researchers individually annotated the moment of VF recurrence after the first successful VF conversion. The annotations by the two researchers were considered to be in agreement if the difference was less than 1 second, which was the case in 94 cases (96%). The cases where disagreement was more than one second, the two researchers annotated the time of VF recurrence by consensus. This annotation was made based on the ECG of the AED or the ECG of the manual defibrillator. We eliminated CPR artifacts from the ECG using filtering software (Physio Control, Redmond WA), which allowed determination of VF recurrence onset during CPR (Figure 1). We merged the AED recordings with those of the manual defibrillator, synchronizing the clock times of both defibrillators. As shown in Figure 2, we measured four time intervals: from the first VF conversion to the start of CPR; from the first VF conversion to VF recurrence; from the start of CPR to VF recurrence; and from VF recurrence to the second effective conversion — this represents the time the patient was in VF after VF recurrence. The percentage of time CPR had been given during AED connection was calculated by dividing the time that CPR was given by the total time the patient was connected to the AED.

The rhythm after VF conversion but prior to the start of CPR, and the rhythm prior to VF recurrence were analyzed during the 5 seconds preceding CPR initiation and VF recurrence, respectively. Rhythms were categorized as asystole or as an organized rhythm, which was defined as at least two QRS complexes within 5 seconds.

**Statistical Analysis**

All time intervals were expressed as median (Q1-to-Q3). Continuous variables of patients treated with a delayed-CPR prompt and the immediate-CPR prompt were compared with the Wilcoxon rank sum test. Binary variables were compared between treatment groups by chi-
squared tests. The cumulative incidence in VF recurrence in both treatment groups was assessed with the Kaplan-Meier method. We used the Gehan-Breslow test to compare treatment groups regarding time to onset of VF recurrence after successful VF conversion. We used the Kolmogorov-Smirnov test to compare treatment groups regarding time to onset of VF recurrence in regards to CPR resumption. The instantaneous hazard of VF recurrence in the first minute after the first VF conversion was calculated by dividing the total amount of VF recurrences by the person-minutes at risk. To examine whether the moment of VF recurrence was associated with the start of chest compressions over time, we separately calculated the hazard for VF recurrence for the first two seconds of CPR resumption, 3 to 5 seconds, 6 to 8 seconds, 9 to 30 seconds, 60 to 120 seconds and more than 120 seconds after CPR resumption. Corresponding confidence intervals were calculated with the Poisson distribution regression.

Analyses were based on the intention-to-treat principle; the patient was analyzed according to the programming of the AED regardless of whether the rescuer followed the resuscitation Guideline prompted by the AED. P-values were two-sided and were based on the standard null hypothesis of no treatment difference. All analyses were performed with the use of SPSS software for Macintosh, version 16.0. All authors reviewed the manuscript and vouch for the accuracy and completeness of the data.

Results

Inclusion and administration of CPR

During 27 months, 410 patients were connected to a randomized AED: the AEDs were programmed to resuscitation Guidelines 2000, prompting delayed CPR after a shock, for 216
patients, and to resuscitation Guidelines 2005, prompting immediate CPR after a shock, for 194 patients. Figure 3 shows the enrollment of patients for the current analysis. None of the patients had been attached to an AED of bystanders prior to the attachment of a first responder AED that was randomized for the purpose of our study. A total of 136 patients met the criteria for inclusion. There was a significant difference between the two study groups in the percentage of time CPR had been given and the rhythm prior to CPR (Table 2). Rescuers resumed CPR after the first successful VF conversion a median time of 30 (Q1, 21; Q3, 39) seconds in patients with a delayed-CPR prompt and of 8 (Q1, 7; Q3, 9) seconds in cases with an immediate-CPR prompt (P<0.001). None of the included patients had ROSC immediately after the first successful VF conversion. In all patients, CPR was resumed within one minute after the first successful VF conversion.

**Recurrence of Ventricular Fibrillation**

VF recurred in 49/68 patients (72%) with a delayed-CPR prompt and in 49/68 patients (72%) with an immediate-CPR prompt. The cumulative incidence of VF recurrence during the first 60 seconds after the first successful VF conversion was substantially lower among patients with delayed-CPR prompt (GL2000) than among patients with an immediate-CPR prompt (GL2005) (Figure 4). The Gehan-Breslow test was statistically significant (P=0.001). There was no appreciable difference in cumulative incidence after 60 seconds.

VF recurred 6 (Q1, 0; Q3, 67) seconds after CPR initiation in patients with a delayed-CPR prompt (GL2000) and 8 (Q1, 3; Q3, 61) seconds after CPR initiation in patients with an immediate-CPR prompt (GL2005; Kolmogorov-Smirnov P=0.046; Figure 5). VF was terminated by the second successful VF conversion after a median 98 (Q1, 62; Q3, 201)
seconds among patients with a delayed-CPR prompt (GL2000) and after a median 141 (Q1, 82; Q3, 245) seconds among patients with an immediate-CPR prompt (GL2005; \( P=0.07 \)).

The instantaneous hazard of VF recurrence per person-minute was low (0.30) between the first effective shock and the start of CPR, (Figure 6) and jumped to 4.68 in the first two seconds of CPR (hazard ratio (HR), 15.5; 95% confidence interval (CI), 5.63 to 57.7). The hazard decreased over time, but remained elevated with hazard ratios of 8.1 (95% CI, 1.2 to 49.8) and 6.9 (95% CI, 1.03 to 43.5) in the next 3-second intervals, respectively. After 8 seconds, the hazard for VF recurrence was once again low (0.41).

Thirteen of the 136 included patients showed VF recurrence before CPR resumption. Of the remaining 123 patients, 48 had an organized rhythm before CPR resumption and 75 had asystole before CPR resumption (Table 2). In total, 98 patients had VF recurrence; in 85 of these, VF recurred after resumption of CPR. Of the 48 patients in an organized rhythm at the moment of CPR resumption, 33 (69%) had VF recurrence during CPR; of the 75 patients in asystole when CPR resumed, 52 (69%) had VF recurrence (\( P=0.95 \)). The increase in the hazard of refibrillation in the first few seconds of CPR did not differ significantly between patients with an asystole prior to CPR resumption and patients with an organized rhythm prior to CPR resumption (HR, 18.0; 95% CI, 5.6 to 57.7 and HR, 11.5; 95% CI, 6.4 to 36.6, respectively). There was no significant difference in the rhythm prior to VF recurrence between the delayed CPR and immediate CPR groups; 32 of the 49 patients (65%) with a delayed-CPR prompt and 37 of the 49 patients (76%) with an immediate-CPR prompt had an organized rhythm before the recurrence of VF (\( \chi^2, 0.78; P=0.38 \)). The remaining patients immediately refibrillated after a single ventricular premature complex. In total, 69 (70%) of the 98 patients who refibrillated did so after an organized rhythm.
Discussion

The main finding of our study is that VF commonly recurs within the first few seconds after CPR is initiated after successful VF conversion. The hazard of VF recurrence was 15.5 times higher in the first two seconds of CPR relative to the time before CPR initiation. Moreover, the timing of VF recurrence relative to the start of CPR did not depend on the timing of the CPR prompt (delayed or immediate); if rescuers started CPR earlier, the patient had earlier VF recurrence as well. Our study is the first to demonstrate the temporal relation between the onset of chest compressions and the onset of VF recurrence in OHCA patients. These findings indicate a causal relationship between the onset of manual chest compressions and the recurrence of VF after the first successful VF conversion.

An earlier retrospective observational study showed that VF recurred in 16 of 32 patients (50%) while chest compressions were administered. The authors concluded that the recurrence of VF during a post-shock organized rhythm is most commonly spontaneous and unrelated to chest compressions. However, the authors did not give a precise definition of when chest compressions were associated with VF recurrence. In contrast to their findings, we found that VF is related to chest compressions. By detailed analysis of timing, we documented a burst of CPR-associated VF recurrence in the first two seconds after CPR resumes.

Similar to our findings, a recent animal study showed that VF recurred within the first two chest compressions in 4 of 8 swine. The authors showed that the electrical stimulation of the ventricles by chest compressions created a long-short activation sequence leading to VF recurrence. The long-short activation sequence is a well-recognized mechanism by which
VF may be initiated. Similarly, low-energy impact to the chest wall (commotio cordis) has been shown to stimulate the ventricle during the vulnerable period and cause arrhythmias as well.

Mechanical stimuli can exert delayed afterdepolarization-like effects mediated by stretch. Mechanoelectric feedback (MEF), the phenomenon by which electrophysiological changes of the heart are brought about by mechanical changes, is a potential mechanism explaining why stretch could contribute to recurrence of VF. Stretch during diastole usually leads to depolarization, resembling delayed afterdepolarization, which may reach threshold and initiate a ventricular premature beat. A completely different mechanism that could play a role in recurrence of VF is coronary reperfusion from chest compressions. Reperfusion arrhythmias are a well-known phenomenon after restoration of coronary blood flow during reperfusion therapy in acute MI. These arrhythmias have been described as premature beats or (slow) ventricular tachycardia, but rarely as VF. Furthermore, it has been shown in animal experiments that it takes at least 2-3 chest compressions for the coronary perfusion to rise substantially. Thus, reperfusion probably does not explain the sudden strong increase in hazard of VF recurrence in the first two seconds of CPR. Hence, we believe that a mechanoelectric mechanism is the most likely explanation of the sudden increase in instantaneous hazard of VF recurrence.

**Consequences for the patient**

This study demonstrates that the immediate resumption of CPR in accordance with resuscitation Guidelines 2005, while significantly decreasing post-shock pause and increasing the percentage of time CPR had been administered, also causes earlier VF recurrence and a trend toward longer lasting VF. It is not yet clear how this finding impacts patient outcome;
the benefit of increased CPR time and a reduced post-shock pause is well documented, but the effect of longer lasting VF is not clearly established. Pre-shock chest compressions for prolonged VF can “coarsen” the VF waveform and improve the rate of successful resuscitation.\textsuperscript{25} Experimental studies have shown that outcome is improved by limiting the pre-shock pause\textsuperscript{26,27} and removing the post-shock pause associated with pulse or rhythm checks.\textsuperscript{28} Some authors have argued that even interruptions for rescue breaths are detrimental for survival rates.\textsuperscript{29,30}

From a metabolic point of view, prolonged VF is more energy consuming than asystole. During VF, each myofibril is activated and contracts at a rate of up to 3-5 depolarizations per second, depleting ATP and glycogen at a high rate, and increasing glucose-6-phosphate and lactate in the myocardium.\textsuperscript{31} This drop in energy availability causes the heart to fatigue, resulting in little contractile force when an organized rhythm returns. Administration of epinephrine during VF, which is advised every 3 minutes by resuscitation ALS Guidelines, increases myocardial adenosine 3’,5’-cyclic monophosphate (CAMP) concentrations and induces an even higher oxygen consumption.\textsuperscript{32} Along these lines, a recent study showed that the duration of VF during resuscitation efforts is inversely correlated to the probability of Return of Spontaneous Circulation (ROSC).\textsuperscript{33} We hypothesize that the high oxygen consumption of earlier VF recurrence partially defeats the increase in CPR fraction. This could explain why the application of resuscitation Guidelines 2005 has improved survival in only one of two observational studies\textsuperscript{34,35} and not in a randomized clinical trial.\textsuperscript{36}

More research is needed to investigate the effect of early VF recurrence during CPR on survival outcome. For example, new methods are being developed to identify a shockable rhythm without interrupting chest compressions.\textsuperscript{37-39} With these techniques, the metabolic
downside of VF can be avoided if the patient is defibrillated shortly after VF recurrence instead of completing the currently recommended 2-minute CPR cycle.

Limitations

Most of the VF recurrences occurred during CPR. The movement artifacts in the ECG caused by CPR make it more difficult to precisely annotate the moment of VF recurrence. However, in 96% of cases the difference between the observations of the two researchers was less than 1 second. Therefore, the filtering software cleared most uncertainty about the exact moment of VF recurrence.

Second, we could not identify the exact underlying mechanism causing VF recurrence. Although motion artifacts were sufficiently filtered to determine the onset of VF, the filtering technique did not allow analysis of a long-short sequence during CPR in all analyzed ECGs.

Third, we only evaluated the moment of the first recurrence of VF. It needs to be further investigated whether our findings are applicable to subsequent VF recurrences as well.

Conclusions

In out-of-hospital cardiac arrest, when CPR is re-initiated after defibrillation, the heart often refibrillates within the first few chest compressions, suggesting that chest compressions are conducive to VF recurrence in this setting. Early resumption of CPR after a defibrillation shock, as advised by the resuscitation Guidelines 2005, is associated with earlier recurrence of VF and possibly longer lasting VF. Further research is needed to determine whether the possible metabolic negative effect of VF recurrence defeats the perfusion benefit from early CPR resumption.
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Conflict of Interest Disclosures: None

References


### Tables

Table 1. The AED Settings for Randomization.

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<tr>
<th></th>
<th>Resuscitation Guidelines 2000</th>
<th>Resuscitation Guidelines 2005</th>
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<tr>
<td>Pre-shock CPR time, s</td>
<td>OFF</td>
<td>15</td>
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<tr>
<td>Post shock rhythm analysis</td>
<td>ON</td>
<td>OFF</td>
</tr>
<tr>
<td>Pulse check, s</td>
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<td>OFF</td>
</tr>
<tr>
<td>Time interval shock – CPR prompt, s</td>
<td>32</td>
<td>7</td>
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<tr>
<td>CPR time, shockable rhythm, s</td>
<td>60</td>
<td>120</td>
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<tr>
<td>Shock sequence</td>
<td>maximum 3 stacked shocks</td>
<td>1 single shock</td>
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<tr>
<td>Energy sequence, Joules</td>
<td>200-200-360</td>
<td>200, then 360</td>
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Table 2: Baseline and Operational Characteristics of the Study Subjects According to Treatment Group.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Delayed-CPR prompt (N=68)</th>
<th>Immediate-CPR prompt (N=68)</th>
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<td><strong>Demographic characteristics</strong></td>
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<tr>
<td>Age, y*</td>
<td>64 (54 to 73)</td>
<td>67 (52 to 76)</td>
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<tr>
<td>Male sex, n (%)</td>
<td>48 (71)</td>
<td>50 (74)</td>
<td>0.70</td>
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<tr>
<td>Caucasian race, n (%)†</td>
<td>59 (87)</td>
<td>58 (85)</td>
<td>0.81</td>
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<td><strong>Resuscitation characteristics</strong></td>
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<td></td>
</tr>
<tr>
<td>Witnessed collapse, n (%)</td>
<td>58 (85)</td>
<td>59 (87)</td>
<td>0.81</td>
</tr>
<tr>
<td>Bystander CPR before AED attachment by first responder, n (%)</td>
<td>39 (57)</td>
<td>45 (66)</td>
<td>0.56</td>
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<tr>
<td>Collapse at home, n (%)</td>
<td>52 (76)</td>
<td>48 (71)</td>
<td>0.34</td>
</tr>
<tr>
<td>AED connection time, min*</td>
<td>3.3 (2.2 to 4.6)</td>
<td>2.7 (1.9 to 4.6)</td>
<td>0.21</td>
</tr>
<tr>
<td>Percentage of time CPR was given</td>
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<td></td>
<td></td>
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<tr>
<td>during AED connection*</td>
<td>44 (34 to 55)</td>
<td>64 (53 to 71)</td>
<td>&lt;0.001</td>
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<tr>
<td>Rhythm before CPR resumption, n (%)</td>
<td></td>
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<td>0.03</td>
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<tr>
<td>Asystole</td>
<td>33 (49)</td>
<td>42 (62)</td>
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<tr>
<td>Organized rhythm</td>
<td>24 (35)</td>
<td>24 (35)</td>
<td></td>
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<tr>
<td>VF</td>
<td>11 (16)</td>
<td>2 (3)</td>
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* Expressed as median (Q1-to-Q3)

† Race was determined by the rescuers onsite.
Figure legends

Figure 1: Continuous ECG Recording before and after Filtering.

Figure 1A shows the continuous ECG recording before filtering. Figure 1B shows the continuous ECG recording after filtering. One second after CPR resumption, a narrow QRS complex is visible. One second later, a ventricular premature complex initiates recurrence of ventricular fibrillation.

Figure 2: Annotations and measured Time Intervals.

The upper Figure shows the annotations of an AED programmed according to the delayed-CPR prompt (Guidelines 2000) with continuous ECG recording. The lower Figure shows the annotations of an AED programmed according to the immediate-CPR prompt (Guidelines 2005) with continuous ECG recording. Only the moment of ‘start CPR’ and ‘VF recurrence’ was annotated manually, all other annotations were registered automatically by the AED. We measured the following time intervals: first effective VF conversion to start of CPR; first effective VF conversion to VF recurrence; start of CPR to VF recurrence; VF recurrence to second effective VF conversion.

Figure 3: Study Subjects Enrollment.

Patients in whom resuscitation was attempted and who had ventricular fibrillation as initial rhythm were included in the study.

Figure 4: The Kaplan-Meier Curve of Refibrillation Incidence for the Time Interval Between the First Effective Defibrillation Shock and the Moment of VF Recurrence.

The VF recurrence rate is clearly larger in the first 25 seconds after shock in the immediate CPR prompt group.

Figure 5: The Cumulative Time Interval between Resumption of CPR and Frequency of Refibrillation for All Patients with VF Recurrence.
Chest compressions are resumed at the time interval of 0 seconds on the x-axis. All
refibrillations before this time point are spontaneous and carry a negative time value. After
120 seconds, the curve slowly and gradually increases. The last patient had VF recurrence at
17 minutes after the start of CPR, at which time the cumulative frequency reaches 1.

Figure 6: The Instantaneous Hazard of VF Recurrence per Person-Minute Prior to CPR and
During CPR, Divided in Six Groups of CPR Duration.
A: Analysis  rVF: VF recurrence
P: Pulse check  sCPR: Start CPR
\: Effective shock

**Delayed-CPR**

Time intervals

ECG Annotations

A 1st A P sCPR rVF 1st rVF rVF 2nd

1 minute of CPR

**Immediate-CPR**

Time intervals

ECG Annotations

A sCPR 1st sCPR rVF A sCPR 2nd

2 minutes of CPR
410 Patients were attached to a randomized AED

216 Were assigned to the delayed-CPR prompt
- 13 Were already dead;
- 6 Were not in cardiac arrest;
- 4 Had missing or incomplete ECGs;
- 4 AEDs had a programming error

189 Were resuscitated and had available ECGs
- 113 Patients did not have VF as initial rhythm
  - 76 Had VF as initial rhythm, all were successfully defibrillated
    - 8 ECGs did not show start of CPR
      - 68 ECGs showed start of CPR

194 Were assigned to the immediate-CPR prompt
- 16 Were already dead;
- 6 Were not in cardiac arrest;
- 0 Had missing or incomplete ECGs;
- 0 AEDs had a programming error

172 Were resuscitated and had available ECGs
- 88 Patients did not have VF as initial rhythm
  - 84 Had VF as initial rhythm, all were successfully defibrillated
    - 16 ECGs did not show start of CPR
      - 68 ECGs showed start of CPR
Cumulative VF recurrence

- Delayed-CPR prompt
- Immediate-CPR prompt

Generalized Wilcoxon

\[ P < 0.001 \]

Interval shock - VF recurrence (sec)

<table>
<thead>
<tr>
<th>Group</th>
<th>No at risk</th>
<th>Delayed-CPR</th>
<th>Immediate-CPR</th>
<th>P</th>
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<tr>
<td>No at risk</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delayed-CPR</td>
<td>68</td>
<td>60</td>
<td>45</td>
<td>36</td>
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<tr>
<td>Immediate-CPR</td>
<td>68</td>
<td>44</td>
<td>37</td>
<td>36</td>
</tr>
</tbody>
</table>
Cumulative frequency of VF recurrence

- Delayed-CPR prompt
- Immediate-CPR prompt

Kolmogorov-Smirnov

$P=0.046$

Interval start CPR - VF recurrence (sec)
Instantaneous hazard of VF recurrence

Duration of CPR (sec)

Prior to CPR

No of events

No of patients
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