Effects of Interrupting Precordial Compressions on the Calculated Probability of Defibrillation Success During Out-of-Hospital Cardiac Arrest

Trygve Eftestøl, PhD; Kjetil Sunde, MD, PhD; Petter Andreas Steen, MD, PhD

Background—Cardiopulmonary resuscitation (CPR) creates artifacts on the ECG and, with automated defibrillators, a pause in CPR is mandatory during rhythm analysis. The rate of return of spontaneous circulation (ROSC) is reduced with increased duration of this hands-off interval in rats. We analyzed whether similar hands-off intervals in humans with ventricular fibrillation causes changes in the ECG predicting a lower probability of ROSC.

Methods and Results—The probability of ROSC after a shock was continually determined from ECG signal characteristics for up to 20 seconds of 634 such hands-off intervals in patients with ventricular fibrillation. In hands-off intervals with an initially high (40% to 100%) or median (25% to 40%) probability for ROSC, the probability was gradually reduced with time to a median of 8% to 11% after 20 seconds ($P<0.001$). In episodes with a low initial probability (0% to 25%; median, 5%), there was no further reduction with time.

Conclusions—The interval between discontinuation of chest compressions and delivery of a shock should be kept as short as possible. (Circulation. 2002;105:2270-2273.)

Key Words: cardiopulmonary resuscitation • defibrillation • electrocardiography • heart arrest • Fourier analysis
Hands-Off Intervals

Each interval was split into 4-second blocks with a 3.75-second overlap. From each block, PROSC was computed on a 500-MHz computer. For a 10-second hands-off-interval, the computer used 1 second to read the consecutive ECG blocks and to compute the signal characteristics and PROSC values. This should be within the requirements for a real-time monitoring device connected to a defibrillator.

Intervals were excluded if the ECG was noisy (muscle artifacts, electrode noise, change of defibrillator components), if the start of the hands-off interval preceded the start of the recording, or if PROSC was not defined at zero time due to the restricted function domain. Thus 141, 66, and 27 intervals, respectively, were removed, leaving 634 intervals for analysis (73% of the total material). Before analysis, we hypothesized that intervals starting with very low PROSC could not deteriorate much further. To avoid the possibility of these intervals overshadowing intervals with higher initial PROSC, which we hypothesized would have a larger potential for indicating the factor of ROSC, P_{ROSC}(v), was then developed using a Bayesian decision support model.8,9

Statistical Analysis

Data are presented as median values (25th and 75th percentiles). For each P_{ROSC}(v) time series subdivision, the P_{ROSC}(v) measurements at t=0 were compared with the measurements at t=5, 10, 15, and 20 seconds using the Kruskal-Wallis nonparametric one-way ANOVA and Scheffe’s multiple comparison test. Statistical significance was set at P<0.05.

Results

The hands-off intervals with a high initial P_{ROSC}(v) deteriorated rapidly within the first few seconds to the medium level, followed by a slower rate of deterioration into the low level (Table and Figure 2). The medium initial level P_{ROSC}(v) subgroup showed a slower deterioration toward the low level and, after 5 seconds, the 2 groups deteriorated in parallel (Table and Figure 2). There was no significant change in P_{ROSC}(v) with time in the low level subgroup (Table and Figure 2).

Discussion

The present prospective ECG study indicates that the chance for successful defibrillation with ROSC decreases during periods without chest compressions in patients starting with a high-to-median chance of success. The probability of success decision support model was determined from VF signal characteristics previously found to discriminate well between ROSC and No-ROSC episodes.8,9 The results are consistent with an outcome study in rats,2 in which the ROSC rate and 24- and 48-hour survival were gradually reduced with an increased interval from 10 to 40 seconds between discontinuation of chest compressions and shock delivery.

### Median (25th–75th Percentile) Probability for Successful Defibrillation With Return of Spontaneous Circulation, P_{ROSC}(v), at the Start (t=0) and After 5, 10, 15, and 20 Seconds of Hands-Off Intervals, Grouped According to Initial P_{ROSC}(v) of 0.00–0.25, 0.25–0.40, and 0.40–1.00

<table>
<thead>
<tr>
<th>Time, s</th>
<th>Group</th>
<th>n</th>
<th>P_{ROSC}(v)</th>
<th>n</th>
<th>P_{ROSC}(v)</th>
<th>n</th>
<th>P_{ROSC}(v)</th>
<th>n</th>
<th>P_{ROSC}(v)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.00–0.25</td>
<td>543</td>
<td>0.05 (0.02–0.10)</td>
<td>543</td>
<td>0.04 (0.02–0.10)</td>
<td>509</td>
<td>0.05 (0.02–0.09)</td>
<td>303</td>
<td>0.05 (0.02–0.10)</td>
<td>139</td>
</tr>
<tr>
<td>0.25–0.40</td>
<td>60</td>
<td>0.32 (0.29–0.35)</td>
<td>59</td>
<td>0.24 (0.14–0.31)†</td>
<td>56</td>
<td>0.21 (0.13–0.29)†</td>
<td>40</td>
<td>0.17 (0.11–0.28)‡</td>
<td>15</td>
</tr>
<tr>
<td>0.40–1.00</td>
<td>31</td>
<td>0.50 (0.45–0.72)</td>
<td>31</td>
<td>0.25 (0.14–0.35)§</td>
<td>30</td>
<td>0.25 (0.13–0.35)§</td>
<td>26</td>
<td>0.15 (0.12–0.24)‡</td>
<td>16</td>
</tr>
</tbody>
</table>

*P<0.0000001; †P<0.000001; ‡P<0.00001; §P<0.001 vs time 0 s within group.
Only 8 of the 31 (26%) hands-off intervals in the group with an initial high level of \( P_{\text{ROS}}(v) \) (median, 50%) were defibrillated with ROSC at the end of the intervals. Assuming an accurate estimate of the initially high level for these intervals, one might speculate a doubled success rate in this group if defibrillated immediately. For the median level group, 14 of 61 patients (22%) had successful outcomes versus an initial median \( P_{\text{ROS}}(v) \) prediction of 32% success. In this group, one might speculate that five or six unsuccessful defibrillation attempts could have been successful if defibrillated immediately.

It is not surprising that the probability of ROSC did not deteriorate further in the hands-off episodes that already had a low (median, 5%) chance of success at the onset. In this group, 520 of 536 shocks were unsuccessful. We would not expect the success rate to be worse if defibrillations had occurred at the beginning of the intervals for this group.

As pointed out earlier, hands-off intervals are required to allow for ECG analysis and capacitor charging when using automated external defibrillators. During rhythm analysis, this is required to avoid contaminating the ECG by CPR artifacts. Recent studies have demonstrated the possibility of removing these CPR artifacts from human VF, indicating the possibility of performing ECG analysis during CPR. This could reduce the hands-off intervals, increasing the expected rate of successful defibrillations.

There are limitations in this study. First, we only reported changes in the ECG indicating changes in the probability of ROSC, not actual rates of ROSC, because that is impossible. As soon as ROSC is attempted by defibrillation, the hands-off interval is, by definition, terminated. Second, the data used to derive \( P_{\text{ROS}}(v) \) are limited to the last 4 seconds of ECG during the hands-off intervals, whereas in the present study, we looked at changes in \( P_{\text{ROS}}(v) \) with time during the entire hands-off interval. We re-ran the experiments after removing the data involved in deriving \( P_{\text{ROS}}(v) \). This gave fewer measurements at 5, 10, 15, and 20 seconds and thus resulted in weaker, but still significant, probability values with the same conclusions. Thus, the conclusion of our probability analysis is still valid when excluding the material from which \( P_{\text{ROS}}(v) \) was derived. Fourth, 27% of the intervals were excluded from the study before the analysis. One might speculate whether this might have biased our results. All intervals were excluded from pre-analysis set criteria. We studied how each of these intervals distributed into the low, medium, and high level groups and found that there was little possibility of this exclusion biasing our results. Finally, the thresholds for \( P_{\text{ROS}}(v) \) between the groups were set in an ad hoc manner, although this was done before performing the analysis. As previously explained, this division was done because we assumed that most hands-off intervals would start with a very low probability of ROSC that could not deteriorate much further. If all data were studied as one group, these intervals could overshadow those with a high initial probability of success, casing a type II statistical error.

We conclude that during resuscitation from VF, the intervals between discontinuation of chest compressions and delivery of a shock should be kept as short as possible.

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References

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