Out-of-hospital circulatory arrest: factors determining the outcome Amsterdam resuscitation study (ARREST) 2 and 3
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Chapter 5
Prevention of deterioration of ventricular fibrillation by basic life support during out-of-hospital cardiac arrest

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Abstract
Survival of cardiac arrest is improved by basic life support (BLS). This study investigated the relationship between ventricular fibrillation (VF) characteristics and survival. In a 2-year prospective study out-of-hospital witnessed nontraumatic cardiac arrests were observed. The probabilities of recording VF, asystole or other rhythms in relation to BLS and the time to the rhythm recording were analyzed with logistic regression. Amplitude and baseline crossings of VF were related to survival, using linear regression analysis. In 873 patients, the probability to record VF decreased per minute (OR 0.92, 95%CI 0.89-0.95) and of asystole increased (OR 1.13, 95%CI 1.09-1.18) as time from collapse elapsed. BLS reduced these trends significantly for VF (OR 0.97, 95%CI 0.94-0.99) and asystole (OR 1.09, 95%CI 1.05-1.13). This effect was not observed for other rhythms. The amplitude of VF decreased in time; significantly less for patients who received BLS than for those who did not (p = 0.009). Survival significantly decreased with lower amplitude of VF (OR 0.23 per mV, 95%CI 0.07-0.79) and with less baseline crossings (OR 0.80 per baseline crossings per second, 95%CI 0.71-0.91). Our study demonstrated that BLS and VF as initial rhythm, considered being "baseline" predictors in survival models, were proved not independent of each other. The decrease of VF amplitude and increase in prevalence of asystole is slowed significantly by BLS. Predicting survival from VF amplitude and baseline crossings alone is limited.

1. Introduction

The most important predictor of survival after out-of-hospital resuscitation is the presence of ventricular fibrillation (VF) as initially recorded rhythm. However, when time elapses VF will gradually deteriorate into asystole1 and consequently decrease the chance of survival.2 In this period there is much to gain by performing basic life support (BLS).3,4 Animal studies5-7 suggest that the mechanism of BLS is the maintenance of myocardial blood flow and thus the preservation of myocardium viability. A human study8 found a relation between myocardial bloodflow and return of spontaneous circulation, but did not study the characteristics of VF.

This study investigated more closely the deterioration in time from VF into asystole and the effect of BLS on that transition and on the characteristics of the VF waveform.

2. Patients and Methods

2.1 Study design

The data for this work were obtained from a community-based study of which the main results were published earlier.9 Between June 1, 1995 and August 1, 1997 all consecutive out-of-hospital cardiac arrests were recorded. Ethical committees approved the study.

Specially trained research personnel collected data at the scene of the cardiac arrests. All information from the family, bystanders and emergency medical service (EMS) personnel was collected, with particular attention to estimating the moment of collapse accurately, the moment of start of BLS and of the first recorded rhythm. The defibrillator ‘power on’ time was taken as the moment of arrival of the EMS personnel at the patient’s side. The initial rhythm was the first observed rhythm after collapse and was divided in three types: VF, asystole and other rhythms. The time stamp on the defibrillator rhythm strip was corrected for the clock drift and all time measurements were adjusted to one standard time.
2.2 Study population

In this study of 1285 patients resuscitation was attempted by EMS personnel, of which 1046 patients had a cardiac etiology for the arrest according to the Utstein definition. Included in the study were the 873 patients over 17 years of age with a witnessed nontraumatic cardiac arrest. In these patients a logistic regression analysis was performed to analyze the transition of VF to asystole and the effect of BLS on this transition.

2.3 Analysis of VF amplitude and baseline crossings

A subset of 191 patients of the study population was analyzed where VF was the first recorded rhythm and where qualitative good rhythm registrations were available. From the rhythm recordings, segments with minimal artefacts and adequate information on ECG amplification were selected. We analyzed the first segment from the start of the rhythm registration over a period of 6 seconds. VF was defined as a disorganized rhythm with a peak-to-trough amplitude of ≥100 μV. Segments of VF were measured using the average peak amplitude method according to Cummins. The number of baseline crossings was measured in the same 6 seconds segment. The total number of times the imaginary baseline was crossed was counted and expressed as number of baseline crossings per second. Success of resuscitation was defined at three levels: return of organized rhythm, ROSC, and survival to discharge. An organized rhythm was defined as the absence of chaotic activity with a minimum of two consecutive ventricular complexes of similar morphology within a 5 seconds interval within the first minute after defibrillation.

2.4 Statistical methods

Multivariate analysis of initial recorded rhythm was done by logistic regression. To determine the relation between BLS and the first recorded rhythm (VF, asystole or another rhythm), we designed models based on the 873 bystander witnessed arrests. These explanatory models evaluated the probability of the first recorded rhythm as a function of time and of the performance of BLS. A significant difference in the models, with or without BLS, was based on the significance of each variable in the model and the significance of change of the log-likelihood; both were tested with the chi-square statistic and a p-value < 0.05.

A multivariate linear regression technique was used to assess the influence of BLS on the relation between amplitude and duration of VF. The difference in angle between the two regression lines from patients receiving BLS and patients who did not receive BLS was used to test the hypothesis that BLS diminished the decay in amplitude.

A logistic regression analysis was used to analyze the predictive value of the variables for survival. Finally, our data were entered into the model as described by Monsieurs: survival index \( = 0.6(VF\text{-amplitude}) + 0.4(VF\text{-baseline crossing}) - 0.4 \). According to this model, a survival index < 0 classified the patient as a non-survivor and a survival index > 0 as a survivor. The predictive value of the survival index was calculated by a 2 x 2 table. All statistics were performed in JMP 3.2 for the Apple Macintosh.

3. Results

3.1 Initial recorded rhythm

In the 476 patients who received BLS, 313 (66%) had VF as initial recorded rhythm; 70 (15%) had asystole; and 93 (19%) had another rhythm. In the 397 patients who did not receive BLS, in 200 (50%) the initial recorded rhythm was VF; in 79 (20%) it was asystole; and in 118 (30%) it was another rhythm. These three initially recorded rhythms in patient with and without
BLS differed significantly, $\chi^2 = 21.1, 4.1, \text{ and } 12.2$, respectively. Eventually, 88 patients (10%) were discharged alive from the hospital.

### Table 1. The logistic regression models describing the probability of asystole or VF as first recorded rhythm by EMS personnel in relation to the time of their arrival and the performance of BLS prior to their arrival.

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OR is odds ratio, CI is confidence interval. \(^a\) per minute delay.

\(^b\) significant difference in coefficients between with and without BLS, within the different groups of heart rhythm. VF is ventricular fibrillation, BLS is basic life support.

A logistic model of the 873 patients included the interval between collapse and the initial rhythm recording, this rhythm and the application of BLS. In patients who did not receive BLS, the probability to record VF as initial rhythm decreased more rapidly per minute delay of EMS arrival than in those who received BLS (Table 1). The opposite was seen for the probability to record asystole, the probability increased more rapidly in the group of patients without BLS than in the group with BLS as the time to EMS arrival elapsed. The effect of BLS was statistically significant in the models for VF as well as for asystole. There was no significant effect of time delay in the model for other rhythms. The effect of time and BLS on the probability to record VF or asystole is graphically presented in Figure 1.

### 3.2 Influence of BLS on characteristics of ventricular fibrillation

From the 513 patients who were found with VF as initial rhythm, 191 patients had a rhythm recording of sufficient quality for mathematical analysis. The median interval between collapse and first VF recording was 13 minutes (range: 4-22 minutes). The median measured amplitude was 400 $\mu$V (range: 100-1700 $\mu$V) and there were median 9 (range: 4-20) baseline crossings per second. With time the amplitude of VF decreased, but in the group of 132 patients that received BLS the decrease in amplitude was less than in the group without BLS (Figure 2). The calculated coefficient of the difference in angle between the two lines was 0.25 which significantly differed from zero ($p = 0.009$).
Figure 1. Probability of asystole or VF as first recorded rhythm in relation to time of EMS arrival and performance of BLS before arrival. With a longer arrival time of the EMS personnel, the probability of recording VF decreased whereas that of asystole increased. BLS significantly diminished this trend. This suggests that BLS delay the transition of VF into asystole. VF denotes ventricular fibrillation. BLS denotes basic life support.

3.3 Outcome

Of the 191 patients with VF and with an adequate rhythm recording, 122 patients (63%) had return of an organized rhythm, 86 patients (45%) ROSC, and 32 patients (17%) survived to hospital discharge. In a multivariate logistic regression survival significantly decreased when VF had a lower amplitude (OR 0.23 per mV, CI: 0.07-0.79) and when the amount of baseline crossings decreased (OR 0.80 per baseline crossings per second, CI: 0.71-0.91).

Table 2. The predicted outcome calculated by the model described by Monsieurs¹² and the observed outcome.
3.4 Comparison with previous model

The predicted outcome calculated by the model described by Monsieurs\textsuperscript{12} and the observed outcome are shown in Table 2. Using the survival index 72% of the survivors and 52% of the nonsurvivors was correctly predicted. Of all cases, 55% was correctly predicted. Survival predictions improved from the a priori probability of 17% to 23% and predictions of death improved from a priori 83% to 90%. The likelihood ratio of a positive test was 1.8 and of a negative test 0.67.

Figure 2. Linear model of the amplitude of VF as a function from time for the subgroups with and without BLS. The common intercept is 656 (μV) and an estimate coefficient of -9.2 for the group with BLS and -18.4 for the group without BLS. The coefficient of the angle between the lines significantly differs from 0, thus proving that the two lines indeed have different angles and that BLS limits the time dependent decrease in VF amplitude. A point may represent more than one patient. BLS denotes basic life support.

4. Discussion

This study showed the magnitude of the effect of BLS on the gradual deterioration of the amplitude of VF into asystole and the decline of survival as a consequence. The likely mechanism is that BLS maintains coronary perfusion sufficiently to preserve myocardial viability, and thus maintains high VF amplitude. Although the amplitude of VF is only an indirect marker of myocardial perfusion, at present it is the best practical measurement for myocardial viability during cardiac arrest.

Weaver\textsuperscript{22} analyzed the amplitude of VF in relation to the time of the collapse and found a decline in amplitude with passing time. Interestingly, the slope in the mathematical description of their linear regression model appears to be an average of the two slopes of the regression lines.
with and without BLS as found in our study and with a similar intercept. He did not find a significant relation with BLS performed with amplitude as a binary (fine versus coarse) outcome. Other studies observed that VF was significantly more frequently present as the first recorded rhythm when BLS was performed, but the factor time was not analyzed. Studies in animals showed the effect of BLS on myocardial perfusion and found a limited but measurable coronary flow during the most vigorous compression depths. One study performed in humans found a positive correlation between coronary perfusion pressure and ROSC. In that study no information was given about the possible influence of coronary perfusion pressure on characteristics of VF. Our study was not designed to demonstrate that BLS improves the perfusion. Our data support these earlier studies indirectly and also demonstrates why BLS works in out-of-hospital circulatory arrest. Another consequence of this finding is that BLS and VF as first recorded rhythm are usually considered "baseline" predictors in survival models, but proved not independent of each other: Finding VF in the first rhythm recording is partly as a result of BLS. In the Utstein template the performance of BLS is registered after the initial rhythm, it would be more appropriate to first register BLS in the template and than the initial rhythm.

It is clear that the amplitude of VF decline relentlessly as time elapses. There is no reason therefore to make a strict separation between VF and asystole based on a certain amplitude like 100 µV, as is done in the Utstein definition and in the algorithms of automatic external defibrillators. This arbitrary asystole should be distinguished from asystole as caused by an absent or blocked impulse formation. Although the probability of survival remains low when VF amplitude reaches the 100 µV level or less, an attempt to defibrillate is warranted, as was included in the ERC guidelines of 1992, but is no longer recommended in the guidelines of 2000. The recommendation of Cobb to first perform BLS when a circulatory arrest has been present for more than 4 minutes without CPR and before a defibrillation attempt, to improve myocardial viability for a certain period of time, may be correct but the hypothesis has not been sufficiently tested.

It should be possible to measure the amplitude of VF at the scene during ongoing resuscitation and use this information as predictor for the outcome of a cardiac arrest. However the clinical implication of this measurement is limited, illustrated by the low likelihood ratios of Monsieurs' model with our dataset. Also, the findings can be used to test new developments in the field of resuscitation. At present a change in chest compressions - ventilation ratio from 5:1 to 15:2 for two rescuers is proposed. Analyzing the effect of BLS on the amplitude of VF could be a method to test the quality of this change in BLS technique.

Study limitations

Many potential disturbing factors such as electrode size, electrode localization, skin condition, chest shape, vectoral changes in wavefront and impedance, influence the amplitude of VF. It is not easy to control the influence of these factors in out-of-hospital resuscitation.

The amplitude and baseline crossing analysis of our study was based on only 191 recordings of sufficient quality from the 513 patients diagnosed to have VF on the arrival at the patient's side. This is explained by practical factors (lost tracings, tracings without gain indication, defibrillators without memory) and there was no indication that a selection bias played a role. The analyzed rhythm strips therefore can be thought of as a random sample of the resuscitation experience of our study.
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References


